Dental Chemistry and Metallurgy.

Fourth Edition: Revised, Enlarged, and with
Many Illustrations.

BY

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FOURTH EDITION.

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PREFACE

TO THE

FOURTH EDITION.

A text-book to be abreast of the times must in these days be conspicuous for its quota of laboratory work. The present edition of the Dental Chemistry is an effort to provide the student with a course which shall include a large number of exercises in experimental chemistry, both inorganic and organic. More than one hundred new pages have, therefore, been inserted in the book which are entirely practical in character, and serve to illustrate the principles covered by the five preceding chapters. This new work in experimental chemistry has been followed by an outline of chemical analysis, the reactions of the more usual metals being considered at much greater length than in previous editions.

Inasmuch as the condition of the teeth has to do with the process of digestion, experimental work in this edition includes physiological chemistry in which that of digestion is considered at some length.

Greater attention is also paid in this edition to the germ theory, ptomaines, leucomaines, and various toxines, knowledge of which has grown appreciably since the first edition of this book was issued. Description of various new alkaloids and antiseptics will also be found in the chapters relating to them.

It is hoped that the large number of pages now relating to experiments which illustrate the general principles of chemistry will render the fourth edition more acceptable to those instructors who insist on grounding their students thoroughly in pure chemistry before attempting applied science. The author also ventures to hope that the book may now find a place in almost any college, whether dental or medical, where the principles of chemistry are taught. All the matter pertaining to dental chemistry has, however, been carefully retained, and considerably more added with reference solely to the needs of the dental student and practitioner.

In conclusion the author must again thank the dental profession for the cordial appreciation of his humble efforts. The demand for a fourth edition in the course of five years is gratifying to any one interested in the application of chemistry to the arts and sciences.

In connection with the publication of the fourth edition the author must acknowledge obligations to Messrs E. H. Sargent & Co. for numerous cuts, and to Dr. W. M. Thomas for aid in revising the proof. The author must also thank his publishers for materially increasing the size of the book without adding appreciably to its selling price.

70 STATE ST., JANUARY, 1896.

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*A special feature of the fourth edition, enabling the student by reference to the index to classify in a rational manner 300 of the most important organic compounds.

Class VII. Esters or ethereal salts; mercaptans, sulphides.

Class VIII. Alkyl compounds of nitrogen, phosphorus, arsenic, antimony.

Class IX. Glycols or diatomic alcohols.

Class X. Glycerins or triatomic alcohols.

Class XI. Carbohydrates.

Class XII. Cyanogen compounds and related substances. Substances related to uric acid.

Class XIII. Furfurane, thiophene, pyrrol.

Class XIV. Aromatics of one nucleus: benzene series and derivatives. Azo and diazo compounds; hydrazines; phenols; quinones; aromatic alcohols; aromatic acids as benzoic, salicylic.

Class XV. Aromatics of more than one nucleus: phthaleins, indigo, naphthalenes, naphthols, pyridine, collidines, etc.

Class XVI. Alkaloids.

Class XVII. Ptomaines, leucomaines, toxalbumins.

Class XVIII. Proteids.

Class XIX. Ferments.

PREPARATION AND PROPERTIES OF IMPORTANT ORGANIC COMPOUNDS:—Hydrocarbons: paraffines, mineral oil, vaseline, oil of turpentine, terpenes, essential oils; oil of cloves, eugenol; India-rubber, dental rubber, gutta-percha, camphor, resins, myrrh, gums, naphthalene, naphthols. Ethyl series of radicals, alcohols, alcohol. Glycerine, glycerites, boroglyceride, glyceroborates. *Creasote. Carbolic acid.* Phenol compounds, resorcin, eucalyptol. Carbohydrates; sugars, honey, gums, collodion, celluloid. Ethers: chloroform, iodoform, iodol; aldehydes: paraldehyde, chloral hydrate. Ketones. Organic acids: acetic, trichloracetic, benzoic, eugenic, hydrocyanic, oleic, oxalic, lactic, salicylic, [salol, betol] sozolic, tartaric, [tartar emetic]. Alkaloids: aconitine, atropine, chinoline, cannabine, cocaine, morphine, quinine, strychnine, veratrine, "antipyrine", "antifebrine," alstonine, apomorphine, caffeine, cytisine, ditaine, erythrophleine, ethyl oxycaffeine, hyoscyamine, isatropyl cocaine, jerubebine, lamine, oxy-propylene-di-iso-amylamine, ulexine.

List of Newer Alkaloids and Glucosides, with Derivation*:—Proteids: albumins, globulin, etc. Fermentation. Ferments. Putrefactive fermentation in the mouth. Fungi. Bacteria. Microbe of dental caries. Pus and suppuration. Disinfection: antiseptics, germicides, disinfectants. *Miller's mouth washes.* Deodorizers. Antiseptics: alantol, betol, bismuth oxyiodide, creolin, cresylic acid, iodine trichloride, mercuric albuminate, mercuric oxy-cyanide oxy-naphthoic acid, tribrom-phenol, sodium silico-fluoride.

Two Hundred New Antiseptics and Therapeutic Agents:—*Antiseptics, antituberculars, hypnotics, analgesics, antipyretics, local anæsthetics, diuretics, uric solvents, mouth washes. Pages 216 to 339.

Chapter V.—The Teeth and the Saliva:—Tooth structure, chemical constitution of the teeth. Enamel, dentine, cement. Table of analyses. Action of various substances on the teeth. Chemistry of caries; chemical theory, vital theory, germ theory. The saliva: physical characters, chemical composition, functions, changes; parotid saliva, submaxillary, sublingual; buccal mucus. Tartar. Salivary calculi . . . . Pages 339 to 360.

Chapter VI.—Laboratory Course Begun. Experiments Illustrating General Principles of Chemistry†:—Apparatus and manipulations. Solution. Solutions of reagents, insoluble substances, distillation, sublimation, precipitation, chemical change, physical solution and chemical solution, chemical combination, decomposition of compounds. Nascent state. Properties of acids and of bases. . . . . Pages 360 to 397.

Chapter VII.—Laboratory Work Continued. Practical Chemistry of the Elements and Their Inorganic Compounds‡:—Oxygen, oxidation and reduction, equations illustrating oxidation, oxides, anhy-

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*Special features of the 4th edition.

†Special feature of the 4th edition.

‡Special feature of the 4th edition,

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*Special feature of the 4th edition.

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*Special feature of the 4th edition.

†Special feature of the 4th edition.

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*A special feature of the 4th edition is the new index of 1,850 terms as compared with 1,000 terms in the 3d edition.

DENTAL CHEMISTRY AND METALLURGY

CHAPTER I.

PHYSICS.

1. Introduction:—

Matter is the term given to that which occupies space and possesses weight. Matter in other words is the object of *sense*, our knowledge of the material world being founded upon experience or the evidence of our senses. A *body* is a definite and limited portion of matter, as, for example, a dust particle, a stone, an aerolite, or a planet. The different *kinds* of matter as water, lime, silver, coal are known as *substances*. Every object, body, or substance which can be perceived *by at least one* of the senses is composed of matter: thus, though air can not be seen, it can be felt when in motion, as wind, therefore air is matter.

The characteristics of the objects about us are different: some are liquid, some solid, some large, some small: moreover they are concerned in certain events or occurrences which naturally take place; for example we see that rain falls, a balloon rises, a ship floats, a piece of lead sinks. These events are what are known as *phenomena* or things which occur. Phenomena are innumerable. The study of science is the study of the relations between objects and between phenomena. A scientific *law* is a generalized statement of what has been observed to occur. A law is not a cause. A law is not always a theory. A theory is the most perfect expression of physical truth and is deduced from both laws and principles that have been established on independent testimony. The terms law, theory, and hypothesis are, however, often used interchangeably. An hypothesis is a guess or assumption which when more completely developed and probable becomes a theory, which in turn *accounts for* a law. Again what has been merely an hypothesis may subsequently become a theory, and a theory may in time become so well confirmed as to be regarded as a highly probable law. Theories are indispensable, for they aid in directing investigation, and thus lead to truth. The atomic theory or hypothesis alone enables us to account for most of the phenomena of matter. It was proposed by John Dalton in 1807 and presupposes the existence of *atoms.*

2. Atoms:—

An *atom* is the smallest division of elementary matter recognized as existing and which can by combining form the molecule. There are only about 70 different kinds of atoms, whose combinations form the universe.

3. Molecules:—

A *molecule* is the smallest part of any substance which can exist alone and exhibit the properties of that substance. A molecule is a cluster of two or more atoms bound together by what we call chemical affinity. Neither molecules nor atoms can be seen by the microscope.

Molecules may be composed of any number of atoms and while there are only about 70 kinds of atoms there is practically no limit to the different kinds of molecules. Molecules differ in kind, number, and arrangement of the atoms which compose them. Each molecule in a body is separated from its neighbor by inconceivably small space, and has a quivering motion, rebounding from its neighbors. Heat increases the size of a body because each molecule then moves faster and pushes its neighbor farther away.

4. Mass:—The term mass is given to a quantity of matter made up of molecules and appreciable to the senses.

5. Divisions of matter:—Mass, molecule, atom.

6. **Attraction of Mass,** or molar attraction: same as attraction of gravitation or tendency of bodies to approach one another.

7. **Molecular Attraction.**—Cohesion or adhesion.

8. **Atomic Attraction.**—Chemism or chemical affinity.

9. **Molar Motion.**—The ordinary, visible, mechanical motion, as that of a machine or its parts.

10. **Molecular Motion.**—Heat, light, magnetism, electricity.

11. **Atomic Motion.**—A constant revolution or swinging of the atom within a limited space.

12. **Properties of Matter.**—Qualities characteristic of matter. Two kinds, chemical and physical.

13. **Chemical Properties.**—Those resulting from the composition of the molecule with reference to its atoms and shown only by change of identity of the molecule: as combustibility, explosibility, etc.

14. **Physical Properties of Matter.**—The different ways in which matter presents itself to our senses. Two kinds, general and specific, or universal and characteristic. *General* properties are those common to all matter, as impenetrability, extension, porosity, etc. *Specific* properties are those observed in certain bodies only, or in certain states of those bodies, as solidity, color, tenacity, etc. Physical properties may be shown without change in the identity of the molecule.

15. **Physical Properties: Impenetrability.**—Property of matter in virtue of which two bodies cannot occupy the same space at the same time. Example: nail driven into wood, particles of wood make way for the nail.

16. **Extension or Magnitude.**—Property in virtue of which every body occupies a limited portion of space.

17. **Divisibility.**—Property of matter by virtue of which a body may be separated into distinct parts. Di-

visibility of matter practically limited *before* molecule is reached; theoretically should be limited by the atom.

18. **Porosity.**—Quality in virtue of which spaces or *pores* exist between the molecules of a body. Example: lead, if hammered, is made smaller because the size of the *pores* is reduced, the molecules being forced nearer together.

19. **Compressibility.**—Property in virtue of which a body may be reduced in size; it is a consequence and proof of porosity.

20. **Expansibility.**—Property in virtue of which a body may be increased in size. Opposite of compressibility. Example: iron when heated becomes larger or expands because its molecules are pushed further apart.

21. **Elasticity.**—Property in virtue of which bodies resume their original form or volume (size) when that form or volume has been changed by external force. Example: a piece of ordinary rubber after being stretched out resumes its original size when the force stretching it ceases to act.

22. **Mobility.**—Property in virtue of which the position of a body may be changed. **Inertia** is the incapability of matter to change its own state of motion or rest. Example: a book on a table cannot move itself and is said to have *inertia*; it can move, however, when sufficient force is applied to it and is said to have *mobility.*

23. **Cohesion.**—Force which unites molecules of the same kind as two molecules of water or two molecules of iron. Cohesion holds substances together and gives them form.

24. **Adhesion.**—Force which unites molecules of different kinds. Example: dip a glass rod into water and, on withdrawing it, a drop

will be found at its lower extremity, which remains suspended or *adheres* to it.

25. **Hardness.**—Property in virtue of which some bodies resist attempts to force passage between their particles. Example: a tooth possesses hardness.

26. **Brittleness.**—Property in virtue of which some bodies may easily be broken. Example: glass is not only hard, but is also easily broken or *brittle*.

27. **Tenacity.**—Property in virtue of which some bodies resist attempts to pull their particles asunder. Example: an iron wire is difficult to pull apart and is said to be tenacious.

Tenacity is proportional to sectional area: a rod of one square inch sectional area* will carry twice the load that a rod of the same material with sectional area of half a square inch will carry.

28. **Malleability.**—Property in virtue of which some bodies may be hammered or rolled into sheets. Example: gold can be beaten into sheets so thin that nearly 300,000 are necessary to measure an inch in height when they are placed one on another.

29. **Ductility.**—Property in virtue of which some bodies may be drawn into wire. Example: iron when heated may be drawn into a wire, hence is said to be ductile.

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*The sectional area of a substance as, for example, a rod, is that of the surface of its cross section.

30. **States of Matter.**— Solid, liquid, gaseous, and radiant. In the first, the attraction of the molecules is greater than their repulsion. In the second, their attraction and repulsion are equal. In the third, repulsion is greater than attraction. In the fourth, so few molecules are in the given space that they rarely strike each other in their paths of motion.

Fluid is a term applied to any thing which will adapt itself to the sides of the vessel containing it, hence includes both liquids and gases.

Vapors are gases produced by heat from substances usually solid or liquid at ordinary temperatures.

Examples: *solids:* wood, metals; *fluids:* air, water; *liquids:* water, oil, alcohol; *gases:* air, oxygen, hydrogen; *vapor:* steam.

31. **Force.**—Cause tending to produce, change, or destroy motion. Example: gravity, friction, electrical or magnetic attraction, etc.

32. **Work.**—Overcoming of resistance.

33. **Energy.**—Power of doing work.

34. **Foot-pound.**—Amount of work required to raise one pound one foot high.*

35. **Horse-power.**—Ability to perform 33,000 foot-pounds in a minute.

36. **Machine.**—Contrivance for utilizing energy by

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*The work required to raise one kilogram through one meter, against the force of gravity, is called a kilogram-meter.

which power can be applied more advantageously to resistance and, in general, intensity of energy be transformed.

37. **Laws of Machines.**—1. Gain in intensity of power =loss in time, velocity, or distance and *vice versa.*

2. Power × distance=weight × distance.

3. Power × velocity=weight × velocity.

38. **Lever.**—Any inflexible bar, straight or curved, resting on a fixed point or edge called the *fulcrum.* Every lever has two arms, the power-arm and the weight-arm. The power-arm is the perpendicular distance from the fulcrum to the line in which the power acts; the weight-arm is the perpendicular distance from the fulcrum to the line in which the weight acts.

When the lever is not a straight bar, or when power and weight do not act parallel to each other, the lever is called a bent lever.

39. **Kinds of Levers.**—(1) Fulcrum between power and resistance (weight) as in crowbar, (2) weight between power and fulcrum as in wheelbarrow, (3) power between weight and fulcrum as in human forearm.

40. **Laws of the Lever.**—

Power × power-arm=weight × weight-arm.

A given power will support a weight as many times as great as itself, as the power-arm is times as long as the weight-arm.

The continued product of the power and lengths of the alternate arms beginning with the power-arm=the continued product of the weight and lengths of the alternate arms beginning with the weight-arm.

41. **Law of Wheel and Axle.**—The power multiplied by the radius, diameter, or circumference of the wheel= the weight × the corresponding dimension of the axle.

42. **Pulley.**—A wheel, turning on an axis, provided with a cord, which passes over the grooved circumference of the wheel. The axis is supported by a frame called the *block.*

43. **Inclined Plane.**—Hard, smooth, inflexible surface used in most cases to aid in the performance of work against the force of gravity. It is inclined so as to make an oblique angle with the direction of the force to be overcome, and in most cases is inclined to the horizon at an acute angle.

44. **Wedge.**—Movable inclined plane in which power usually acts in a direction parallel to base. It is used for moving great weights short distances. More commonly a wedge is *two inclined planes* united at their base. With given thickness, the longer the wedge the greater the gain in intensity of power.

45. **Screw.**—Cylinder with spiral groove or ridge, called the *thread*, winding about its circumference. By aid of the screw a given power will support a weight as many times greater than itself as the circumference described by the power is times as great as the distance between two adjoining turns of the thread.

46. **Friction.**—Resistance encountered by a moving body from the surface on which it moves. Is greatest at beginning of motion, increases with roughness of surfaces, greater between soft bodies than hard ones, is nearly proportional to pressure, is not affected by extent of surface within ordinary limits, is greater between surfaces of the same material than between those of different kinds; rolling friction less than sliding friction; friction diminished by polishing or lubricating the surfaces.

47. **Capillarity.**—When a glass rod is placed vertically in water the latter rises above its level at the sides of the glass. The finer the rod the greater the capillary ascent. If the rod be dipped into a liquid *which does not wet* it, as mercury, the liquid will be depressed instead of raised.

48. **Displacement.**—A body which sinks in water dis-

places exactly its own bulk of water and loses in weight an amount just equal to the weight of water displaced.

49. **Specific Gravity.**—Relative weights of equal bulks of bodies referred to an assumed standard; for liquids and solids, the standard is distilled water at a temperature of 4° C. or 39.2° F. For gases, the standard is air or hydrogen. If a substance weighs four times as much as the same bulk of water, it is said to have a sp. gr. of 4.

50. **Calculation of Specific Gravity of Solids and Liquids.**—(*a*) For solids use the following formula:

$$\text{Sp. gr.} = \frac{W}{W - W^1}$$

in which W = weight of body in air, W^1 its weight in water (suspended by a light thread from the scale pan). Example: weight of a body in air, *i. e.,* ordinary weight, is 50 ounces; its weight in water is 42 ounces. W = 50, $W^1 = 42$, $W - W^1 = 50 - 42$ or 8; $\frac{W}{W - W} = \frac{50}{8} = 6.25$, sp. gr. In other words the weight of the body divided by the weight of an equal volume (bulk) of water is the specific gravity of the body.

(*b*) If the body is lighter than water, fasten a heavy body to it and weigh in water. Weigh the heavy body in water. Weigh the light body in air. Then subtract the water weight of the combined mass from the water weight of the heavy body, and add to the difference the air weight of the light body. Then divide air weight of cork by the sum. Example: required to find the specific gravity of a piece of cork. Attach to it a piece of iron:

1. Weight of combined mass in water - 51.5 grains.
2. Weight of iron in water - - - 66.9 grains.
3. Weight of cork in air - - - 4.6 grains.
4. $66.9-51.5=15.4$.
5. $15.4+4.6=20$.
6. $\frac{4.6}{20}=0.23$, sp. gr. of cork.

(*c*) To find the sp. gr. of solids which dissolve in water, weigh them in some liquid in which they are insoluble, and find the specific gravity as before. Multiply result by specific gravity of liquid used and the product will be the true specific gravity. Example: to find specific gravity of sugar. Suppose it weighs 10 grains in air and 4.56 grains in oil of turpentine. $10-4.56=5.44$ grains. $10\div5.43=1.84$ or sp. gr. referred to turpentine. Ascertain from tables the sp. gr. of turpentine($=0.86$), multiply 1.84 by 0.86, and the product, 1.58, is the true sp. gr. of the sugar.

(*d*) To find the specific gravity of a powder insoluble in water, weigh a flask empty; weigh the flask full of water; weigh the flask partly full of the powder; fill the flask now containing powder full of water and weigh again. Subtract weight of flask filled with water from weight of flask filled with powder and water mixed. *The difference will be the loss of weight of the powder.* Divide the weight of the powder in air by the loss of weight in water, and the quotient will be the specific gravity of the powder.

(*e*) To find the sp. gr. of liquids a special flask, called a picnometer or sp. gr. flask, is used which contains a certain weight of water when filled. This weight is marked on the flask. To ascertain the sp. gr. of a liquid by means of its use, weigh it, fill it with the liquid and weigh it, subtract weight of flask, and divide difference by number marked on the flask. The quotient will be the sp. gr. of the liquid. The temperature of the liquid should be that marked on the flask.

Instruments called *hydrometers*[*] are also used for finding the sp. gr. of liquids, and are long, narrow, glass or metal tubes provided with a bulb near the bottom filled with air, and a smaller one below it filled with mercury. To find the sp. gr. it is merely necessary to drop the hydrometer into the liquid and read off the number on the scale at the surface of the liquid.

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[*] Hydrometers should be those carefully standardized to a certain temperature, as 77° F., and used in liquids warmed or cooled to that temperature.

51. **Density.**—In chemistry, the term density should mean the weight of a gas referred to *hydrogen* as a unit. [Specific gravity of gases means their weight referred to *air* as a unit. Thus the density of chlorine is said to be 35.5, but its specific gravity 2.47. This means that chlorine is 35.5 times as heavy as hydrogen, but 2.47 times as heavy as air. In this book the term density will be used only in the case of gases. In some books the term density is used to mean specific gravity and is applied to solids].

52. **Law of Avogadro.**—Equal volumes of all bodies in the state of gas, and at the same temperature and pressure, contain the same number of molecules. Hence (*a*) the specific gravities of any two gases are to each other as the weights of their molecules, and (*b*) their molecules are all of the same size.*

53. **Law of Mariotte.**—Volume of a confined gas is inversely proportional to the pressure. That is, the greater the pressure the less the volume and *vice versa.* The standard pressure is 760 millimetres or 30 inches of the barometric pressure.

54. **Law of Charles.**—Volume of a gas varies directly with the absolute temperature†. That is, the cooler the gas the smaller its volume, and *vice versa.* A gas expands $\frac{1}{273}$ its volume in passing from 0° to 1° C. or $\frac{1}{460}$ its volume for one degree Fahrenheit.

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*Avogadro's law finds application in the determination of molecular weights.

†The temperature of —273° C. is called the *absolute zero* of temperature. Absolute temperatures are obtained by adding 273 to the reading on the Centigrade thermometer.

55. **Standard Temperature and Pressure.**— 0° C. and 760 m. m. pressure. (See page *32*)

56. **Effects of Heat.**—In general, heat in the first place expands bodies, then overcomes cohesion to such extent that the body melts and becomes liquid, then finally overcomes cohesion entirely and the liquid boils and passes into the gaseous state.

57. **Laws of Fusion.**—(1) Every solid begins to melt at a certain temperature, which is invariable for the given substance if the pressure be constant. When cooling, the substance will solidify at the temperature of fusion. (2). The temperature of the solid, or liquid, remains at the melting point from the moment that fusion or solidification begins until it is complete.

58. **Thermal Unit.**—Amount of heat necessary to raise one pound of water from 0° C. to 1° C., or 1390 foot pounds. Sometimes applied to amount of heat necessary to raise one pound of water from 32° to 33° F., or 772 foot pounds.

59. **Specific Heat.**—When equal weights of different bodies are raised through the same number of degrees of temperature, they take up different amounts of heat; that is, different bodies possess different capacities for heat. Thus the amount of heat needed to raise a kilogram of water through 100° C. is 31 times as great as that needed to raise the same weight of platinum through the same interval of temperature. Water then being taken as a unit, the specific heat of platinum is $\frac{1}{31}$ or 0.032.

60. **Boiling Point.**—Temperature at which a liquid gives off vapor rapidly from the whole liquid;at sea level boiling point of water is 100° C. or 212° F. **Superheated** steam is the result of applying considerable pressure to a boiling liquid, when its temperature will rise until the tension of the steam will overcome the pressure.

61. **Evaporation.**—Quiet formation of vapor at the surface of a liquid.

62. **Distillation.**—Conversion of a liquid into gas and recondensation of the gas into liquid. Operation performed in a still, consisting of a retort in which the liquid is boiled and a condenser for changing the vapor back to liquid.

63. **Fractional Distillation.** — Different substances boil at different temperatures. Raising the temperature of a mixture of two liquids to a point above the boiling point of one, but below that of the other, will vaporize the one but not the other.

64. **Destructive Distillation.**—Distillation of dry substances so as to destroy them and obtain liquids or gases. Example: coal for illuminating gas.

65. **Sublimation.**—Such solids as do not melt when heated, but pass directly into vapor, are said to sublime. Example: camphor.

66. **Solution.**—May be either *physical* or *chemical.*

Physical, either (*a*) result of adhesion of liquid to solid overcoming cohesion of molecules of the solid, or (*b*) feeble combination of the solid with water and diffusion of this compound through remaining water. Example of (*a*): sugar dissolved in water; on boiling away the water the sugar may be recovered entirely unchanged. Example of (*b*): dried alum when dissolved in water separates again in crystals in which water is found.

Chemical when, by chemical action between two substances, a soluble compound is formed, which dissolves in the water present. Example: silver forms with nitric acid by chemical action a soluble compound, silver nitrate, which then dissolves in water that may be present. Similarly an acid, attacking tooth structure, forms more or less soluble compounds with the lime and magnesia of the tooth.

67. **Solvents.**—All liquids are solvents.

Water is the best general solvent especially for metallic salts. Alcohol is the best solvent for resins. Mercury dissolves many metals. Gases may be dissolved in liquids. Some liquids dissolve in liquids, as essential oils in alchohol, and the process is called *liquid diffusion.*

68. **Saturated Solution.**—When a liquid has dissolved all of a solid that it can at a given temperature, the solution is called a *saturated* one.

69. **Solubility.**—The solubility of a substance is denoted by the amount of it, *by weight,* which a given amount of a solvent, as water or alcohol, will take up at a given temperature. Thus one part of alum is soluble in 10.5 parts of water at 59° F.

70. **Deliquescence.**—Bodies, which absorb water from the air and become liquid, are said to *deliquesce.* Example: zinc chloride. Such substances are said to be *hygroscopic.*

71. **Efflorescence.**—Substances, which on exposure to air lose water from their crystals,

are said to effloresce. Example: ferrous sulphate (ordinary green vitriol.)

72. **Dialysis.** — Liquid diffusion, when liquids are separated by some porous diaphragm as bladder or parchment paper. Passage of liquid through the diaphragm is called *Osmosis.*

73. **Dialyzer.**—Glass cylinder open at one end and closed at the other by the membrane used as a separating medium.

74. **Colloids and Crystalloids.**—Easily crystallizable bodies pass through the membranes readily. Those which do not crystallize pass through with difficulty and are called *colloids.* Examples: crystalloid, alum; colloid, gelatine.

75. **Dialysate.**—Term applied to a substance which has been dialyzed, *i. e.* has passed through the membrane of the dialyzer.

76. **Crystals.**—Solid substances bounded by plane surfaces symmetrically arranged according to fixed laws. (See Section 80).

77. **Crystallization.**—Change of substances from melted state or solution to solid state, with assumption of geometrical form. Essential condition, possibility of free motion of smallest particles.

78. **Amorphous—Polymorphous.**—A body never obtained in crystalline state is said to be *amorphous, i. e.,* without definite form or shape; a body having two or more different crystalline forms is called *polymorphous.* The same body always assumes the same crystalline form under the same conditions, but under

different conditions may assume different crystalline shapes. A substance is said to be *isomorphous* with another when it crystallizes in exactly the same form. Example: glue is amorphous, sulphur is polymorphous, sulphate of magnesium is isomorphous with sulphate of zinc.

79. **Water of Crystallization.**—Water taken by substances separating from solutions as a necessary part of their crystals. Amount invariable for same substance at same temperature. Example: each crystal of alum has 24 molecules of water to one of alum itself, and the formula of the crystal is $K_2Al_2(SO_4)_4.24H_2O$.

80. **Systems of Crystals.**—Based on imaginary lines called *axes* passing through the centre of the crystal and connecting opposite angles or opposite parallel sides. For convenience, six systems of crystals may be considered.

First system: axes three, at right angles, equal lengths. *Isometric system.* Forms: cube, octahedron.

Examples of the first system of crystals: native silver, chloride of silver, calcium fluoride, native copper, native gold.

Second system: axes three, right angles, one longer or shorter than other two. *Tetragonal* or *Dimetric system.* Form: right square prism.

Example of the second system: copper pyrites.

Third system: axes three, right angles, unequal lengths. *Trimetric* or *Orthorhombic system.* Forms: right rhombic prism and rhombic octahedron. Examples of third system crystals: sulphates of lead, zinc, barium, magnesium.

Fourth system: axes three, unequal, only one at right angles to plane of other two. Simplest form: oblique rhombic prism. Examples: borax, green vitriol. *Monoclinic system.*

Fifth system: axes three, all unequal, and all inclined to each other. Crystals complicated and apparently irregular: rhomboidal prism, acute and obtuse rhombohedrons. Examples: blue vitriol, boracic acid. *Triclinic system.*

Sixth system: four axes, three in one plane at angle of 60° to one another, fourth longer or shorter than other three and at right angles to their plane. Example: quartz. *Hexagonal system.*

81. **Chemical Effects of Light.**—Many chemicals are affected by exposure to light. Solutions of several metals, among them silver and gold, throw down a part of the metal on exposure to sunlight; the latter has certain rays capable of producing chemical changes and known as actinic rays.

82. **Electricity due to Chemical Action.**—

All chemical change produces electricity. This kind of electricity is called voltaic or galvanic, and is most often developed by chemical action between liquids and metals. Example: when a strip of copper and a strip of zinc are placed in dilute sulphuric acid, a current of electricity will be found to flow in a wire connecting the two strips of metal above the acid. The apparatus is called a *galvanic element* or *cell.*

83. **Current of Electricity**.—In every galvanic cell, the plates and connecting wires must be conductors of electricity and the liquid used must be one which will act with greater vigor on one of the metals than on the other. The metal most actively attacked by the liquid forms the *positive* or generating plate; the other, the collecting or *negative* plate. *The current runs in the liquid from the positive plate to the negative; in the wire connecting the plates the current runs from the negative plate to the positive.*

84. **Closed Circuit.**—When wires from the two plates are in contact. When not, the circuit is *broken.*,

85. **Electrodes.**—Ends of the wires. Also called *poles.* The negative pole is attached to the positive plate and vice versa. Platinum strips are often fastened to the ends of wires and constitute the electrodes, and the wires are called *rheophores.*

86. **Galvanic Battery.**—A number of galvanic elements so connected that the current has the same direc-

tion in all. Usually they are connected "in series", that is, positive plate of one element with negative of the next.

87. **Forms of Cells.**—Hydrogen gas is generated by the action of an acid on a metal, and the various kinds of cells indicate the means used by their inventors to prevent the hydrogen from accumulating on the negative plate.

Potassium bichromate battery: two zinc plates having between them a carbon plate, all hung in a solution of potassium bichromate in dilute sulphuric acid. To make the latter, pour 167 C.c. of sulphuric acid into 500 C.c. of water and let the mixture cool. Dissolve 115 grams of potassium bichromate in 335 C.c. of boiling water and pour while hot into the dilute acid. Let the whole cool before using. [1 gram=15½ grains Troy; 30 C. c.=1 fluid ounce]. Chromic acid is formed, which destroys the hydrogen. Zinc plates should be removed from battery, when the latter is not in use. The zincs should be *amalgamated* by washing in dilute sulphuric acid, then pouring mercury on them while still wet with the acid. Rub in the mercury well and keep a little of it in the bottom of each cell.

The *gravity battery* is one in which the two solutions, zinc sulphate and copper sulphate, are separated, owing to the difference in their respective weights, the saturated solution of copper sulphate being heavier than that of the zinc sulphate, when the latter is in its proper condition.

88. **Storage Batteries.**—Are of many forms. They may be made from any pair of chemical compounds unstable in presence of each other. They are called also *secondary* batteries. They have no electro-motive force of their own, but are capable of being acted on by an external source of electricity, in such a way as to acquire the

power to give out an electric current, opposite in direction to that of the external source by which they are treated.

In some storage batteries the cell contains two or more large plates of sheet lead, and the liquid used is dilute sulphuric acid. A current is passed through the battery, and hydrogen gas accumulates on one plate and oxygen on the other. Disconnect the charging battery and a current in the opposite direction may now be obtained from the polarized cell*. Storage batteries are used by dentists to furnish motive power for the engine.

89. **Induced Current.**—Name given to instantaneous current produced in a conductor by the influence of a neighboring current or magnet.

90. **Faradic Battery.**—The current induced in a conductor by the influence of a neighboring current is known also as a secondary, interrupted, or Faradic current. In producing it an *induction coil* is used, which is a *double* coil of wire wound around a hollow cylinder of wood. The first or *primary* coil is made of large, thick, copper wire covered with silk or insulated. Upon this coil, and carefully insulated from it, is wound the *secondary* coil of longer and thinner wire. A bundle of soft iron wire is inside the inner coil to act as a magnet whenever a current from a battery shall be sent through the coil. Before the end of the bundle of wires there vibrates a piece of soft iron fastened to a spring. The latter rests against a screw which connects the inner coil by a wire with a galvanic battery. When a current is sent through the inner coil, an induced current is produced in the outer coil in the

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*The polarization of the plates is caused by the accumulation of oxygen (negative) on the zinc (positive) plate, and of hydrogen (positive) on the carbon (negative) plate. Owing to the layers of gas on each plate a new or secondary current is developed.

opposite direction and the bundle of soft iron wires is magnetized at the same time. In consequence of the latter the hammer or soft iron in the spring is drawn toward the bundle and the current is thus broken. The bundle then becomes demagnetized and the hammer is brought back to the screw by the spring, the induced current now taking the opposite direction to what it did when the hammer was in contact with the bundle, and so on. The process is repeated as long as the current from the battery is sent through the primary coil. The induced current is therefore a *to and fro* current, or a *make* and *break* current, the make current being in opposite direction to the break. The *break* currents are the most powerful and are reinforced by the sudden demagnetization of the bundle or core of iron wires.

91. **Electrolysis.**— Many chemical compounds in solution may be decomposed by a strong galvanic current. This process is called electrolysis. Example: if a strong galvanic current is passed through water containing a little sulphuric acid, the water will be decomposed, that is, broken up into hydrogen and oxygen gases, the former being given off at the negative pole and the latter at the positive.

92. **Terms used in Electricity.**—*Circuit:* the entire path of the electrical current, including the battery itself, and the conducting medium, which unites the poles.

Dynamo: the dynamo-electric machine is one in which energy in the form of moving power is transformed into energy in the form of electricity.

Electricity.—Different kinds: galvanic electricity, also called *Voltaic*, is the term given to electricity evolved by chemical action, as in the bichromate battery. It is also called *dynamical*, or current-electricity.

Static electricity is that developed by friction.

Thermo-Electricity is that produced by the agency of heat. All metals are capable of producing thermo-electric currents.

Magneto-Electricity is the name given to electric currents developed by the relative movements of magnets and wires.

Potential: term used to denote the degree to which a body is electrified. The electrical condition of the earth's surface is taken as the potential zero point, and all bodies positively electrified, are said to have a higher potential than the earth, and all bodies negatively electrified, to have a lower potential. When electricity moves or tends to move from one place to another, there is said to be a *difference of potential* between the two places.

Resistance: term given to the obstruction offered to the passage of a current by the substance of the circuit through which it passes. Silver offers the least resistance, gutta percha very great.

Electro-motive force: term used to indicate that property of any source of electricity by which it tends to do work by transferring electricity from one point to another. Ten cells have ten times the electro-motive force of one cell.

Quantity: as applied to current electricity, term used to mean the strength of the current, or the amount per second acting to produce heat, magnetism, etc. It is the margin of effective electricity produced by any battery after the resistance of the circuit has been overcome.

Standard units of electrical measurement: the unit of electro-motive force is called the *volt:* the Daniell cell is said to have the electro-motive force of *one volt*, that is, the electro-motive force required to produce a current of the strength of one *ampere* in a circuit having a total resistance of one *ohm.* An ohm is the unit of resistance, and is approximately equal in resistance to that of a wire of pure copper one-twentieth of an inch in diameter, and two hundred and fifty feet long, or that of one-sixteenth of a mile of No. 9 galvanized-iron wire of ordinary quality. An ampere is the unit of current strength and represents the strength of current passing in a circuit having a total resistance of one ohm, with an electro-motive force of one volt. The *coulomb* or *weber* denotes the amount of electricity which a current of the strength of one ampere can furnish per second of time. It is the unit of quantity. The *farad* is the unit of capacity and represents the capacity of a condenser which contains one coulomb of electricity when the difference of potential between its opposing plates is one volt. A microfarad is a millionth of a farad.

93. **Ohm's Law.**—The effective strength of current in any given circuit is equal to the electro-motive force divided by the total resistance.

94. **Galvanic Electricity in the Mouth.**—Unpleasant sensations, from a disagreeable taste up to a slight shock, are sometimes experienced by those having metal in the mouth either in form of fillings or in teeth-plates. This is due to the development of galvanic electricity by contact with some other metals, as when pins, needles, metallic tooth-picks, etc. are touched to the fillings, or when the clasps or plates of artificial dentures come into contact with fillings, under peculiar conditions of oral fluids.

The fillings themselves, especially if of different metals, are thought to be a source of electricity, taken in connection with the fluids of the mouth; effort has been made to explain the destruction of certain fillings, as due to the development of such electricity.

95. American Weights and Measures:

APOTHECARIES' FLUID MEASURE.

60 minims (m.) make 1 fluid drachm............... fʒ
8 fluidrachms make 1 fluid ounce.................. f℥
16 fluid ounces make 1 pint......................... O.
8 pints make 1 gallon.........................Cong.

APOTHECARIES' WEIGHT.

20 grains (gr.) make 1 scruple................ sc. or ℈
3 scruples make 1 drachm................ dr. or ʒ
8 drachms make 1 ounce................. oz. or ℥
12 ounces make 1 pound................. lb. or ℔

SCALE.

lb.		oz.		dr.		sc.		gr.
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

TROY WEIGHT.

24 grains (gr.) make 1 pennyweight............... dwt.
20 pennyweights make 1 ounce................... oz.
12 ounces make 1 pound................... lb.

SCALE.

lb.		oz.		dwt.		gr.
1	=	12	=	240	=	5760
		1	=	20	=	480
				1	=	24

AVOIRDUPOIS WEIGHT.

16 drachms (dr.) make 1 ounce.................. oz.
16 ounces make 1 pound.................. lb.
25 pounds make 1 quarter.................. qr.
4 quarters make 1 hundredweight........... cwt.
20 hundredweight make 1 ton..................... T.

SCALE.

T.		cwt.		qr.		lb.		oz.		dr.
1	=	20	=	80	=	2000	=	32000	=	512000
		1	=	4	=	100	=	1600	=	25600
				1	=	25	=	400	=	6400
						1	=	16	=	256
								1	=	16

96. **Metric System:**

MEASURES OF LENGTH.

1 millimetre	=	0.001 of a metre.
1 centimetre	=	0.010 of a metre.
1 decimetre	=	0.100 of a metre.
1 metre	=	**1 metre.**
1 decametre	=	10 metres.
1 hectometre	=	100 metres.
1 kilometre	=	1,000 metres.
1 myriametre	=	10,000 metres.

MEASURES OF SURFACE.

1 centiare	=	1 square metre.
1 Are	=	**100 square metres.**
1 hectare	=	10,000 square metres.

MEASURES OF VOLUME.

1 Cubic metre	=	1,000 Cubic decimetres.
	=	1,000 litres, or one kilolitre.
	=	1 stere.

MEASURES OF CAPACITY.

1 Litre	=	1 Cubic decimetre, or 1000 Cubic centimetres.

MEASURES OF WEIGHT.

1 milligramme	=	0.001 of a gramme.
1 centigramme	=	0.010 of a gramme.
1 decigramme	=	0.100 of a gramme.
1 gramme	=	**1 gramme**

MEASURES OF WEIGHT.—*Continued.*

1 decagramme = 10 grammes.
1 hectogramme = 100 grammes.
1 kilogramme (kilo) = 1000 grammes.
1 tonneau = 1000 kilogrammes.

Metric Equivalents.

WEIGHT

Unit of measurement.	Approximate equivalent.	Accurate equivalent.
1 gramme	15½ grains	15.432
1 grain	0.064 gramme	0.064
1 kilogramme (1000 grammes)	2⅕ pounds, avoirdupois	2 204
1 pound, avoirdupois	½ kilogramme	0.453
1 ounce, avoirdupois (437½ grains)	28⅓ grammes	28.349
1 ounce, troy or apothecary (480 gr.)	31 grammes	31.103

BULK.

Unit of measurement.	Approximate equivalent.	Accurate equivalent.
1 Cubic centimetre	0.06 cubic inch	0.061
1 cubic inch	16⅓ Cubic centimetres	16.386
1 litre (1000 Cubic centimetres)	1 U. S. standard quart	0.946
1 United States quart	1 litre	1.057
1 fluidounce	29½ Cubic centimetres	29.570

LENGTH.

Unit of measurement.	Approximate equivalent.	Accurate equivalent.
1 inch	2½ centimetres	2.539
1 centimetre (1-100 metre)	0.4 inch	0.393
1 yard	1 metre	0.914
1 metre (39.37 inches)	1 yard	1.093
1 foot	30 centimetres	30.479
1 kilometre (1000 metres)	⅝ mile	0.621
1 mile	1½ kilometres	1.609

SURFACE.

Unit of measurement.	Approximate equivalent.	Accurate equivalent.
1 hectare (10,000 square metres)	2½ acres	2.471
1 acre	⅖ hectare	0.404

Suppose we are directed to use 175 grammes of chloride of sodium, how much is it in ounces? We see by the table that one ounce equals 31 grammes; divide 175 by this, and we have 5.6, the required number of ounces. If we wish to measure 53 Cubic centimetres of any liquid, 53÷29.5, the number of Cubic centimetres in one fluid ounce, =1.8 fluid ounces, the required amount. Conversely, suppose we have a quantity of some chemical weighing three-quarters of a pound, and wish to find the metric equivalent. As one pound is equal to 0.453 kilogramme, three-quarters of a pound will be equal to three-quarters of that weight, or 0.33975 of a kilogramme; or, as one kilogramme equals 1000 grammes, three-quarters of a pound will equal 339.75 grammes.

1. To convert troy grains into centigrammes, multiply by 6.
2. To convert centigrammes into troy grains, divide by 6.
3. To convert troy grains into milligrammes, multiply by 60.
4. To convert milligrammes to troy grains, divide by 60.
5. To convert troy grains to grammes, or minims into fluidgrammes, divide by 15.
6. To convert grammes into grains, or fluidgrammes into minims, multiply by 15.
7. To convert drachms into grammes, or fluidrachms into fluidgrammes, multiply by 4.
8. To convert grammes into drachms, or fluidgrammes into fluidrachms, divide by 4. (All results approximate).

97. **Percentage Solutions.**—In order to make a percentage solution of a solid in a liquid *both* should be weighed. A five per cent solution by weight means a solution 100 parts of which contain 95 parts by weight of water to 5 parts by weight of the solid.*

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*It is a common error to suppose that a five per cent solution is 5 grains of solid *to* 100 of water.

Ascertain the weight of a bottle, put into it the proper weight of solid then add liquid enough to make up the final weight.

For example, suppose it is required to make a 4 per cent. solution of cocaine hydrochlorate: weight of bottle, 400 grains; weight of bottle plus cocaine, 404 grains. It is evident that enough water must now be poured into the bottle, while in the scale-pan, to make the final weight 500 grains. Result, four grains of cocaine in ninety-six of water, or a four per cent solution.

Examples: supposing weight of bottle to be 400 grains how would a one per cent solution of corrosive sublimate be made? a one in 1000?† a 20 per cent solution of carbolic acid? Give total weights (bottle included) and the weights of the separate ingredients.

Answers: one grain of corrosive sublimate and ninety-nine of water. One grain of the solid and nine hundred and ninety-nine grains of water.

98. **Specific Volume.**—The relative bulks of equal weights of different bodies is their specific volume. Water being taken as a unit, the specific volume of any substance is the volume of a certain weight of it compared to that of an equal weight of water at 15° C. (59.6° F.).

To find specific volume, divide the volume of a given weight of the liquid by the volume of an equal weight of water, or divide the specific gravity of water (which is 1 or 1000) by the specific gravity of the liquid.

For example: what is the specific volume of glycerine? 100 grains of glycerine measure 84 minims; 100 grains of

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†Carefully notice the difference between one *in* a thousand and one *to* a thousand.

water measure 105 minims; 84÷105=0.8; or 1000÷1,250 (the sp. gr. of glycerine)=0.800, sp. vol. of glycerine. That is, a given weight of glycerine will only measure eight-tenths as much as the same weight of water.

99. **To find the volume of a given weight of water in the American system.**— To change av. oz. of water to fl. oz. multiply by 0.96; tr. oz. of water to fl. oz. multiply by 1.05; grams of water to fl. oz. multiply by 0.0338.

Examples: how many fluidounces in 60 avoirdupois ounces of water? how many fluidounces in 10 troy ounces of water? how many fluidounces in 20 grams of water?

Answers: 60×0.96. 10×1.05. 20×0.0338.

100. **To find the volume of a given weight of any liquid.**—Multiply the volume of an equal weight of water by the specific volume of the liquid; or divide the volume of an equal weight of water by the sp. gr. of the liquid.

Examples: how many fluidounces in 200 troy ounces of nitric acid? 200 troy ounces of water are (200×1.05) fluidounces, or 210 fluidounces (see previous rule). 210 multiplied by the specific volume of nitric acid, 0.704, (found by dividing the specific gravity of the water by the specific gravity of the acid, 1.42) will give 147.8, which is number of fluidounces required.

101. **To find the weight of a given volume of water.**—Fluidounces to avoirdupois ounces, divide by 0.96; fluidounces to troyounces, divide by 1.05; fluidounces to grams, divide by 0.0338.

Examples:· what is the weight of 13 fluidounces of water? of a pint of water? of three pints? (Give answers in both avoirdupois and troy).

Answers: 13÷0.96. 13÷1.05. 16÷0.96. 16÷1.05. Three times the third and fourth answers.

102. **To find the weight of a given volume of any liquid.**—Divide the weight of an equal volume of water by the sp. vol. of the liquid, or multiply the weight of an equal volume of water by the sp. gr. of the liquid.

Example: find the weight (troy) of 200 fluidounces of nitric acid of sp. gr. 1.42. The weight troy of 200 fluidounces of water is 200÷1.05 or 190.4. Divide this by the specific volume of nitric acid, which is 0.704, and we have 270.4, which is the weight required in troy ounces.

103. **Thermometry.**—The Centigrade thermometer has its zero at the freezing point and its boiling point at 100°, the number of intervening degrees being 100. One degree Centigrade equals 1.8° of Fahrenheit. To convert Centigrade to Fahrenheit multiply by 1.8 and add 32. To convert Fahrenheit to Centigrade subtract 32 and multiply by $\frac{5}{9}$.

Examples: Convert 60° Centigrade to the corresponding Fahrenheit. 60 times 1.8 equals 108. The latter plus 32 equals 140. [Turning to the table on page 31, we find 60° C. equals 140° F]. Now find what degree Centigrade corresponds to 770° Fahrenheit. 770 less 32 equals 738. The latter multiplied by $\frac{5}{9}$ equals 410. [Consulting the table on page 33, we find 770° F equals 410° C.]

In general it is easier to consult the table if the latter is at hand when wanted, but as such is not always the case it is advisable to become familiar and ready with the rule.

Comparison of Centigrade and Fahrenheit Degrees.*

Cent.	*Fahr.*	*Cent.*	*Fahr.*	*Cent.*	*Fahr.*	*Cent.*	*Fahr.*
—40	—40.0	—5	+23.0	+30	+86.0	+65	+149.0
39	38.2	4	24.8	31	87.8	66	150.8
38	36.4	3	26.6	32	89.6	67	152.6
37	34.6	—2	28.4	33	91.4	68	154.4
36	32.8	—1	30.2	34	93.2	69	156.2
35	31.0	0	32.0	35	95.0	70	158.0
34	29.2	+1	33.8	36	96.8	71	159.8
33	27.4	2	35.6	37	98.6	72	161.6
32	25.6	3	37.4	38	100.4	73	163.4
31	23.8	4	39.2	39	102.2	74	165.2
30	22.0	5	41.0	40	104.0	75	167.0
29	20.2	6	42.8	41	105.8	76	168.8
28	18.4	7	44.6	42	107.6	77	170.6
27	16.6	8	46.4	43	109.4	78	172.4
26	14.8	9	48.2	44	111.2	79	174.2
25	13.0	10	50.0	45	113.0	80	176.0
24	11.2	11	51.8	46	114.8	81	177.8
23	9.4	12	53.6	47	116.6	82	179.6
22	7.6	13	55.4	48	118.4	83	181.4
21	5.8	14	57.2	49	120.2	84	183.2
20	4.0	15	59.0	50	122.0	85	185.0
19	2.2	16	60.8	51	123.8	86	186.8
18	—0.4	17	62.6	52	125.6	87	188.6
17	+1.4	18	64.4	53	127.4	88	190.4
16	3.2	19	66.2	54	129.2	89	192.2
15	5.0	20	68.0	55	131.0	90	194.0
14	6.8	21	69.8	56	132.8	91	195.8
13	8.6	22	71.6	57	134.6	92	197.6
12	10.4	23	73.4	58	136.4	93	199.4
11	12.2	24	75.2	59	138.2	94	201.2
10	14.0	25	77.0	60	140.0	95	203.0
9	15.8	26	78.8	61	141.8	96	204.8
8	17.6	27	80.6	62	143.6	97	206.6
7	19.4	28	82.4	+63	145.4	98	208.4
—6	+21.2	+29	+84.2	64	+147.2	+ 99	+210.2
						+ 100	212.0
110	+230	+210	+410	+310	+590	410	770
120	248	220	428	320	608	420	788
130	266	230	446	330	626	430	806
140	284	240	464	340	644	440	824
150	302	250	482	350	662	450	842
160	320	260	500	360	680	460	860
170	338	270	518	370	698	470	878
180	356	280	536	380	716	480	896
+190	374	290	554	390	734	490	+914
+200	+392	+300	+572	+400	752	+ 500	+932
+500	+932	+800	1472	+1100	+2012	+1400	2552
600	1112	+900	+1652	1200	2192	1500	2732
+700	+1292	+1000	+1832	+1300	+2372	+1600	+2912

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*Barker.

CHAPTER II.*

CHEMICAL PHILOSOPHY.

104. **Chemistry defined.**—Chemistry is the science which studies the properties, constitution, and laws of composition of bodies, whether crystalline, volatile, natural, or artificial.

105. **Field of chemistry.**---Chemistry studies such properties of matter as result from its atomic composition.

Chemical Philosophy treats of the general facts of chemistry, the general laws deduced from these facts, and the operations which lead to a knowledge of the internal composition of matter. It comprises and classifies our knowledge of those phenomena which imply a change of substance.

Special Chemistry studies the character and properties of certain definite bodies, and shows in what manner they are governed by the laws of general chemistry, or chemical philosophy.

106. **Analysis and Synthesis.**—Chemical analysis is an operation by which the composition of matter is ascertained by splitting up a substance and separating its constituents from

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*The student must thoroughly master the contents of Chapter II up to Section 148 before attempting the laboratory work of Chapter VI.

one another. *Synthesis* is an operation by which simple bodies are combined to form compound ones, or compounds combined to form complex ones.

107. **Definitions---Molecule, Atom, Element, Compound.**---*Matter* or substance is the general term given to that which has length, breadth, and thickness. Any portion of matter which we perceive by the senses is called a *mass* of matter. Every mass of matter consists of molecules. A *Molecule* is the smallest particle into which any substance can be divided without losing its identity as that substance. The smallest particle into which common salt can be divided and still be salt and nothing but salt, is termed a molecule of salt. The smallest particle of iron which can exist free, that is, uncombined with anything else, is called a molecule of iron. Molecules are too small to be seen even with the aid of the most powerful microscope. Their existence, however, is now very generally admitted, as we are able to account for numerous phenomena if we assume that molecules exist. When a substance loses its identity, its molecules split up into small particles called *atoms*, which, however, have an attraction for one another and tend to form new molecules by coming together in groups. Thus, the molecule of mercuric oxide is composed of an atom of mercury combined with an atom of oxygen; when this substance is heated, its molecules break up, and the substance is no longer the oxide of mercury, but mercury and oxygen. When the molecules of oxide of mercury split up, the constituent atoms re-arrange themselves, those of the mercury forming molecules of mercury, and those of oxygen molecules of oxygen.

The molecule, then, is composed of atoms, held together by a certain attraction called by some *chemism*, by others *chemical affinity*. Each atom has an attractive power for other atoms, which is definite in quantity but neutralized when a sufficient number of other atoms approach it.

Definition 1. A **molecule** is the smallest particle of any substance which can exist by itself and remain free and uncombined. Molecules are destructible and divisible.

Definition 2. An **atom** is the still smaller particle entering into the composition of the molecule. Atoms cannot, in all probability, remain free and uncombined; they are indestructible and indivisible.

It follows from definition 2, that matter is indestructible.

Definition 3. **Element: a substance whose molecules are composed of the same kind of atoms,** as the molecules of gold; the molecules of any substance in Table 1 are composed of atoms of that substance, and of nothing else.

Definition 4. **Compound: a substance whose molecules are composed of different kinds of atoms.** The molecule of salt is not composed of atoms of sodium alone, nor of chlorine alone, but of an atom of sodium and an atom of chlorine.

Definition 5. **Mixture:** two or more substances form a *Mixture* when the particles of one are scattered throughout those of the other or others, without any change taking place in the chemical or specific properties of one or the other. Example: sand and sugar.

108. **Law of Avogadro.**—Equal volumes of all bodies in the state of gas and at the same temperature and pressure contain the same number of molecules. Therefore (*a*) the molecules of all bodies in the gaseous state are of the same size and (*b*) the weight of any molecule, as compared with that of hydrogen, is in proportion to the weight of any volume given, as compared with the same volume of hydrogen.

109. **How to determine the number of atoms in the hydrogen molecule.**—Suppose a given volume of hydrogen contains 10,000,000 molecules; by Avogadro's law the same volume of chlorine will contain 10,000,000 molecules. Combined, they form *two* volumes of hydrochloric acid gas which will necessarily contain 20,000,000 molecules. Analysis shows each molecule of hydrochloric acid gas to consist of two atoms, one of hydrogen and one of chlorine, that is, the 20,000,000 molecules of hydrochloric acid gas will contain 20,000,000 atoms of hydrogen and 20,000,000 of chlorine. Now there were but 10,000,000 molecules of hydrogen in the start, before combination, therefore each molecule of hydrogen must have contributed two atoms of hydrogen. So also with the chlorine.

From this it follows that there are two atoms in every molecule of hydrogen; and the weight of the atom (atomic weight) of hydrogen being taken as 1, the weight of its molecule (molecular weight) will be 2.

110. **Symbols.**—Chemists designate each element by an abbreviation called a *Symbol*,

which is often the first letter or first two letters of its Latin name.

Thus the symbol for potassium is K (Latin *Kalium*) that of gold Au (Latin *Aurum*).

A symbol not only designates an element but just one atom of that element having a definite weight (atomic weight).

Thus O not only signifies oxygen, but *one atom* of oxygen, or 16 parts by weight of oxygen.

The symbols of the elements with the atomic weights, specific gravity, specific heat, and melting point are now shown by Table 1.

The beginner should pay particular attention to those elements printed in large type. Note that the *metals*, as a rule, are positive to hydrogen, while the *non-metals** are negative to it. Observe that hydrates of elements at the positive end form bases, while hydrates of those at the negative end form acids.

Table 1 is that of Professor W. H. Seaman, M. D. The atomic weights are from the "Laboratory Yearbook" of Professor John Howard Appleton, as are also forty of the figures of specific gravity.†

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*Antimony resembles metals in *physical* properties not chemical.

†The forty are those of Li, K, Na, Cl, Ca, Mg, P, S, Gl, C, Si, Al, Sr, Br, I, As, Te, Sb, Cr, Zn, Sn, Fe, Mn, Co, Ni, Cd, Mo, Cu, Bi, Ag, Rh, Pb, Pd, Hg, W, U, Au, Pt, Ir.

Those who intend to pursue the study of chemistry more in detail will do well to read Lothar Meyer's work on Theoretical Chemistry, or Remsen's book entitled "The Principles of Theoretical Chemistry." Among other works on chemistry of general value are those of Beilstein, Roscoe, and Schorlemmer, Jungfleisch. For an elementary work, Nichol's "Abridgment" of Eliot and Storer is satisfactory; the beginner will find the appendix valuable in its instructions about chemical manipulations.

Table I.

Constants of the Elements.

(Arranged by Prof. Seaman.)

Electro-Chemical Series.

Positive end: hydrates form bases. NAME.	SYMBOLS. Perissad	 Artiad.	Atomic weights.	Approx Atomic wghts.	Specific gravity (Water=1)	Specific Heat.	Melting Point. Centigrade
Cæsium	Cs		132 5830	132.6	1.88		26.5°
Rubidium	Rb		85 2510	85.3	1.52		37.0
POTASSIUM (Kalium)	K		39.0190	39.0	0.86	0.1695	62.5
SODIUM (Natron)	Na		22 9980	23.0	0.97	0.2934	97.0
LITHIUM	Li		7.0073	7.0	0.59	0.9408	180.0
BARIUM		Ba	136.7630	136.8	4 00		
STRONTIUM		Sr	87.3140	87.4	2.54		
CALCIUM		Ca	39.9900	40.0	1.58		
MAGNESIUM		Mg	23.9590	24.0	1.70 to 1.74	0.2499	
Glucinum (Beryllium, Be)		Gl	9.0850	9.1	2.10		
Yttrium	Y		89.8160	89.8	4.80		
Erbium	E		165.8910	165.9			
ALUMINIUM	Al		27.0090	27.0	2 50 to 2.67	0.2143	425.0
Zirconium		Zr	89.3670	89.4	4.10		
Thorium		Th	233.4140	233.4	7.90		
CERIUM		Ce	140.4240	140.4	6.62		
Didymium	D		144.5730	144.6	6.40		
Lanthanum	La		138.5260	138.5	6.10		
MANGANESIUM		Mn	53.9060	53.9	8 01 to 8.03	0.1217	
Gallium	Ga		68.8540	68.9	6.00		
ZINC		Zn	64 9045	64.9	7.10 to 7.20	0.0955	412.0
IRON (Ferrum)		Fe	55.9130	55 9	7.79 to 7 84	0.1138	2000.0
NICKEL		Ni	57.9280	57.9	8.60 to 8.82	0.1086	2000.0
COBALT		Co	58.8870	58.9	8.49 to 8.51	0.1069	1670.0
Thallium	Tl		203.7150	203.7	11.80	0.0338	294.0
CADMIUM		Cd	111.8350	111.8	8.45 to 8.69	0.0556	315.0
LEAD (Plumbum)		Pb	206.4710	206.5	11.33 to11.39	0.0314	325.0
Indium	In		113.3980	113.4	7.40		
TIN (Stannum)		Sn	117.6980	117.7	7.30	0.0562	230.0
BISMUTH	Bi		207.5230	207.5	9 80	0.0308	264.0
Uranium		U	238.4820	238.5	18.40	0.0619	
COPPER (Cuprum)		Cu	63.1730	63.2	8.93 to 8.95	0.0951	1200.0
SILVER (Argentum)	Ag		107.6750	107.7	10 40 to10.57	0 0570	1000.0
MERCURY (Hydrargyrum)		Hg	199 7120	199.7	13.60	0.0319	−40°.0
Palladium		Pd	105.7370	105.7	11.80	0.0592	High
Ruthenium		Ru	104.2170	104.2	11.40		"
Rhodium		Rh	104.0550	104 1	11.00 to11.20	0.0562	"
PLATINUM		Pt	194.4150	194.4	21.50	0.0324	3000
Iridium		Ir	192.6510	192.7	21.80	0.0325	1000
Osmium		Os	198.4940	198.5	22.40	0.0311	
GOLD (Aurum)	Au		196.1550	196.2	19.26 to19.34	0.0324	1250
HYDROGEN	H		1.0000	1.0		3.4090	
SILICON		Si	28.1950	28.2	2.49	0.1774	
Titanium		Ti	47.9997	48.0			
Columbium (Niobium Nb)	Cb		93.8120	93.8	7.10		
Tantalum	Ta		182.1440	182.1	10.78		
Tellurium		Te	127.9600	128.0	6.18 to 6.24	0.0473	
ANTIMONY (Stibium)	Sb		119.9550	120.0	6 72	0.0557	450
CARBON		C	11.9736	12.0	2.27 to 3.52	0.1468 to 0.2415	nearly inf.
BORON	B		10.9410	10.9	2 63	0.2500	
Wolfram (Tungsten)		W	183.6100	183.6	17.20 to 18.30	0.0334	
Molybdenum		Mo	95.5270	95.5	8.62 to 8.64	0.0721	
Vanadium	V		51.2560	51.3	5.50		
CHROMIUM		Cr	52.0090	52.0	7.01		High
ARSENICUM	As		74.9180	74.9	5.63 to 5.67	0.0814	3000
PHOSPHORUS	P		30.9580	31.0	1.83 to 1.96	0.1887	
Selenium		Sc	78.7970	78.8	4.28 to 4.80	0.0746	44
IODINE	I		126.5570	126 6	4.95	0.0541	100 to217
BROMINE	Br		79 7680	79.8	2.99 to 3.19	0.0813	
CHLORINE	Cl		35.3700	35 4	1.33 (liquid)	0.1210	107
Fluorine	F		18.9840	19.0			
NITROGEN	N		14.0210	14 0		0 2438	
SULPHUR		S	31.9840	32 0	1.98 to 2.07	0.1776	
OXYGEN		O	15.9633	16 0		0.2175	

NEGATIVE END: hydrates form acids.

Such elements as neptunium, davyum, phillipium. decipium, etc., etc., are of no importance to the dentist. Moreover, Crookes, in his address to the Chemical Society of Great Britain, has questioned the elementary character of the so-called rare earths and proposes the term "meta-elements" for those substances which are neither compounds, mixtures, nor elements.

111. **Number of Atoms in Molecules of Elements.**—At ordinary temperatures most of the elements given in Table 1 contain two atoms in the molecule and are called, therefore, *Diatomic.* **Exceptions:** mercury, cadmium, zinc, barium are **Monatomic,** *i. e.*, have one atom in the molecule; ozone contains three atoms of oxygen; the molecule of phosphorus and of arsenic contains four atoms; that of sulphur, six, but at high temperatures, two.

Elemental Atoms and Molecules.—The symbols given in Table 1 should not be used to represent the elements in general; each symbol represents **one atom** of the element; thus, Zn does not represent zinc in general, but one atom of the element zinc with the properties of that atom, namely, definite unchanging weight and definite power of attraction for other atoms.

Rule 1.—To Denote a Number of Atoms of an Element, write the Symbol of the Element with the required number in Arabic Figures at the lower right hand corner of the Symbol.—Zn_2 means two atoms of zinc; H_3 means three atoms of hydrogen; O_4 means four atoms of oxygen. Where one atom of an element is to be represented, write the symbol only.

Rule 2.—To Denote a Molecule of an Element, write the Symbol of that Element with

the Figure 2 at its lower right hand corner.—Exceptions: write the **symbols only** of mercury, cadmium, zinc, and barium; write four after the symbols of phosphorus and arsenic, and six after sulphur. O_2 means one molecule of oxygen, composed of two atoms. Hg means one molecule of mercury, composed of one atom; P_4 means one molecule of phosphorus, composed of four atoms; S_6 means one molecule of sulphur, composed of six atoms. (See 111 for Atomicity).

Rule 3.—To Denote a Number of Molecules of an Element, write the required Number as a full sized Figure before the expression for one Molecule. $2O_2$ means two molecules of oxygen, each composed of two atoms. 2Zn means two molecules of zinc, each composed of one atom.

112. **Atomic weight.**—The atomic weight of an element denotes the weight of an atom of it referred to the weight of an atom of hydrogen as unity.

The *proportions* in which atoms combine also represent the weights of the atoms: thus, oxygen unites with other elements in proportions of 16, therefore 16 is the weight of the atom of oxygen.

113. **Determination of atomic weight.**—By quantitative analysis the weights of two elementary substances forming a compound is ascertained. The proportion of these weights, one to another, will be either the ratio of the atomic weights of the two elements, or else that

of some simple multiple, the latter being previously known from a comparison of the compounds of the element whose weight we are seeking. Thus, suppose it is desired to find the atomic weight of zinc. Suppose that on using a given weight of zinc and of hydrochloric acid a certain volume of hydrogen is evolved. Make a proportion:

Weight of hydrogen found: weight of zinc used = 1 : x. Now x will be either the atomic weight of zinc, or some multiple of it. From a comparison of the numerous zinc compounds we know the result obtained to be half the atomic weight. Double the value to find the accepted weight.

114. **Quality of Combining Power of Atoms. Positive and Negative Elements.**—When a current of electricity of sufficient strength is passed through a chemical compound in state of solution, *i. e.*, dissolved, the compound is broken up into its constituent elements. Of these elements some are found at the positive pole of the battery, others collect at the negative.

An element attracted to the *positive* pole is called a *negative* element; one attracted to the *negative* pole a *positive* element. Elements are not absolutely positive or negative but only relatively so, *i. e.*, with reference to one another. In Table 1 the list of elements is so arranged that each element is negative to the one below it and positive to the one above it. For example, suppose it be required to know which of the two elements, sulphur and oxygen, is positive to the other and which negative. Consulting Table 1, it will be found that oxygen is written *below* sulphur, therefore negative to it; sulphur is written *above* oxygen, therefore *positive* to oxygen.

115. **Quantity of combining power of Atoms.***—*One* atom of an element does not necessarily combine with, or take the place of, one atom of, another element. It may unite with 1, 3, or 5 atoms of another element, or with 2, 4, or 6 atoms of it. An atom of bromine for example may combine with one atom of hydrogen, but an atom of oxygen requires *two* of hydrogen, one of nitrogen requires *three* and so on.

The equivalence or quantivalence of an atom of an element, by which we mean the quantity of combining power which it has, is expressed as 1, 2, 3, 4, 5, 6, or 7, according as the atom will attach to itself, or be exchanged for, 1, 2, 3, 4, 5, 6, or 7 atoms of hydrogen, or the equivalent of those atoms.

If the atom combines with one atom of hydrogen, or exchanges for one atom of hydrogen, it is called a **Monad**, if with two a **Dyad**, if with three a **Triad**, if with four a **Tetrad**, if with five a **Pentad**, if with six a **Hexad**, if with seven a **Heptad**. Monads are equivalent to monads, dyads to dyads, etc. Dyads are equivalent to two monads, triads to three monads, etc. One monad and one dyad are together equivalent to one triad, etc.

The following table should now be carefully committed to memory:

TABLE 2. QUANTIVALENCE.†

MONADS.	DYADS.	TRIADS.
Potassium.	Barium.	Bismuth.
Sodium.	Calcium.	Gold.

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*The terms quantivalence, equivalence, equivalency, and valence are all used to denote the quantity of the combining power of atoms.

†The elements are arranged in electro-chemical order, beginning with the positive and ending with the negative or least positive.

TABLE 2.—*Continued.*

Lithium.	Magnesium.	Antimony.
Silver.	Zinc.	Boron.
Hydrogen.	Lead.	Arsenic.
Iodine.	Copper.	Phosphorus.
Bromine.	Mercury.	Nitrogen.
Chlorine.	Sulphur.	
Fluorine.	Oxygen.	

TETRADS.	HEXADS.
Aluminium.	Manganese.
Tin.	Iron.
Platinum.	Chromium.
Silicon.	
Carbon.	

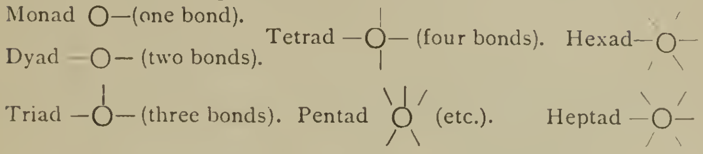
Notice that those in-*ine* are all monads, that the gases hydrogen, oxygen, nitrogen are monad, dyad, and triad respectively.

Monads are said to be *univalent.*
Dyads " " *bivalent.*
Triads " " *trivalent.*
Tetrads " " *tetravalent.*
etc., etc., etc.

Rule 4. To express the Equivalence (Quantivalence) of an Atom, place a Roman Numeral above and to the right of the Symbol.

O^{I} means one atom of oxygen having 2 as its quantivalence, or *equivalence* as it is often called. N means one atom of nitrogen having 3 as its equivalence.

N. B.--Quantivalence is sometimes expressed by dashes, thus: O″, N‴; by some the points of attraction, or bonds, of an atom are expressed as follows:



116. **Variations in Quantivalence.**—Unfortunately for the learner, the various elements do not always adhere to the quantivalence established in Table 2. Certain of the elements are not only of the quantivalence of Table 2, but of other quantivalence also.

This is the most difficult thing in chemical theory for the beginner to understand. It has been found by analysis that nitrogen, for example, is sometimes a monad, sometimes a triad, and sometimes a pentad. This is because one element may form several *different* compounds with another element.

Let the student now commit to memory the following table:

Table 3.—VARIATIONS IN QUANTIVALENCE.

List I.—Elements often either Monads, Triads, or Pentads.

Chlorine	I, III, V.
Bromine	I, III, V.
Iodine	I, III, V.
Nitrogen	I, III, V.
Phosphorus	I, III, V.
Arsenic	I, III, V.

List II.—Elements often either Triads or Pentads.

Antimony	III, V.
Bismuth	III, V.

List III.—Elements often either Dyads or Tetrads.

Carbon	II, IV.

Silicon....................II, IV.
Tin.........................II, IV.
Lead......................II, IV.
Platinum.................II, IV.

List IV.—Elements often either Dyads, Tetrads, or Hexads.

Sulphur...............II, IV, VI.
Selenium.............II, IV, VI.

Other elements varying in quantivalence will be noticed whenever necessary. Table 3 includes the most important variations. It must be noticed that the equivalence of an atom always increases or diminishes by two; thus, chlorine may be either I, III, or V, but not I, II, or III.

117. **Artiads and Perissads.**—Atoms (or radicals)* which have an even number of free bonds, that is, dyads, tetrads, and hexads, are called *Artiads*. Those which have an uneven number of free bonds, that is, monads, triads, pentads, and heptads, are called *Perissads*.

118. **Theory of Variation in Quantivalence.**—The hypothesis is that an atom has but one equivalence, namely the highest it ever exhibits. If now two of its bonds mutually saturate one another, the quantity of combining power which the atom now has is less by two than its highest combining power; if two pairs of bonds mutually saturate each other, the atom has an equivalence now less by four than its highest, and so on. A heptad may thus become pentad, triad, and monad; a hexad may become tetrad and dyad.

COMPOUND MOLECULES.

119. **Relation of Molecular Weight to density of compound gases.**—All molecules have the same size (Avoga-

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*For radicals see section 126

dro's law) therefore every molecular formula not only expresses the weight of the molecule, but also the volume it occupies. The volume occupied by the atom of hydrogen is assumed to be unity; the volume of its molecule will therefore be two, and of all molecules of all bodies, two also. Molecular weight, then, represents the weight of *two* volumes; density represents the weight of *one*.

Therefore *the density of any homogeneous substance in the state of gas is one-half its molecular weight.* Conversely, given the density of a substance in the state of gas and its *molecular weight is always equal to twice the density.*

120. **Law of definite and multiple proportions.**—A given compound always contains the same elements in the same proportions. Thus, a molecule of water is *always* composed of hydrogen atoms and oxygen atoms, and always of just so much hydrogen, two atoms, and of so much oxygen, one atom. Moreover, when two elements are capable of uniting in different proportions, the quantities of one which unite with a given quantity of another usually bear a simple relation to one another.

121. **Differences between Molecules.**—Molecules are of two classes, *elementary** (composed of like atoms) and *compound* (composed of unlike atoms).

122. **Formulæ.**—Compound molecules are represented by the symbols of the different elements forming the

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*Elementary molecules have already been considered.

compound. This representation is termed a formula; thus, KCl is a formula representing one atom of potassium and one atom of chlorine, the two together combining to form a compound molecule.†

123. **Compound Molecules.** (*a*) **Binaries.** — Compound molecules are of two kinds: 1, Binary; 2, Ternary.

Binary Compounds are those whose molecule is composed of two atoms each one of a different element, as KCl.

Definition 6. **A Binary Compound is one formed by the direct union of two different elements or radicals, one of which must be positive to the other.**

Rule 5. **To name Binaries, put the name of the positive element first and the name of the negative element second. Then change the termination of the negative element to -ide.**

A compound of sulphur and potassium is named as follows:

(1). Consult Table 1, and find which is positive to the other.

(2). Put the name of the positive element first, that of the negative second: thus, potassium sulphur.

(3). Change the termination of the negative one, sulphur, to -ide, and we have potassium sulphide.

Example 1. Name compounds of the following: silver and chlorine, sodium and sulphur, iodine and potassi-

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†The entire number of bonds in a molecule must be even.

um, hydrogen and oxygen, hydrogen and arsenic, phosphorus and zinc. Answers: silver chloride, sodium sulphide, potassium iodide, hydrogen oxide, hydrogen arsenide, zinc phosphide.

124. **Meaning of the terminations -ic,-ous, and hypo-ous.**—When the positive of two elements forming a compound is one of those which varies in equivalence (see Table 3) this variation is indicated by the use of the termination **-ic, -ous,** and **hypo-ous.**

Rule 6. **To name a binary compound whose positive element is one which varies in equivalence,** write the names of the elements precisely as in rule 5, but change the termination of the positive element to *-ic*, if this element exerts its highest equivalence (Table 3), to *-ous* if its next highest, and to *hypo–ous* if its lowest.

A compound of tetrad tin and chlorine would be called stann*ic* chloride; of dyad tin and chlorine, stann*ous* chloride; of monad chlorine and oxygen, *hypo*chlor*ous* oxide. (Notice in Table 1 that oxygen is negative to chlorine).

Example 2. What do triad chlorine and oxygen form? pentad antimony and chlorine?

Answers: Chlorous oxide. Antimonic chloride.

Rule 7. **To write the formula for a binary compound,** write the symbol of the positive element first, then the symbol of the negative element. At upper right hand of symbol of positive element write the equivalence of that element; do the same to the negative. Transfer the Roman numerals indicating equivalence of positive element to lower right hand of negative element. Transfer the Roman numerals indicating equivalence of the negative element to the lower right hand of positive element. Write all transferred numerals in Arabic figures, changing them from Roman.*

To write the formula for stannic chloride:

(1) Symbol of positive element, Sn;
(2) Symbol of negative element, Cl;
(3) Arranged in order, $SnCl$;
(4) Equivalence indicated, $\overset{IV}{Sn}\overset{I}{Cl}$;
(5) Numerals transferred, $SnCl_4$

N. B.—It is really never necessary to write the figure 1, as the symbol itself indicates one atom.

If **several molecules** of the binary compound are to be denoted, write the formula, inclose in brackets, and write the multiplier as a small-sized figure at lower right hand, or write a full-sized figure before the formula not inclosed in brackets.

Suppose it be required to denote 3 molecules of sodium iodide: the formula is NaI which denotes *one molecule* with all the properties of that molecule, namely, a certain unchangeable weight—the sum of the weights of the two atoms, called the molecular weight—or, in the case of

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*Rule 7 has been deduced from the following: in all cases of chemical combination the chemical affinity of each atom must be satisfied. Atoms of the same valence, then, may mutually saturate one another, and unite in the ratio of one to one. Atoms of different valence cannot unite in the ratio of one to one; each one must furnish the same number of bonds, which number is in all cases the least common multiple of the two valences. Divide this l. c. m. by each valence to obtain the number of atoms of each constituent in the compound. Thus, triad nitrogen and dyad oxygen: $6 \div 3$ shows the number of nitrogen atoms; $6 \div 2 =$ the number of oxygen atoms.

gases, a certain volume always the same; to denote 3 molecules, write the figure 3 before the formula: thus, $3NaI$; or bracket the formula (NaI) and write the figure 3 in small-sized type at the lower right hand: thus $(NaI)_3$.

Example 3. Denote five molecules of magnesium oxide, six of silver chloride, three of chlorous oxide.

Answers: $5MgO$ or $(MgO)_5$, $6AgCl$ or $(AgCl)_6$, $3Cl_2O_3$ or $(Cl_2O_3)_3$.

Remark: In order to apply Rule 7 successfully, the following must be borne in mind: if a formula, obtained by Rule 7, shows after each symbol figures which contain common factors, these common factors must be removed from the figures; thus, the formula for stannic oxide, according to Rule 7, is Sn_2O_4; but 2 and 4 contain the common factor 2, therefore divide each by 2 and the result, SnO_2, is the proper formula. *

Example 4. Write the formulæ for platinic sulphide, hyposulphurous oxide, stannous sulphide:

Answers. PtS_2, SO, SnS.

125. **Variation in Equivalence of Certain Elements.**—Certain elements vary in equivalence in a puzzling manner, e. g. mercury, copper, iron, aluminium. As compounds of these metals are important, it is desirable that the variations in equivalence be thoroughly understood.

Mercury is a dyad; in some compounds, however, we find two atoms of mercury and two of a monad, as for example in calomel, the formula for which is Hg_2Cl_2. The formula Hg_2Cl_2 is explained graphically:

$$\begin{array}{l} \mathrm{Hg—Cl.} \\ \;| \\ \mathrm{Hg—Cl.} \end{array}$$

Two atoms of dyad mercury would have four bonds (Rule 4, N. B.), and ought to take four atoms of monad chlorine, *but two of the bonds of the mercury satisfy*

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*Sn_2O_4 is the same as $2SnO_2$ or $(SnO_2)_2$, that is two molecules of SnO_2.

each other instead of requiring two bonds of chlorine; the other two bonds of the mercury are satisfied by means of two chlorine bonds, hence $Hg_2 Cl_2$, and not Cl_4 as might be expected. The same may be said of copper. Such compounds are called mercurous or cuprous compounds. Variation in equivalence may, in general, be explained by graphic formulæ.

Rule 8. **To write formulæ containing mercury or copper,** assign to *mercuric* atoms and *cupric* atoms an equivalence of *two* as in table 4; to *mercurous* and *cuprous* assign an equivalence of one. N. B. In the case of mercurous and cuprous note that two atoms of mercury or copper require two only of a univalent element.

Example 5. Write the formulæ for mercuric chloride, mercurous iodide, cupric oxide, mercurous chloride.

Answers. $HgCl_2$, HgI or Hg_2I_2, CuO, $HgCl$ or Hg_2Cl_2.

Compounds of **iron** are known to exist in which the molecule may consist of two atoms of iron and six of a monad, as for example, ferric chloride, Fe_2Cl_6; to such compounds the term *ferric* is applied.

Rule 9. **To write formulæ containing** *iron*, give two atoms of iron together, an equivalence of *six*, if the compound is called *ferric*. In *ferrous* compounds assign equivalence of *two* to iron.

N. B. While Hg_2Cl_2 is often written in the simpler form $HgCl$, it is not customary to write Fe_2Cl_6 in any simpler fashion; the formulæ of other compounds are usually simplified.

Example 6. Write the formulæ for ferric chloride, ferric oxide, ferrous sulphide, ferrous oxide, aluminic chloride.

Answers. Fe_2Cl_6, Fe_2O_3, [that is $(Fe_2)_2O_6$], FeS, FeO, Al_2Cl_6—like ferric.

Rule 10. **To read Binary Formulæ,** observe from figure at lower right hand of negative element what the equivalence of the positive element is. If the positive element is in its highest equivalence (Table 3) change its termination to -ic etc., as in Rule 6. Note that where sulphur is the positive element and the negative element oxygen, the figure 3 at the lower right hand of oxygen will denote sulphur as a hexad, hence sulphur*ic*: e. g., S_2O_6 or SO_3 is sulphur*ic* oxide.

In reading binary formulæ, the termination of the negative element is always changed to -ide.

Example 7. Read the formulæ of the following compounds used in dental medicine:

1, KBr. 2, KI. 3, HCl. 4, $SnCl_2$. 5, KCl. 6, K^2O. 7, H_2O. 8, Al_2Cl_6. 9, As_2O_3. 10 $AuCl_3$. 11, $HgCl_2$. 12, HgCl. 13, HgI. 14, ZnI_2. 15, ZnO. 16, MgO. 17, CaO.

Answers. 1, potassium bromide. 2, potassium iodide, 3, hydrogen chloride. 4, stannous chloride. 5, potassium chloride. 6, potassium oxide. 7, hydrogen oxide. 8, aluminic chloride. 9, arsenous oxide. 10, auric chloride. 11, mercuric chloride. 12, mercurous chloride (see Rule 8). 13, mercurous iodide. 14, zinc iodide. 15, zinc oxide. 16, magnesium oxide. 17, calcium oxide.

Example 8. Read the following formulæ (of use in studying ternaries): Cl_2O_5, N_2O_5, SO_3, SO, Cl_2O, Cl_2O_3, CO_2.

Answers. Chloric oxide, nitric oxide, sulphuric oxide, hyposulphurous oxide, hypochlorous oxide, chlorous oxide, carbonic oxide.

126. **Radicals.**—A radical is an unsaturated group of atoms. It possesses free bonds, hence may enter into combination like single atoms.

Example: HO is an unsaturated group of atoms, for one bond of the oxygen is unprovided for, thus, H—O—. Hence HO is a radical.

127. **Nomenclature, and equivalence of radicals.**–The *names* of compound radicals end in -yl. Thus, HO is called hydroxyl.

The equivalence of compound radicals is always equal to the number of unsatisfied bonds, that is to the difference resulting from the subtraction of the equivalence of one of its constituents from that of the other:

Thus the equivalence of HO is *one* because it has one unsatisfied bond, that is, 2 (equivalence of oxygen) minus 1 (equivalence of hydrogen) equals 1 (equivalence of hydroxyl).

Radicals are therefore *perissad* and *artiad* like atoms. Perissad radicals can not exist free except by combining with one another.

128. **Ternary Compounds.**—

Definition 7. A ternary compound is one whose molecule is composed of three or more different kinds of atoms: thus, $KClO_3$ is a ternary because composed of K, Cl, and O. In every ternary formula there are at least three different symbols.

In ternaries the dissimilar atoms are linked together by a third atom, and ternaries are of two classes, (*a*) those whose dissimilar atoms are linked by a bivalent atom, and (*b*) those whose dissimilar atoms are linked by a trivalent atom. The first class comprises many inorganic compounds, the second many organic.

In the first class the linking is usually performed by oxygen, sometimes by sulphur, sometimes by selenium and tellurium.

129. Ternaries of the first class. Dissimilar atoms linked by oxygen or sulphur.

There are three kinds: acids, bases, and salts.

Definition 8. **Acids** are corrosive substances having usually a sour taste, neutralizing alkalies, and changing blue vegetable colors to red. They give off hydrogen when brought into contact with a metal. Acids are either (hydracids), **ox-acids**, or **sulpho-acids**. [Hydracids are *binary* compounds of hydrogen, and are hydrochloric, HCl; hydrobromic, HBr; hydriodic, HI; hydrosulphuric, H_2S. They are also called hydrogen (or hydric) chloride, hydrogen or hydric bromide, etc.].

Ox-acids are composed of hydrogen, some negative element, and oxygen: as HNO_3, nitric acid.

Sulpho-acids are composed of hydrogen, some negative element, and sulphur, as H_2CS_3, sulpho-carbonic acid.

Rule 11. **To write the formulæ of many ox-acids and sulpho-acids:***

1. Write the formula of corresponding oxide or sulphide, simplifying if possible.

2. Add formula for a molecule of water, H_2O, in case of an ox-acid, or H_2S in case of a sulpho-acid.

3. Simplify if possible.

Suppose the formula for nitric acid be required: first write the formula for the corresponding oxide. By this we mean nitric† oxide and not nitrous or hyponitrous. Formula for nitric oxide is N_2O_5; add H_2O and we have $H_2N_2O_6$—the only thing to be added arithmetically being O to O_5 making O_6. Now simplify by taking out the common factor 2 and we have HNO_3. (See also Table 4 and note Rule 14, page 60).

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*Rule 11 is deduced from the following: 1. An acid molecule is one consisting of one or more negative atoms united by oxygen to hydrogen.

2. Ternaries are formed by the direct union of the oxide of a more positive atom with the oxide of a less positive or negative atom. Whenever water is the positive oxide, the body produced is an acid: thus, of the two oxides, sulphuric and hydric, sulphuric oxide is the negative and hydric oxide (water) the positive, therefore the two on combining form an *acid.*

3. An acid, then, may be formed by the combination of a negative oxide with water.

Acids are also formed from water, H—O—H, by exchanging an atom of H for a negative monad. Thus, hypochlorous acid: exchange one atom of H for Cl and there is formed Cl—O—H.

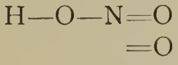
†This rule gives always hydrated acids and is of service in obtaining formulæ of salts. The use of Table 4 is to be preferred.

Note. The formulæ for phosphoric, boric, arsenic, arsenous, and hypophosphorous acids are obtained by adding more than one molecule of water or (better) by Table 4, page 60.

Example 9. Write the formulæ for the following acids: sulpho-carbonic, sulphuric, sulphurous, hypochlorous, nitrous.

Answers: H_2CS_3, H_2SO_4, H_2SO_3, $HClO$, HNO_2.

N. B. The oxygen or sulphur of acids is said to have a linking function, uniting the hydrogen to the rest of the molecule; thus, the formula for nitric acid may be represented graphically as follows:



$$\begin{array}{r} H\text{—}O\text{—}N{=}O \\ {=}O \end{array}\Bigg\}$$

the hydrogen atom being linked to the rest of the molecule by the oxygen atom.

Definition 9. **Bases** are the opposite of acids. They neutralize acids, either partly or entirely, restore blue colors to vegetable colors turned red by acids, when concentrated decompose fats, forming soap, and act on the tissues as caustics.

Acids unite with metals to form salts, bases with acids to form salts, hydrogen being evolved in the one case, water formed in the other.

Inorganic bases are termed hydrates, by which term we shall hereafter call them. The molecule of a hydrate is composed of a positive atom or atoms, hydrogen, and oxygen: thus, R O H. R denoting any number of positive atoms.

The oxygen of bases is said to link the hydrogen to the positive element.

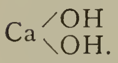
The formula for sodium hydrate may be represented graphically as follows: Na—O—H, in which the positive atom is linked by the atom of oxygen to the hydrogen.

Rule 12. **To write the formula for a hydrate,** first write the symbol of the positive element with its equivalence over it, then write OH in brackets with an equivalence of 1 over it. Next exchange figures representing equivalences, as in binaries.*

To write the formula for calcium hydrate:

1. Ca^{II}.
2. $(OH)^{I}$.
3. $Ca^{II}(OH)^{I}$.
4. $Ca(OH)_2$. Calcium hydrate.

Calcium hydrate represented graphically would be



$$Ca\begin{matrix}\diagup OH\\ \diagdown OH.\end{matrix}$$

Example 10. Write the formulæ for barium hydrate, mercuric hydrate, arsenous hydrate, cuprous hydrate.

Answers. $Ba(OH)_2$, $Hg\ (OH)_2$, $As(OH)_3$, CuOH.

N. B. Where one molecule only of OH occurs it is not necessary to bracket. Instead of OH some authors write HO.

Definition 10. A **salt** resembles neither an

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*Rule 12 is deduced from the following: a molecule of water consists of two atoms of hydrogen linked by oxygen. Exchange one of these hydrogen atoms for a positive univalent atom, and a base results. Thus, water is H—O—H: exchange H for K and we have K—O—H. But when it is necessary to form the hydrate of a bivalent atom it is necessary to take two molecules of water and one of the bivalent element. Thus, if calcium hydrate be required, take 2 H_2O, or H_4O_2. Substitute Ca for H_2 and we have CaH_2O_2 or $Ca(HO)_2$, The formulæ of bases may be obtained also by direct union of water with a positive oxide.

acid nor a base; its molecule consists of a positive atom united by oxygen to a negative atom; thus, KNO_3: K positive atom, N negative, O oxygen.

Exceptions. A salt may be formed from an acid and a metal, the latter replacing all the hydrogen of the acid; acids whose molecule contains two atoms of hydrogen may not always exchange both atoms for atoms of a metal, but one may be replaced and the other not: thus, $NaHSO_4$. Such a salt is called an *acid* salt. Those described in Definition 10 are called *normal* salts. *Double* salts are those whose molecules consist of two, different, positive atoms united by oxygen to the negative atom: thus, $KNaSO_4$, called potassium sodium sulphate, or the double sulphate of potassium and sodium.

Rule 13.* **To write the formula of a salt.**—First write the formula of the acid which, with the metal, forms the salt; bracket the non-hydrogen part of the acid formula, erase the H, and put in its place the symbol of the metal; write the equivalence of the metal after the bracket, and simplify if possible.

Note that *-ate* in a salt corresponds to *-ic* in an acid, *-ite* to *-ous*, hypo-ite to hypo-ous.

Examples: sodium sulph*ate* is formed from sulphur*ic* acid, sodium sulphite from sulphur*ous* acid, sodium hypochlorite from hypochlor*ous* acid.

Suppose the formula for mercuric nitrate be required. The termination *-ate* in a salt is used by chemists to sig-

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*In writing the formulæ of a salt, as many molecules of the acid must be taken as is necessary to furnish a number of hydrogen atoms equal to the L. C. M. of the number of hydrogen atoms in the acid (*basicity*) and the valence of the replacing atom.

nify a higher equivalence of the negative element, just as *-ic* is used in the case of acids:

1. Write the formula for nitric acid: HNO_3.
2. Bracket the non-hydrogen part: $H(NO_3)$.
3. Erase the H and put into its place the symbol of the metal mercury: $HgNO_3$.
4. Write the equivalence of metal after bracket: $Hg(NO_3)_2$.
5. Simplify. (Not possible in this case).

The formulæ of salts may be written much more rapidly if the following table of compound **negative radicals** be committed to memory.

TABLE 4.

MONADS.

NO_3 (Nitrates).
NO_2 (Nitrites).
ClO_3 (Chlorates).
PH_2O_2 (Hypophosphites).
ClO (Hypochlorites).

DYADS.

SO_4 (Sulphates).
SO_3 (Sulphites).
CO_3 (Carbonates).
CrO_4 (Chromates).
Cr_2O_7 (Bichromates).

TRIADS.

PO_4 (Phosphates).
AsO_4 (Arsenates).
AsO_3 (Arsenites).
BO_3 (Borates).

TETRADS.

$FeCy_6$* (Ferrocyanides).
SiO_4 (Silicates).
P_2O_7 (Pyrophosphates).

HEXADS.

Fe_2Cy_{12}* (Ferricyanides)

Rule 14. **To write the formula of a salt by use of Table 4.** First write the symbol

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*These will be explained under the head of theory of organic chemistry.

for the metal, with its equivalence indicated over it; next write the formula for the compound radical with its own equivalence over it; exchange equivalences; simplify if possible.

Suppose the formula of zinc hypophosphite be required:

1. $Zn^{II}(PH_2O_2)^{I}$.
2. $Zn(PH_2O_2)_2$.

N. B. Acids being regarded by some as salts of hydrogen, their formulæ may be written from Table 4: thus, sulphuric acid may be written as hydrogen sulphate:

1. $H^{I}(SO_4)^{II}$.
2. H_2SO_4.

Phosphoric acid and boric acid should be written from Table 4 altogether, as they are meta- and ortho-acids respectively, as regards their salts used in dental medicine.*

Example 11. Write the formulæ for the following salts used in dental medicine: cadmium sulphate, cupric sulphate, zinc sulphate, magnesium sulphate, magnesium hypochlorite, calcium sulphite, calcium hypophosphite (by Table 4), calcium carbonate, silver nitrate.

Answers: $CdSO_4$, $CuSO_4$, $ZnSO_4$, $MgSO_4$, $Mg(ClO)_2$, $CaSO_3$, $Ca(PH_2O_2)_2$, $CaCO_3$, $AgNO_3$.

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*An ortho-acid is one whose molecule contains as much H as O: thus, ortho-phosphoric acid is H_5PO_5. The term "ortho-phosphoric" acid is, however, often given to H_3PO_4, which is really di-meta-phosphoric acid. A meta-acid is derived from an ortho-acid by subtraction of one or more molecules of water from the formula of the ortho-acid.

Example 12.† For practice write the formulæ of the following:

1. Cupric ferrocyanide,
2. Barium chromate,
3. Lead sulphate,
4. Ferric sulphate,
5. Ferric hypophosphite,
6. Aluminic hydrate,
7. Ferrous sulphate,
8. Sodium hypophosphite,
9. Potassium hypochlorite,
10. Calcium hypochlorite,
11. Potassium sodium sulphate,
12. Potassium sodium acid phosphate, or potassium sodium hydrogen phosphate,
13. Sodium hydrogen carbonate or sodium bicarbonate.

Answers:—

1. Cu_2FeCy_6,
2. $BaCrO_4$,
3. $PbSO_4$,
4. $Fe_2(SO_4)_3$,
5. $Fe_2(PH_2O_2)_6$,
6. $Al_2(HO)_6$,
7. $FeSO_4$,
8. $Na(PH_2O_2)$,
9. $KClO$,
10. $Ca(ClO)_2$,
11. $KNaSO_4$,
12. $KNaHPO_4$,
13. $NaHCO_3$.

TERNARIES OF THE SECOND CLASS. DISSIMILAR ATOMS LINKED BY TRIADS.

130. Ternaries of the second class are linked mostly by nitrogen. There are three kinds of those linked by nitrogen:-*amides*,in whose molecule *negative* atoms are linked to hydrogen by nitrogen,—*amines*, in whose molecule *positive* atoms are linked by nitrogen to hydrogen, and *alkalamides*, in whose molecule positive atoms are linked by nitrogen to negative ones. All may be derived by substitution from ammonia.

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†This example may, at the discretion of the teacher, be omitted.

Rule 15. To read formulæ: commit to memory the following table:

TABLE 5.—USUAL TERMINATIONS IN VARIOUS BINARY AND TERNARY FORMULÆ.*

BINARIES.

Hydrochloric acid and all chlorides end in Cl_n.†

Hydrobromic acid and all bromides end in Br_n.

Hydriodic acid and all iodides end in I_n.

Hydrosulphuric acid and all sulphides end in S_n.

Hydrofluoric acid and all fluorides end in F_n or Fl_n.

All oxides end in O_n.

TERNARIES.

All hydrates end in $(OH)_n$.

Sulphuric acid and all sulphates end in $(SO_4)_n$.

Phosphoric acid and all phosphates end in $(PO_4)_n$.

Chromic acid and all chromates end in $(CrO_4)_n$.

Boric acid and all borates end in $(BO_3)_n$.

Nitric acid and all nitrates end in $(NO_3)_n$.

Chloric acid and all chlorates end in $(ClO_3)_n$.

Sulphurous acid and all sulphites end in $(SO_3)_n$.

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*Graphic formulæ are not included in this table.

†n denoting any number.

Hypochlorous acid and all hypochlorites end in $(ClO)_n$.

Hypophosphorous acid and all hypophosphites end in $(PH_2O_2)_n$.

Suppose now that the formula to be read be HNO_3: it begins with H and contains no positive element, therefore is an acid; it ends in NO_3, therefore by Table 5 is ni*tric* acid. Suppose it be required to read the formula $Al_2(OH)_6$; it is not an acid because it does not begin with H, but is a hydrate, because it ends in OH; and it is alumin*ic* hydrate by Rule 9. Suppose the formula be K_2CO_3. It is not an acid, nor a hydrate, but is a salt, because ending in oxygen preceded by a negative element. It is a carbonate by Table 5, hence is potassium carbonate. Suppose the formula be $Fe_2(CrO_4)_3$; it is a salt, and by Table 5 a *chromate*, and by Rule 9, *ferric* chromate.

Example 13. Read the formulæ given in the answers to example 12.

N. B. Consideration of formulæ of organic compounds is deferred to Chap. IV, but, as a sharp line of demarcation cannot always be drawn between many inorganic and organic compounds, the beginner will do well to note the following:

TABLE 6—ORGANIC COMPOUNDS.

BINARIES.

Hydrocyanic acid and all cyanides end in $(CN)_n$.

Hydroferrocyanic acid and all ferrocyanides end in $(FeCy_6)_n$.

Hydroferricyanic acid and all ferricyanides end in $(Fe_2Cy_{12})_n$.

Sulphocyanic acid and all sulphocyanates end in $(CNS)_n$.

TERNARIES.

Acetic acid and all acetates end in $(C_2H_3O_2)_n$.

Oxalic acid and all oxalates end in $(C_2O_4)_n$.

Tartaric acid and all tartrates end in $(C_4H_4O_6)_n$.

Salicylic acid and all salicylates end in $(C_7H_4O_3)_n$.

Example 14.* Read the following formulæ: $Pb(C_2H_3O_2)_2$, $K_2C_2O_4$, KCN, $K_4Fe(CN)_6$ or Cy_6, $KNaC_4H_4O_6$, Na(CN)S or CyS, $Na_2C_7H_4O_3$.

Answers. Plumbic acetate, potassium oxalate, potassium cyanide, potassium ferrocyanide, potassium sodium tartrate, sodium sulphocyanate, sodium salicylate.

N. B. (*a*) **Ammonium Compounds** begin with (NH_4), a univalent positive radical: ammonium chloride is, therefore, $(NH_4)Cl$, ammonium sulphate $(NH_4)_2SO_4$, etc., etc.

Example 15. Read the following: NH_4NO_3, NH_4HO, NH_4MgPO_4.

Answers. Ammonium nitrate, ammonium hydrate, ammonium-magnesium phosphate.

(*b*) **Nomenclature — Old and New.**—The prefixes *proto-* and *per-* are used in older works instead of *-ic* and *-ate* on the one hand and *-ous* and *-ite* on the other; for example, instead of *mercurous iodide*, older writers speak of the *protiodide* of *mercury;* instead of *ferric sulphate* the *persulphate* of *iron* is the name given.

The term *acid* in some of the older books is given to what is now called *anhydride* or negative oxide; thus *arsenous acid* is used by some writers as the name for As_2O_3 which in this book is called arsenious anhydride or arsenous anhydride. The term *anhydrous acid* is also used by

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*This example may be omitted until organic chemistry be taken up.

some writers instead of anhydride or oxide, and the term *hydrated acid* for what in this book is called simply *acid*. Oxides of sodium, potassium, magnesium, etc., are called *soda*, *potassa*, *magnesia*, *lime*, etc., by some authors.

Example 16. Give the new names for the following: baryta, perchloride of tin, protoxide of mercury, perchloride of iron, potash, alumina, protochloride of mercury, anhydrous phosphoric acid.

Answers. Barium oxide, stannic chloride, mercurous oxide, ferric chloride, potassium oxide, aluminum oxide, mercurous chloride, phosphoric anhydride or oxide.

N. B. Remember that in modern text books the term anhydride simply means an oxide which can combine with the elements of water to produce an acid, or in other words an acid minus water.

In many new text books, notably those by English authors, we find numeral prefixes, as di–, tri–, pent–, etc. Thus, CS_2 is called carbon disulphide, P_2O_5 phosphorus pentoxide, etc., etc. The old term for di– is bi–. Older writers use the prefix *sesqui–* in compounds where there are two atoms of one element and three of another; they also call hydrochloric acid *muriatic acid*, and term chlorides *muriates*. Sulphides are termed *sulphurets* by some.

Example 17. Give new names for the following: sesquioxide of iron, bisulphuret of carbon, sesquisulphide of iron, muriate of ammonia, bichloride of mercury, protosulphuret of iron, peroxide of hydrogen.

Answers. Ferric oxide (Fe_2O_3), carbonic disulphide, ferric sulphide (Fe_2S_3), ammonium chloride, mercuric chloride, ferrous sulphide, hydric dioxide.

Commercial terms.—For these, such as "salts of tartar," "sal volatile," etc., etc., see Glossary at the end of the book.

131. **Chemical change.**—In every chemical change one or more substances called *factors*

change into one or more substances called *products*.

Example: zinc and sulphuric acid change into zinc sulphate and hydrogen. Factors: zinc and sulphuric acid. Products: zinc sulphate and hydrogen.

132. **Fundamental laws of chemical change.**—I. The sum of the weights of the products of a chemical change are exactly equal to the sum of the weights of the factors. (Law of conservation of mass.—Lavoisier's Law).

Example: if phosphorus be burned in a closed jar, the latter will weigh as much after the combustion as before. That is, the weight of the products of the combustion is the same as that of the factors.

II. In any well-marked chemical change the relative weights of the several factors and products are definite and invariable.

(Law of Definite Proportions by Weight).

Suppose a given amount of sal-soda yields with hydrochloric acid a given amount of common salt. Five times the amount of sal-soda will yield five times the amount of salt.

III. In any well-marked chemical change the relative volumes of the aëriform factors or products, if measured under the same conditions, bear to each other a simple numerical ratio. (Law of Definite Proportions by Volume—Gay-Lussac's Law).

Example: oxygen combining with sulphur forms sulphurous oxide gas: the *volume* of the sulphurous oxide is the same as that of the oxygen; two volumes of hydrogen gas combine with one of oxygen to form two volumes of vapor of water.

133. **Reactions**—The chemical action between two substances on each other when brought together is called a **reaction**. The body, which when added to another causes the change, is called a **reagent**.

134. **Manner of Chemical Action.**—Chemical changes may take place as follows:

(*a*) By direct union of simpler molecules, forming a more complex one.

(*b*) By separation of a complex molecule into simpler ones.

(*c*) By substitution in a molecule of one atom or group of atoms for another or for several others.

(*d*) By mutual exchange of atoms between molecules.

(*e*) By re-arrangement of atoms within a single molecule, as shown by conversion of ammonium cyanate into urea.

Examples:

1. Chemical change of the first kind is represented by *synthetical* reactions; thus, hydrogen (one molecule) and chlorine (one molecule) form hydrochloric acid (two molecules).

2. Chemical change of the second kind is represented by analytical reactions: thus calcium carbonate (one molecule) yields one molecule of calcium oxide and one molecule of carbon dioxide.

3. Chemical change of the third kind is represented by the so-called substitution reactions, as for example when one atom of potassium replaces, *i. e.*, is substituted for, one atom of hydrogen in the molecule of water, forming potassium hydrate.

4. Chemical change of the fourth kind is represented

by the so-called metathetical reactions, as when ammonium sulphate and calcium carbonate exchange atoms mutually between their molecules, forming ammonium carbonate and calcium sulphate. This is sometimes called "double decomposition."*

135. **Laws of Double Decomposition.**—Berthollet's laws may be stated as follows:†

(*a*). Whenever in a mixture of two or more substances it is possible by a rearrangement of the radicals to form a compound, volatile at the temperature of the experiment, such rearrangement will occur and the volatile compound will be formed. (*b*). Whenever on mixing two or more substances in solution, it is possible, by rearrangement of the radicals. to form an insoluble‡ compound, that rearrangement will occur and the insoluble compound will be formed as a precipitate.

In other words if solutions of two salts be mixed, and by double decomposition an insoluble salt can be formed, the double decomposition will take place and the insoluble salt will be formed. If the salt be only difficultly soluble, the double decomposition will take place be-

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*Professor J. H. Salisbury explains double decomposition as follows: in many cases of substitution the element displaced combines with the element or radical with which the displacing element was previously combined and two new compounds are formed in which the radicals have changed places with each other. When compounds of two basylous radicals or metals are brought together in solution, a double decomposition occurs, consisting in change of place on part of the metals or basylous radicals with each other.

†Woody,

‡Insoluble in the menstruum present.

tween concentrated solutions, but not between dilute. If by double decomposition a volatile substance can be formed, the double decomposition will take place and the substance will be formed. If the volatile substance is soluble in water, the double decomposition may not take place until the solutions are concentrated, or until the substances are entirely deprived of water. For example, sodium nitrate and sulphuric acid may exist together in dilute solution, but upon concentration double decomposition takes place, the volatile nitric acid being given off.*

The insoluble compound formed by double decomposition separates from the solution as a *precipitate*.

In order that the student may become familiar with the principle of the laws, it is necessary that the principal insoluble and volatile compounds be known.

Inorganic Compounds Insoluble in Water.

1. Most compounds of the heavy metals.
2. Almost all oxides.
3. Nearly all carbonates and phosphates.

Exceptions.

1. Chlorides, sulphates, chlorates, and nitrates are soluble, but lead chloride, mercurous chloride, and silver chloride are insoluble; barium sulphate and strontium sulphate are insoluble; oxides, hydrates, sulphides, and iodides of the alkalies† and alkaline earths‡ are not insoluble.

136. **Important Volatile Compounds.** — Ammonia, carbonic acid, nitric acid, hydrochloric acid, sulphuretted hydrogen.

Example 18. How may lead sulphate be made by

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*J. H. Salisbury.

†K, Na, NH_4.

‡Ca, Ba, Sr.

double decomposition? Calcic carbonate? Barium sulphate? Silver chloride?

Answers. From hydrogen sulphate, or a soluble sulphate, and lead nitrate or other soluble salt of lead. From sodium carbonate and calcium chloride. From barium ——and ——— sulphate. From silver ——— and hydrogen ———.

137. **Modes of Decomposition.**—The separation of a compound body into its constituent elements may be produced in various ways:

1. By heat: when limestone is heated, it is decomposed into lime and carbonic acid. Chemically speaking, calcium carbonate is decomposed by heat into calcium oxide and carbon dioxide. When an amalgam is heated, it is separated into mercury, which is driven off, and some other metal or metals.

2. By electricity: electricity decomposes many substances, provided they are in a liquid or gaseous state. Hydrochloric acid gas may be decomposed by passing an electric *spark* through it; water, by passing an electric *current* through it. Solutions of the metals may be decomposed by electricity and the metals themselves deposited. (See Copper Amalgam).

4. By light: see Section 83.

138. **Chemical Equations.**---These represent what actually takes place in a reaction. The sum of the weights of the **factors** is always equal to the sum of the weights of the **products**.

Rule 16. **To write Chemical Equations.**—

1. Write formulæ of factors.

2. Connect formulæ of factors by plus sign.

3. Write formulæ of products, connected by sign of plus.

4. Between factors and products write the sign =.

Thus, silver nitrate and hydrogen chloride give silver chloride and hydrogen nitrate; to represent the reaction by an equation:

1. Formulæ of factors: $AgNO_3$, HCl.
2. Connected by plus sign: $\mathbf{AgNO_3 + HCl}$.
3. Formulæ of products: AgCl, HNO_3.
4. Connected by plus sign: $\mathbf{AgCl + HNO_3}$.
5. 2 and 4 placed equal to one another:

$$\mathbf{AgNO_3 + HCl = AgCl + HNO_3}.$$

Rules for determining the changes which take place in chemical reactions.—To decide why, for example, silver nitrate and hydrogen chloride give silver chloride and hydrogen nitrate, certain rules should be committed to memory:

1. Find out which elements or radicals are positive and which negative. [In the above equation in the left hand member we find the metal, silver, (Table 1) positive, the radical, NO_3, negative, (Table 4).Hydrogen is positive and chlorine negative. (See Table 1). **Positives** combine with **negatives** and vice versa, hence on the right hand side in the products, Ag will be found with Cl, and not with H, and the latter with NO_3, and not with Ag].

2. Cause the positives to change places.

3. Pay due attention to quantivalence. [In the above equation, Ag being monad can take the place of H to form AgCl, and H being monad can take the place of Ag to form HNO_3].

4. Notice that compound radicals usually remain unchanged in products.

5. N. B. An acid and an alkali cannot exist free in the same solution, and the strongest acid usually selects the strongest base with which to combine.

Example 19. Complete the following equations:

1. $Zn + H_2SO_4 = ?$
2. $(NH_4)_2 SO_4 + CaCO_3 = ?$
3. $H_2 + Cl_2 = ?$
4. $(NaCl)_2 + H_2SO_4 = ?$
5. $(KClO_3)_2 = ?$
6. $FeS + H_2SO_4 = ?$
7. $S + O_2 = ?$
8. $P_2O_5 + (H_2O)_3 = ?$
9. $CaCO_3 = ?$

ANSWERS.

2. $CaSO_4 +$ ——— .
5. ——— $+ (O_2)_3$.
8. $H_6P_2O_8$ or ——— .
9. $CaO +$ ——— .

Example 20. In example 18 give two equations illustrating each answer.

139. **Chemical Arithmetic.**—By use of equations we may calculate the weight of any substance required by any given process. The rule is, as the formula of the given substance is to the formula of the required substance so is the weight of the given substance to the weight of the required substance. Thus, how much sulphate of zinc can be made from 5 pounds of zinc?

Reaction: $Zn + H_2SO = ZnSO_4 + H_2$.

Proportion: $Zn : ZnSO_4 = 5 : x$.

Reduced to figures: $65 : 161 = 5 : x$.

Product of means put equal to that of extremes: $65\,x = 161 \times 5$.

Algebraically: $x = \frac{161 \times 5}{65} = \frac{161}{13} = 12.3$ lbs.

Note: after the formulæ are written in the proper proportion, the molecular weights are substituted for them.

140. **Relations of Chemical Change to Force.**—Chemical change is accompanied by heat, electricity, often by light, and bears a relation to vital force.

Solution is accompanied by heat, as when caustic soda is dissolved in water.

Neutralization is accompanied by heat, as when sodium hydrate is added to sulphuric acid.

Chemical action is accompanied by heat, as when sulphuric acid acts on zinc.

Precipitation is accompanied by heat, as when copper sulphate solution is precipitated by a strip of zinc.*

The heat evolved in any chemical process is a measure of its energy, and the tendency is toward those combinations and conditions which involve the greatest evolution of heat.

141. **Light.**—The luminous effects witnessed in many chemical combinations are due to the high temperature produced. Luminous flames are nothing more than gaseous matters containing solids heated to the point of incandescence.

142. **Electricity.**—All chemical reactions are accompanied by a disturbance of electrical equilibrium. Chemical reactions between metals and liquids are the most productive of electricity. When a liquid acts chemically on a metal, the liquid assumes the positive electrical condition and the metal the negative.

A galvanic current is produced whenever two metals are placed in metallic contact in a liquid which acts more powerfully on one than on the other.

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*The heat is not always perceptible in all cases, and to measure it an instrument called a *calorimeter* should be used.

143. **Vital Force.**—An uninterrupted succession of chemical reactions goes on in the living body. New molecules are constantly arriving and old ones departing. Almost every vital act in the body may be said to be accomplished by oxidation, and therefore by a consumption of oxygen. Between the food and the absorbed oxygen an interplay of changes is essential to the maintenance of the vital functions, whether these consist in the production of heat, in muscular contraction, in mental activity, or in assimilation. The ultimate products of oxidation in the body are urea, carbonic acid, and water.

144. **Chemical Affinity.**—Bodies most opposed to each other in chemical properties evince the greatest tendency to combine together, and conversely. The metals and hydrogen have strong affinity for oxygen, chlorine, and iodine, but the attraction of metals for one another is more feeble by far, as is also the attraction of chlorine for iodine, etc., etc. Acids are drawn toward alkalies, and alkalies toward acids.

145. **Circumstances influencing Chemical Attraction.**—(*a*) Alteration of temperature: mercury absorbs oxygen at one temperature but gives it off at a higher one. (*b*) Solution: tendency toward formation of a substance *insoluble* in the medium of solution. (*c*) Heat: tendency toward formation of a *volatile* compound when substances are mixed and heated. (*d*) Nascent state: substances combine better in the *nascent state*, that is, when each is simultaneously liberated from some previous combination. (*e*) Influence of a base: as, for example, oxidation of platinum by fused po-

tassium hydrate. (*f*) Mere *presence* of certain bodies as ferments. (See Fermentation).

Porous bodies by their presence favor certain chemical change. Hydrogen and vapor of iodine mixed in a tube heated to redness do not combine, but immediately unite if spongy platinum be present with them. This change may be classified under *catalytic action* and further examples are not necessary.

Heat, light, and *electricity* are favorable to chemical change. Moreover, the *physical condition* of bodies, and *pressure* are to be reckoned as factors. Chemical change between substances in liquid or gaseous state, as a rule,is more easily brought about than when the substances are in the solid state. For example, tartaric acid and bicarbonate of sodium, if mixed dry, do not effervesce, but immediately do so when water is added.

Pressure arrests certain changes, notably, such as give rise to disengagement of gas. Thus, zinc is not attacked so well by acids in a closed tube as in an open one, owing to the pressure of the disengaged hydrogen. Pure zinc is not attacked by pure sulphuric acid, owing to condensation of gas on the surface of the metal. *Pressure facilitates* certain changes: under pressure chloride and nitrate of silver are decomposed by hydrogen; silver is displaced and hydrochloric acid or nitric acid formed. Under pressure of 20 atmospheres, an alcohol flame becomes as bright as that of a candle.

146. **Classification of the Elements.**—It is difficult to classify the elements in a manner which shall be entirely satisfactory.

There are a number of well-marked groups in which there is some connection between the atomic weights and the properties of the elements; as, for example, in one group chlorine, bromine, iodine; in another, sulphur, selenium, tellurium; in a third, lithium, sodium, potassium.

If in each of these groups the atomic weights of the first and last be added, and the sum divided by 2, there results very nearly the atomic weights of the middle members. Moreover, the chemical properties of an element in each group are much like those of others of the same group. Mendeleef has shown that, if all the light elements of atomic weights from 7 to 36 be arranged in the order of their atomic weights, the result is as follows:

I. Li = 7; Be = 9; B = 11; C = 12; N = 14; O = 16; Fl = 19.

II. Na = 23; Mg = 24; Al = 27; Si = 28; P = 31; S = 32; Cl = 35.5.

Proceeding from left to right, there is a gradual change in the properties of members of the series; basic properties grow weaker and acid properties stronger; the metals are at the left end, the non-metals at the right, and those classed sometimes with metals, sometimes with non-metals, in the middle, as, for example, silicon.

All the elements may be arranged in series like the above. The changes in the properties of the elements will be noticed to be *periodic*; that is, they change according to the increasing atomic weights, and are then repeated in a *new period*.

Corresponding members of the even periods or of uneven periods resemble one another more closely than the members of the even periods resemble those of the uneven periods; that is, for example, those of the 4th and 6th are more alike than they are to those of 5th and 7th, and those of 5th and 7th resemble each other closely.

For further consideration of the periodic law the reader is referred to "Remsen's Theoretical Chemistry." Other authorities are Meyer, Ostwald, Hortsmann, and M. M. Pattison Muir. The work of Muir on the Principles of Chemistry will be an aid to those who are not familiar with the German language.

Table 7.—Mendeleef's Tables.*

No. I.

Series.	Group I. — R_2O	Group II. — RO	Group III. — R_2O_3	Group IV. RH_4 RO_2	Group V. RH_3 R_2O_5	Group VI. RH_2 RO_3	Group VII. RH R_2O_7	Group VIII. — RO_4
1	H = 1							
2	Li = 7	Be = 9	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27	Si = 28	P = 31	S = 32	Cl = 35.5	
4	K = 39	Ca = 40	Sc = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe=56, Co=59, Ni = 59, Cu = 63
5	(Cu = 63)	Zn = 65	Ga = 70	Ge = 72	As = 75	Se = 79	Br = 80	
6	Rb = 85	Sr = 87	Y = 89	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru=103, Rh = 104, Pd = 106, Ag=108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 120	Te = 125	I = 127	
8	Cs = 133	Ba = 137	La = 139	Ce = 142	Di = 145	—	—	— —
9	(—)	—	—	—	—	—	—	— —
10	—	—	Yb = 173	—	Ta = 182	W = 184	—	Os=195?, Ir = 193, Pt = 195, Au=196
11	(Au = 196)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

*None but approximate atomic weights are given.

Explanation of Table I.

R denotes the symbol of any element in the group. R_2 O would mean that in uniting with oxygen, two atoms of any element in the group unite with one of oxygen. Each series is called a *small period*. Series 1 and 2 form the first *large period*; series 3 and 4 the second, and so on.

No. II.

			I.	II.	III.	IV.	V.	VI.
R_2O	I.		Li=7	K 39	Rb 85	Cs 133	— —	— —
RO	II.		Be=9	Ca 40	Sr 87	Ba 137	— —	— —
R_2O_3	III.		B 11	Se 44	Y 89	La 139	Yb 173	— —
RO_2	IV.	(H_4C)	C=12	Ti 48	Zr 90	Ce 142	— —	Th 231
R_2O_5	V.	(H_3N)	N=14	V 51	Nb 94	Di 145	Ta 182	— —
RO_3	VI.	(H_2O)	O=16	Cr 52	Mo 96	— —	W 184	U 240
R_2O_7	VII.	(HF)	F=19	Mn 55	— —	— —	— —	— —
				Fe 56	Ru 103	— —	Os 195?	— —
RO_4	VIII.			Co 59	Rh 104	— —	Ir 193	— —
				Ni 59	Pd 106	— —	Pt 195	— —
R_2O	I.	H=1	Na=23	Cu 63	Ag 108	— —	Au 197	— —
RO	II.		Mg 24	Zn 65	Cd 112	— —	Hg 200	— —
R_2O_3	III.		Al 27	Ga 70	In 113	— —	Tl 204	— —
RO_2	IV.	(H_4R)	Si 28	Ge 72	Sn 118	— —	Pb 207	— —
R_2O_5	V.	(H_3R)	P 31	As 75	Sb 120	— —	Bi 208	— —
RO_3	VI.	(H_2R)	S 32	Se 79	Te 125	— —	— —	— —
R_2O_7	VII.	(HR)	Cl 35.5	Br 80	I 127	— —	— —	— —

Explanation: in Table II the elements are in groups, but in such a way as to indicate the difference between the even and uneven periods. Thus at the top in line with, and to the right of R_2O, I, will be seen from left to right, the members of the even series: Li, K, Rb, etc., which belong to series 2, 4, 6, etc.

Then after those of the even series have been finished those of the odd are taken up, beginning with H and going on to Na, Cu, etc., from left to right.

In other words corresponding members of even periods are given first, then corresponding members of odd periods.

147. **Meyer's Classification.**—Lothar Meyer arranges the periods somewhat differently, not in horizontal lines, but in lines so inclined that, if the table were pasted on a cylinder of the right size, the table would form a continuous spiral, beginning at the top with lithium, and ending at the bottom with uranium. Meyer has shown a very close connection to exist between the atomic weights and various properties of the elements.

The work of Mendeleef, and also of Meyer, has been of the greatest interest to chemists. The author has not thought it desirable to go further into details concerning the various classifications of the elements in a book like a Dental Chemistry, which is essentially practical in nature and limited in scope. But it is very desirable that those intending to teach chemistry should familiarize themselves as thoroughly as possible with the theoretical principles of the science. For this purpose the following books should be owned: J. P. Cooke's "Chemical Philosophy" and "New Chemistry"; Lothar Meyer's "Modern Theories of Chemistry", elsewhere referred to; M. M. Pattison Muir's "Treatise on the Principles of Chemistry." German text-books of value are Ostwald's "Lehrbuch der Allgemeinen Chemie", and A. Horstman's "Theoretische Chemie" to be found in Band I. 2. Graham-Otto's "Ausführliches Lehrbuch der Chemie." [Wöhler's "Outlines of Organic Chemistry" has been translated from the 8th German edition by Professor Remsen, and is useful in studying the Carbon Compounds]. Going into more special works of interest to the dentist, we find Krupp's "Die Legirungen", to be had in English with additions under the name of "The Metallic Alloys" by W. T. Brannt. There is also a work known as the "Techno-Chemical Receipt Book", which may prove handy for reference at times in regard to matters purely practical. But the subject of chemistry as a whole can not be intelligently comprehended until very diligent study has been given to theory.

TABLE 8.

Lothar Meyer's Arrangement of the Elements.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.		
Li 7.01	Be 9.08	B 10.9	C 11.97	N 14.01	O 15.96	F 19.06			
Na 22.99	Mg 23.94	Al 27.04	Si 28	P 30.96	S 31.98	Cl 35.37			
K 39.03	Ca 39.91	Sc 43.97	Ti 48	V 51.1	Cr 52.45	Mn 54.8	Fe 55.88	Co 58.6	Ni 58.6
Cu 63.18	Zn 64.88	Ga 69.9	Ge 72.32	As 74.9	Se 78.87	Br 79.76			
Rb 85.2	Sr 87.3	?Y 89.6	Zr 90.4	Nb 93.7	Mo 95.9	? 99	Ru 103.5	Rh 104.1	Pd 106.2
Ag 107.66	Cd 111.7	In 113.4	Sn 117.35	Sb 119.6	Te 126.3	I 126.54			
Cs 132.7	Ba 136.86	La 138.5	Ce 141.2	Di? 145	? 151	? 152			
? 165	? 170	Yb 172.6	? 176	Ta 182	W 183.6	? 185	Os 195?	Ir 192.5	Pt 194.3
Au 196.2	Hg 199.8	Tl 203.7	Pb 206.39	Bi 207.5	? 210	? 211			
? 222	? 226	? 230	?Th 231.96	? 234	?U 239.8				

The spaces left blank are to be filled with elements yet to be discovered.*

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*Mendeleef predicted the discovery of an element between calcium and titanium. Scandium was discovered and filled the place.

148. **General Properties of the Metallic Elements.**—Metals are, as has already been seen, elementary bodies, solids with exception of mercury, insoluble in water, and possessed of certain properties as lustre, fusibility, etc. Among the more important properties of metals we find

lustre,—power of reflecting light;

tenacity,—resistance to any attempt to pull asunder their particles;

malleability,—capability of being hammered or rolled into thin sheets;

ductility,—property of being drawn out into wire;

high specific gravity,—or weight relative to water;*

high conducting power,—for heat and electricity;

fusibility,—property of becoming liquid when heated;

capacity for heat, or specific heat;

expansibility,—property of expanding when heated;

crystalline structure,—shown by metals on cooling from fusion;

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*Only seven have a sp. gr. below 6.72, but they vary from osmium, 22, to lithium, 0.59.

volatility,—property of being converted into vapor;

color;

odor and taste.

149. **The most lustrous metals** are gold, silver, platinum, palladium, steel, aluminium; zinc and lead are inferior in lustre; tin is naturally a brilliant metal, but not hard enough to be polished like steel.

150. **The specific heat of metals** is the amount of heat necessary to raise equal weights of different metals from the same given temperature to another given temperature. Water is assumed as the standard, and we find that the capacity for heat of the different metals is in the following order: iron, nickel, cobalt, zinc, copper, palladium, silver, cadmium, tin, antimony, gold, lead, platinum, bismuth. Suppose, now, a cubic inch of iron and a cubic inch of tin were both heated to the same temperature for the same time and placed each on a cake of paraffine, which would melt its cake the sooner? Iron, because its capacity for heat is greater than that of tin.

151. **All metals are somewhat volatile:** some are noticeably volatile, as mercury, arsenic; others to a limited extent, and a few with difficulty even at highest temperatures. Gold is somewhat volatile when alloyed with certain metals.

152. **The characteristic color of metals** ranges from pure white to bluish.* A few metals, as iron, copper, and zinc have an **odor**, especially when heated.

153. **The noble metals** are mercury, silver, gold, platinum, palladium, rhodium, ruthenium, osmium, iridium; they may be separated from their oxides by merely heating to redness.

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*Lead is feebly tinted with blue, bismuth with pink, calcium with yellow.

154. **The decomposition of acids** by metals and replacement of hydrogen has already been alluded to.

155. **Metals are opaque**, except gold which if in thin leaves, transmits a greenish or purplish light.

156. Metals are nearly all **sectile**; that is, when cut with a knife they do not crumble. For example, gold is perfectly sectile, but pyrites and other minerals like it crumble under the knife.

Metals can be fused together and unite in all proportions forming alloys.

157. The metallic elements used in dentistry will be tabulated with reference to their symbols, Latin names, valence, specific gravity, etc., etc. Before studying them, certain definitions and explanations are necessary.

Fusing point: the temperature at which the various metals melt and become liquid. Lead melts at 617° Fahrenheit, hence its fusing point is said to be 617°.

Length of bar at 212° F., which measures 1 at 32° F. It is well known that heat expands metals: thus, a bar of aluminium, which at 32° F. is 1 foot long, at 212° F. will be $1 \frac{22}{1000}$ foot. In the tabulated statements concerning length of bar in metals, fourteen, namely: aluminium, antimony, bismuth, cadmium, copper, gold, iron, lead, magnesium, palladium, platinum, silver, tin, and zinc are considered. Given any unit of measurement then, whether an inch, a foot, etc., etc., there will be at 212° F. a certain gain in length of the bar. It must, however, be remembered that, for the same kind of metal, the greater its specific gravity the greater its expansion for a given increase in temperature.

*Tensile strength** is the resistance of the fibres or particles

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*Under tensile strength the *absolute* tenacity of the metal is expressed in figures, while under tenacity it is expressed *relatively* as regards other metals.

of a body to separation, and the amount of weight or power required to tear asunder one square inch of a metal is given, in figures, in tons; thus, the tensile strength of iron (wrought) is said to be 29. This means that a weight of 29 tons, or a power equivalent to 29 tons, is necessary to tear asunder one square inch of the metal.

Tenacity: the metals are compared as regards tenacity with lead, which is the weakest; the tenacity of copper is said to be 18, which means that it is 18 times *more tenacious* than lead; copper is said to be in "3d rank," because of the ten metals, steel, iron, copper, platinum, silver, gold, palladium, zinc, tin, lead, there are only two which are more tenacious. Care should be taken to note that the "rank" of a metal is strictly relative, and, unless the metals with which it is compared be known, the idea conveyed by the term is wholly vague.

Malleability: the metals are compared with *gold*, which is the most malleable; *eight* metals in all are compared, namely: gold, silver, copper, tin, platinum, lead, zinc, iron. The malleability of zinc is said to be 7, which means that there are six metals more malleable; its rank, therefore, among the eight, is 7th.

Ductility: the standard is gold which is the most ductile. Ten metals are compared: gold, silver, platinum, iron, copper, palladium, aluminium, zinc, tin, iron. The ductility of zinc is said to be 8, which means that seven of the ten metals are more ductile. It is therefore 8th in rank. *It will be noticed that the comparison in regard to tenacity is made differently from either that in regard to malleability or to ductility.*

Conducting power with reference to heat: the metals are compared with silver, which is the best conductor, and *eleven* metals in all are considered; the conducting power of zinc is said to be 5, which means that four metals are better conductors; it is, therefore, 5th in rank.

Conducting power with reference to electricity: the metals are compared with silver, which is the best conductor of electricity. *Twelve* metals are considered, namely: silver, gold, copper, zinc, palladium, platinum, iron, nickel, tin, lead, antimony, bismuth. The conducting power of zinc for electricity is 290, silver being taken as 1,000 in conducting power. In other words, silver is $\frac{1000}{290}$, or 3.44, times a better conductor than zinc. But zinc is 4th in rank among the twelve, for only three are better conductors of electricity.

Resistance to air, etc: resistance to dry, pure air is one thing, but resistance to air containing moisture, carbonic acid, etc., is quite another. Under this head also, is mentioned the effect of sulphuretted hydrogen on the metal.

Solubility: under this head the best solvents for the metal are given, that is, substances having the power, like acids, to attack the metal and convert it into a liquid.

Direct combinations: under this heading is given a list of substances which unite directly with the metal, either in the cold or when heated, rubbed, or triturated with it, without the intervention of oxygen.

Structure: many of the metals have a crystalline structure, *i. e.*, when small particles of them are seen under the microscope, certain definite geometrical shapes are observed as cubes, rhombohedrons, etc. The form in which iron tends to crystallize is a regular octahedron: an eight-sided figure with equal axes at right angles to one another. Crystalline forms are classified into six systems. (See Chap. I). Many of the metals are to be found in the first or *isometric* system, in which there are three axes of equal length, and at right angles to each other, as in case of the cube and the octahedron. Copper crystals are examples of the isometric system.

Compounds: the metals form various compounds according to their equivalence, and Latin names are often used instead of English: for example, iron as a dyad, uniting with other elements, forms *ferrous* compounds; silver compounds are sometimes called *argentic*, as *argentic nitrate*, etc., etc.

TABLE NO. 9—NAMES AND PROPERTIES OF THE MORE IMPORTANT METALS.

Names.	Sp. gr.	Fusing Point; approximate Fahrenheit.	Weight of One Cubic Foot in Pounds.	Tensile Str'gth per sq. inch in tons.
*Aluminium	2.67	1292°	163.8	12.0
Antimony	6.72	1150°	419.5	0.5
Bismuth	9.80	507°	613.0	1.5
*Cadmium	8.69	442°	542.5	
*Cobalt	8.51	less than iron.	558.7	same as iron
*Copper	8.95	1996°	558.1	13 to 15
*Gold	19.34	2016°	1208.6	9.1
*Iron	7.84	3500°	489.4	29 (maximum)
Lead	11.36	617°	709.2	0.8 to 1.5
Magnesium	1.74	850°	108.6	
Manganese	8.01	less than iron	500.0	
Mercury	13.59	—39°	848.4	
*Nickel	8.67	less than iron	541.2	same as iron
*Palladium	11.8	same as iron	736.6	
*Platinum	21.53	greater than iron	1344.0	
Silver	10.53	1873°	657.3	18.2
Tin	7.30	442°	455.1	2 to 3.5
*Zinc	7.14	773°	445.7	3.3 to 8.3

N. B.—The star* refers to the wrought metal. Mercury, tin, cadmium, bismuth, lead, and zinc, are all fusible *below* red heat. Antimony, just below red heat. Silver, copper, gold, and aluminium, at bright red heat. Iron, cobalt, manganese, and palladium, at highest forge heat. Osmium, iridium, platinum, at heat of oxy-hydrogen blowpipe. Steel is to be melted in a furnace of special construction, called a wind furnace.

TABLE NO. 10—TENACITY, RELATIVE MALLEABILITY, AND DUCTILITY OF THE MORE IMPORTANT METALS.

Name.	Tenacity.	Malleability.	Ductility.
Lead	1.00	6	10
Cadmium	1.20		
Tin	1.33	4	9
Zinc	2.00	7	8
Palladium	11.50	(10)	6
Gold	12.00	1	1
Silver	12.50	2	2
Platinum	15.00	5	3
Copper	18.00	3	5
Iron	27.50	8	4
Steel	42.00		
Aluminium			7

Explanation: *tenacity*: if the weight required to pull asunder a wire of lead be taken as a standard and called 1, the weight required to pull asunder a wire of cadmium would be a little more, namely 1.2; that to pull asunder a wire of steel, for example, 42 times as much as the lead. *Malleability*: if the difficulty with which a mass of gold can be hammered or rolled into a thin sheet, without being torn, be represented by 1, iron will be found to be 8 times as difficult. *Ductility*: if the difficulty with which gold can be drawn into a wire be represented by 1, tin, for example, will be drawn with 9 times the difficulty.

TABLE NO. 11—CONDUCTING POWERS OF METALS.

Name.	Heat.	Electricity.
Silver	1	1000, (standard).
Gold	2	779, (3d).
Copper	3	999, (2d).
Aluminium	4	
Zinc	5	290, (4th).
Iron	6	168, (7th).
Tin	7	123, (9th).
Platinum	8	180, (6th).
Lead	9	83, (10th).
Antimony	10	46, (11th).
Bismuth	11	12, (12th).
Palladium		184, (5th).
Nickel		131, (8th).

Explanation: in the table under *heat*, the metals are arranged in the order of their conducting power, silver being the best conductor, gold next, etc., etc. In the table under *electricity*, silver is taken as the standard, as it is the best conductor of electricity, and the other metals are compared with it, in the pure state at 32° F. In some works gold is given 3d place in heat-conducting power, copper 2nd.

Properties of metals and uses: mercury is useful for *amalgamating* or dissolving other metals; antimony has the property of hardening lead and tin, when melted with them; bismuth and cadmium make tin capable of being melted at lower temperatures; nickel whitens copper, and is used in the manufacture of German silver. Gold, platinum, palladium, silver are limited in use by their high price, and the same is true to a certain extent of aluminium, although the price of this metal is lower now than formerly. Zinc has a comparatively high degree of expansibility; gold is the most malleable of metals as also the most ductile; silver is the best conductor of heat and electricity; the tenacity of metals is *usually* diminished by heating; malleability and ductility are developed in some metals by heating, but impaired by carrying heat too far; in alloys, heating impairs tenacity, malleability, and ductility; crystalline metals, as bismuth, lack malleability, etc.; metals may be obtained in crystalline form by electrolysis, either by introducing other metals in strips or rods into their solutions, as a rod of zinc into a solution of a lead salt, or by passage of a weak electric current through their solutions. Gold may be obtained in crystalline form by introduction of a stick of phosphorus into a solution of one of its salts.

158. **General properties of alloys of the metallic elements.**—Alloy is the name given

to a combination obtained by fusing metals together. Alloys are, as a rule, chemical compounds dissolved in excess of one of the constituent metals, but many are merely mechanical mixtures, or *molecular mixtures,* as the term is. All alloys exhibit the metallic nature in their physical characteristics.

As regards **specific gravity**, an alloy of gold and silver is lighter than the theoretical mean of its constituents; brass, and an alloy of lead and tin, heavier; in other words, the gold and silver alloy is formed by expansion, the latter by contraction. In the formation of some alloys there is no change in volume. In **color**, alloys are usually **gray,** unless there is sufficient copper or gold to impart the characteristic color of those metals. Alloys are usually **harder** and **more brittle, less ductile** and **less tenacious,** than the constituent metal exhibiting these qualities in the highest degree; aluminium bronze is an exception, its tenacity being greater than that of either of the constituent metals.

The **fusibility** of an alloy is generally greater, *i. e.*, the alloy melts more readily than that of the least fusible constituent metal and sometimes than that of any constituent metal.* An alloy **heated gradually** to near its fusing point undergoes a change; its constituents reunite to form a mass now fusible; if the fluid be poured off, a solid alloy is obtained less fusible than the original. In this way copper is separated from silver. An alloy of zinc or of mercury is **decomposed** by heat, but at a higher temperature than the point of ebullition of the metal. As regards *temperature*, an alloy of 94 copper to 6 tin, if *slowly* cooled, becomes brittle, but, if cooled *rapidly* with cold

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*Thus, tin unites with gold far below the melting point of gold.

water, malleable. Mercury, bismuth, tin, and cadmium give fusibility to alloys, tin hardness and tenacity, lead and iron hardness, antimony and arsenic brittleness. Metals are usually **fused** under a layer of charcoal to prevent oxidation; they are mixed by agitation and allowed to cool slowly.

Certain peculiarities of alloys as to **solubility** must be noticed: platinum is insoluble in nitric acid, but an alloy of platinum with silver or gold is soluble in the acid. Silver is readily soluble in nitric acid, but an alloy of silver with 25 per cent. gold is insoluble.

The **affinity** of an alloy for **oxygen** is greater than that of the separate metals, but the action of **air** is in general less on alloys than on the separate metals composing them, with some exceptions.

Some difficulty is occasionally experienced in obtaining **a perfectly uniform alloy,** on account of the different specific gravities of the metals composing it—each metal assuming the level due to its specific gravity. This result is not so likely to occur, when the metals employed are in small quantities, briskly stirred, and suddenly cooled. In alloying three or more metals differing greatly in fusibility, or that have but little affinity for one another, it is better to unite first those that most readily combine, and then this combination with the remaining metal or metals. If, for example, it is desired to unite a small quantity of lead with brass or bronze, some difficulty would be experienced in forming the alloy by direct incorporation of the metals, but union could be readily effected by first melting the lead with zinc or tin, and then adding the melted copper.

Alloys consisting of two metals, one readily oxidizable, the other possessing less affinity for oxygen, **may be readily decomposed** by the combined action of heat and air.

159. **Solders:** it is often necessary to unite several pieces of the same metal, or of different metals. For such work a kind of alloy called *solder* is used. Solders usually contain the metal on which they are to be used, together with some other metal or metals, which shall reduce the fusing point without affecting the color.

[A solder suitable for use in prosthetic dentistry should fuse at a much lower temperature than the plate upon which it is to be used. Its color should be as nearly as possible the same, and it should withstand the action of the fluids of the mouth nearly as well. These properties may be obtained by the addition of small amounts of silver, copper, or brass. (Essig.)].

Solders have been divided into two classes: (*a*) solders made by the fusion of the metal itself, without others, and (*b*) solders made on a metal with another metal; or by an alloy applied to the surfaces which are to be united. In the last case the metal or alloy must be more fusible than the metal to be soldered, and have a more powerful chemical affinity for it.

Hard solder is used for metals difficult to melt, *soft* solder for those not so difficult.

160. **General properties of the non-metallic elements.**—It is difficult to draw a sharp line between metals and metalloids, but as a general rule those that are not gaseous at ordinary temperatures have no metallic lustre, are of low specific gravity, neither malleable nor ductile, conduct heat and electricity very imperfectly. The nitrogen group, N, P, As, Sb, and Bi is remarkable for a change from non-metallic properties to metallic as the atomic weight increases, beginning with nitrogen, atomic weight 14 and gaseous, and ending with bismuth, 210,

which has well-marked metallic properties. Arsenic is a metalloid with strongly metallic characteristics, uniting with chlorine like a basic metal, but on the other hand uniting with oxygen to form anhydrides.

161. **Classification according to valence.**—Owing to the didactic character of this book those elements of importance to the dentist will be studied in such a way as to keep their *valence* and *electro-chemical* relations constantly in view.* Table 1 of Professor Seaman† will be taken as a basis for the classification.

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*Those interested in the further study of theoretical chemistry should procure Lothar Meyer's "*Modern Theories of Chemistry*," translated by Bedson and Williams.

†Professor Seaman divides, for didactic purposes, the elements as follows:

A. Gases: O, H, N, Cl, F.
B. Halogens: I, Br, Cl.
C. Metals: As, Sb, Fe, etc.

[Sub-classes of metals: metals of the alkalies, Na, K, Li; metals of the alkaline earths, Ba, Ca, Sr, Mg; metals proper, as Fe, Pb, Sn.].

D. Metalloids: as C, P, Si, S.

Witthaus's classification is excellent in many respects: Class I, typical elements: H and O. Class II, elements whose oxides plus water form acids, viz: Fl, Cl, Br, I, S, N, P, As, etc. Class III: elements whose oxides plus water in some form bases, in others acids: Au, Cr, Mn, Fe, Al, Pb, Bi, etc. Class IV, elements whose oxides plus water form bases only: Li, Na, K, Cu, Mg, Zn, etc.

CHAPTER III.

Inorganic Chemistry. The Elements and Their Inorganic Compounds.

Monads.—The elements will be taken up in the order of their valence, monads first. Of monads those positive* to hydrogen will be treated first, then those negative to it.

Table 12. Monads.

Potassium	Monads positive to hydrogen.
Sodium	
[Ammonium]	
Lithium	
Silver	
Hydrogen	
Iodine	Monads negative to hydrogen.
Bromine	
Chlorine	
Fluorine.	

Hydrogen forms *hydrides* with those elements positive to itself, as KH, potassium hydride. Combined with those negative to it iodides, bromides, chlorides, and

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*See Table 1. The student will do well to study the properties of hydrogen (section 176) and of oxygen (section 241) before beginning this chapter.

fluorides are formed. Moreover, all in the list *above* hydrogen are positive to all in the list *below* hydrogen. The elements positive to hydrogen in this list are all metals, those negative, non-metals.

Potassium:—*Symbol:* K. *Latin name:* Kalium. *Equivalence:* I. *Specific gravity:* 0.86. *Atomic weight* (approx.): 39. *Revised atomic weight:* 39.0196. *Electrical state:* +. *Fusing point:* 144°F.

Brilliant, white metal, with high degree of lustre, soft, floats on water and takes fire spontaneously when thrown on it, yielding an alkaline solution.

162. Potassium compounds.

TABLE 13—SOME COMPOUNDS OF POTASSIUM.

Name.	Formulæ.	Uses, etc.
Chlorate	$KClO_3$	White, soluble in water (6 in 100). Used in mouth washes and gargles. In large doses is poisonous. Sparingly soluble in alcohol.
Bicarbonate	$KHCO_3$	Antacid, used in mouth washes. In large doses is corrosive poison. Soluble in water, insoluble in alcohol.
Bromide	KBr	White, soluble crystals. Given internally in convulsions, etc., and used locally to diminish sensibility before taking impressions.

TABLE 13.—*Continued*

Chloride	KCl	Transparent, colorless solid, soluble in water. Found in the body in fluids, blood corpuscles, and in muscle juice.
Iodide	KI	Made by dissolving iodine in potassium hydrate. Large, white translucent, cubical crystals of a saline taste. Readily soluble in water. Solutions dissolve iodine.

163. **Potassium hydrate.**—

Synonyms: Potassa U. S. P., Potassa Caustica (Br. P.), caustic potash.

Theoretical constitution: KHO or KOH, the hydrate (hydroxide) of potassium. Molecular weight, 56.

Preparation: by boiling potassium carbonate with slacked lime (calcium hydrate):

$$K_2CO_3 + Ca(HO)_2 = CaCO_3 + 2KHO.$$

Properties: the impure contains lime and is called potash by lime: purified by dissolving in alcohol and evaporating to dryness, remelted, and cast in sticks it is known as *potash by alcohol*. White, opaque sticks or lumps, alkaline, readily soluble in water, caustic, escharotic, and corrosive poison.

Potassa cum calce: equal parts KHO and CaO, grayish-white powder, milder, and less deliquescent; in a paste called *Vienna* paste, used in dentistry.

Robinson's remedy contains potassium hydrate and carbolic acid, equal parts.

Liquor potassæ is a 5 per cent solution of potassium hydrate in water.

Toxicology: potassium hydrate is a corrosive poison and its action on tissues is very violent and penetrating. Forty grains have caused death. In the treatment the stomach pump must *not* be used, dilute vinegar should at once be given, lemon juice, orange juice, olive oil, and milk freely. Stimulants are indicated if there is much pain. Solutions of potassium hydrate or carbonate have a soapy "feel" and are alkaline in reaction. Burns from the agent should be treated with dilute vinegar and then with oil.

164. **Potassium Nitrate.**—

Synonyms: nitre, saltpetre, Sal Prunella. Official name, Potassii Nitras.

Theoretical constitution: KNO_3, 1 atom of potassium, 1 of nitrogen, and 3 of oxygen to the molecule. Molecular weight, 101.

Preparation: made from crude sodium nitrate by double decomposition with potassium chloride.

Properties: colorless crystals, anhydrous, very soluble in hot water, readily soluble in cold, nearly insoluble in alcohol, permanent in dry air, neutral, odorless.

Uses in dentistry: locally and in mouth washes as an antiseptic and refrigerant. In refining gold, when it is used as an oxidizing agent for metals alloyed with gold. Roasting an alloy with nitre will often set the gold free.

Toxicology: potassium nitrate is poisonous, causing severe burning, abdominal pains, nausea, vomiting of blood, great prostration, tremors, collapse. One ounce has proved fatal. The treatment is to give an emetic, mucilaginous and demulcent drinks, and stimulants.

165. **Potassium Permanganate.**—

Synonyms: permanganate of potash. Official name, Potassii Permanganas.

Theoretical constitution: $K_2Mn_2O_8$ or $KMnO_4$, derived from permanganic acid. Permanganic acid, $H_2Mn_2O_8$, may be deemed to be derived from manganese heptoxide (Mn_2O_7) plus water (H_2O); potassium permanganate $K_2Mn_2O_8$, by exchanging the two atoms of hydrogen in the acid for two of potassium. Molecular weight, 313.8.

Properties and dental uses: potassium permanganate occurs in the form of dark purple crystals which impart a fine, deep, purple color to water even when in very minute proportions. It is a deodorizer, disinfectant, and, in concentrated solution, a caustic.

Condy's Fluid contains 32 grains of it to the pint of distilled water.

Liquor Potassii Permanganatis contains 64 grains to the pint of distilled water.

In dental practice the permanganate is used locally as a deodorizer, disinfectant, and antiseptic.

166. **Sodium:**—

Symbol: Na. *Latin name*: Natrium or Natron. *Equivalence*: I. *Specific Gravity*:—0.97. *Atomic weight* (approx.): 23. *Revised atomic weight*:—22.998. *Electrical* *state*:—×. *Fusing point*:— 206.°6 F. *Properties*:—Soft, white, readily oxidized metal.

167. **Sodium Compounds.—**

Sodium Hydro-Carbonate or Bicarbonate.

Synonyms: bicarbonate of sodium, bicarbonate of soda, sodium acid carbonate, sesquicarbonate of sodium, "baking soda."

Theoretical constitution: sodium hydrocarbonate, $NaHCO_3$, is what is called an **acid salt,** because *all* the hydrogen atoms of the acid from which it is derived have *not* been replaced by the positive atom. The term **acid salt** should not confuse the beginner as to the *reaction* of the substance to litmus paper, which has nothing to do with the theoretical name.

Sodium bicarbonate is composed of one atom of sodium, one of hydrogen, one of carbon, and three of oxygen. By weight 23 of sodium, 1 of hydrogen, 12 of carbon, 48 of oxygen; molecular weight, 84.

Preparation: made by passing carbon dioxide over sodium carbonate from which the larger portion of water of crystallization has been expelled:

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2} = \underset{\text{sodium bicarbonate.}}{2NaHCO_3.}$$

The *sodium carbonate* used is, as will thus readily be seen, an entirely different substance from the bicarbonate. The former is known in commerce as "sal soda," and familiarly known as "washing soda."

Properties: sodium bicarbonate is a white powder, having a mildly saline, cooling taste, a slightly alkaline reaction, is soluble in 12 parts of water, insoluble in alcohol; 8 parts of the bicarbonate are soluble in 100 of glycerine (by weight). Its solutions are nearly neutral to litmus paper.

Use in dentistry: sodium bicarbonate is in particular used as an antacid ingredient of dentifrices, and its uses, in general, in dental practice are in consequence of its antacid properties.

168. Various sodium compounds: all are soluble in water to a greater or less degree and most of them in solution turn red litmus blue. Many of them are white or colorless.

TABLE 14—SODIUM COMPOUNDS.

Name.	Formulæ.	Origin, Uses, etc.
Chloride	$NaCl$	Common salt is found in every fluid and organ of the body.
Sulphite	Na_2SO_3	Antiseptic, disinfectant, and deodorizer. Used in bleaching teeth with boracic acid.
Sulphate	Na_2SO_4	Glauber's salt.
Carbonate	$Na_2CO_3,10H_2O$	Washing Soda.
Arseniate	$Na_2HAsO_4, 7H_2O$	Poisonous, colorless, efflorescent.
Hydrate	KHO	Caustic soda. Comes in form of sticks. Readily soluble.
Phosphates	Na_3PO_4	*Basic* phosphate, alkaline, and purgative.
	Na_2HPO_4	*Neutral* phosphate. Found in the tissues.
	NaH_2PO_4	Acid phosphate of sodium.

169. **Sodium Borate or Borax.**—

Synonyms: sodium biborate, sodium tetraborate, Sodii Boras (U.S.P), Sodæ Boras (B.P.).

Theoretical constitution: formula $Na_2B_4O_7$, explained by regarding it as $Na_2O.(B_2O_3)_2$ or $Na_2O.2B_2O_3$. Boric oxide (anhydride) B_2O_3, has the property of uniting directly with oxides of the positive elements sodium, potassium, etc. Borax is not, therefore, derived from boracic acid but formed by the direct combination of sodium oxide, Na_2O, with boric oxide or anhydride, B_2O_3. The molecule of sodium oxide combines with *two molecules* of boric oxide, forming $Na_2O.2B_2O_3$. Borax contains also ten molecules of water of crystallization, so that the full formula is $Na_2O.2B_2O_3 + 10H_2O$.

Properties and uses in dentistry: borax is a white, soluble, efflorescent substance which melts at a low heat, swells greatly, at a higher temperature becomes a clear liquid, then a vitreous substance (borax glass). It is useful in blow pipe analysis, as by the "borax bead" method; as a flux for melting metals; in soldering metals; in solution, for hardening plaster casts; as a local application, etc., etc.

170, **Sodium Hypochlorite.**—

Theoretical constitution: NaClO, one atom of sodium, one of chlorine and one of oxygen in its molecule. This substance is only indirectly of interest as one of the ingredients of the chlorinated soda solution.

Liquor Sodæ Chloratæ:

Synonyms: Labarraque's solution, solution of chloride of soda; chlorinated soda solution.

Preparation: made by decomposing a solution of chlorinated lime with one of sodium carbonate:

$$\underbrace{[Ca(ClO)_2 + CaCl_2]}_{\text{Chlorinated lime.}} + 2NaCO_3 = \underbrace{[2NaClO + 2NaCl]}_{\text{Chlorinated soda.}} + \underbrace{2CaCO_3}_{\text{Calcium carbonate.}}$$

Properties: clear, pale liquid, slightly greenish yellow in color, of faint chlorine odor, alkaline taste and reaction. Sp. gr., 1.044. Powerful disinfectant, deodorizer, antiseptic, bleaching agent.

Use in dentistry: used locally for its antiseptic properties and, in combination with powdered alum, as a bleaching agent for discolored teeth. It slowly decomposes on exposure to air and light, and should be kept in a dark place in a bottle provided with a glass stopper. It is advisable to keep soda and potash solutions in bottles whose glass stoppers have been dipped in paraffine.

Eau de Javelle contains *potassium* hypochlorite.

171. **Ammonium and its Compounds.—**

Ammonium (NH_4) is what is known as a *radical.* (See Organic Chemistry). It is not positively known to exist nor is its oxide. There are reasonable grounds, however, for supposing that it does actually exist in certain compounds called the ammonium compounds, all of which contain NH_4 in their formulæ. Ammoni*um* is not ammon*ia;* the latter is a well-known gas, NH_3, while ammonium has never been isolated and has, therefore, only a hypothetical existence. Ammonium would seem in the main to resemble sodium and potassium; there are, however, points of dissimilarity.

TABLE 15. COMPOUNDS OF AMMONIUM.

Names.	Formulæ.	Properties.
Hydrate, (Ammonia water).	H_4NHO or NH_4HO Sometimes written AmHO. May be deemed a hydrate of the radical ammonium.	Volatile, caustic liquid of powerful odor. Aqua Ammoniæ is a solution of ammonia gas in water, of sp. gr. 0.959. Aqua Ammoniæ Fortior contains 28 per cent. of the gas and is of sp. gr. 0.900; it is a powerfully corrosive poison.
Carbonate, Ammonii carbonas. Hartshorn salt. Sal Volatile.	(NH_4HCO_3, $NH_4NH_2CO_2$) Really a mixture of the acid carbonate and the carbamate. Molecular wt., 157.	Has strong odor of ammonia and is freely soluble in water. Loses CO_2 and NH_3 on exposure to the air.
Chloride, or muriate. Sal ammoniac.	$NH_4Cl = 53.4$	White, crystalline powder; very easily soluble in water, but not hygroscopic. Used as flux in refining gold, etc., and locally.

Lithium:—

Symbol: Li. *Latin name:* Lithium. *Equivalence:* I. *Specific gravity:* 0.59. *Atomic wt.* (approx.): 7. *Atomic wt.* (revised): 7.0073. *Electrical State:* +. *Fusing point:* 356° F. *Properties:* White, oxidizable metal and the lightest metal known.

172. Silver.—

Symbol: Ag. *Latin name:* Argentum. *Equivalence:* I and III. *Specific gravity:* 10.40 to 10.57. *Atomic weight* 108. *Revised atomic weight:* 107.675. *Electrical state:* +. *Fusing point:* 1873°F. Expands on solidifying. *Length of bar* at 212 : 1.0021; (6th rank). *Wt. of cubic ft. in lbs.:* 657.3. *Tensile strength:* 18.2; (lead = 1). *Tenacity:* 12.5*; (5th rank). *Malleability:* 2; (2d rank). *Ductility:* 2; (2d rank). *Conducting power*, heat: 1; (1st rank). *Conducting power*, electricity: 1; (1st rank). *Resistance*

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*Compared with lead.

to air, etc,; tarnished by sulphuretted hydrogen, but not affected by air. *Solubility:* in nitric acid, hot strong sulphuric, hydrochloric with difficulty; not attacked by caustic alkalies nor by melted nitre. It is dissolved by mercury. *Direct combinations:* with halogens, chlorine, bromine, etc., and with sulphur and phosphorus. *Color* white, brilliant. *Structure:* isometric crystals, when cooled slowly from fusion. *Consistence:* soft. Intermediate in hardness between gold and copper. *Compounds:* argentic, as argentic nitrate, etc. *Ordinary alloys:* silver coins, gold solders, silver solders, silver vessels, silver jewelry.

Occurrence: silver is found in combination with some of the halogens as chlorine, bromine, iodine, with various other non-metals as sulphur, arsenic, antimony, and with copper. It occurs in the Western states, in Mexico, Saxony, Hungary, Norway, South America and elsewhere. It is sometimes found *native**.

Preparation: the methods are various and elaborate. The Washoe process is to grind the ores with water, in iron pans heated by steam. Mercury is added, the sulphide of silver is decomposed by the iron, sulphide of iron formed and metallic silver set free, dissolved in mercury and the mercury separated by pressure and distillation.

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*Native silver is that found not as a sulphide, etc., but uncombined. Native silver is found in crystals, threads, or amorphous masses, weighing often several pounds. It is associated, nearly always, with other metals in small quantities, and accompanied by its sulphide or chloride.

Pure silver may be prepared by reducing the chloride, by fusing it with dry sodium carbonate. Other methods are also used: one is to dissolve standard or other grades of silver in slightly diluted nitric acid, precipitate the solution by excess of common salt, place the well-washed chloride in water acidulated with hydrochloric acid, and add a few pieces of clean wrought iron: hydrogen is evolved which, uniting with the chlorine of silver chloride, leaves the silver as a spongy mass. After the removal of the iron and decantation of the liquid, the silver is well washed in hot water containing a little hydrochloric acid, dried and melted.

Uses in dentistry: silver is used in amalgam alloys and, according to Flagg, is the first, most important, and essential metal of a good amalgam alloy for filling teeth; it is the largest component of every truly good "submarine," "usual," or "contour" alloy in the market. Its presence in an amalgam is essential to proper setting; it notably maintains the bulk integrity of the filling; though discolored by sulphuretted hydrogen, the silver sulphide formed is highly conducive to the permanent saving of teeth largely decayed and predisposed to continued decay. Silver has also been used in dental plates.

173. **Silver alloys** and **alloys resembling silver.**—Silver coinage: silver 90, copper 10. Silver vessels: silver 95, copper 5. Silver jewelry: silver 80, copper 20. **An alloy** used in England **for temporary dentures** is silver 24 parts, platinum 3 to 10 parts.

German silver contains no silver, but is an alloy of copper, nickel, and zinc, in the proportions of 40.4 copper, 31.6 nickel, 25.4 zinc, and sometimes 2.6 iron.

174. *Silver solder* is 32.3 parts copper, 38.5 silver, 29.2 zinc. Others are as follows: (Richardson).

No. 1.	No. 2.	No. 3.
Silver, 66 parts.	Silver, 6 dwts.	Silver, 5½ dwts.
Copper, 30 parts.	Copper, 2 dwts.	Brass wire, 40 grains.
Zinc, 10 parts.	Brass, 1 dwt.	

When the plate to be united consists of pure silver alloyed with platinum, the solder may be formed of the standard metal (coin), with $\frac{1}{10th}$ to $\frac{1}{6th}$ its weight of zinc, according to the amount of platinum in the alloy.

175. Compounds of silver.

Silver Nitrate or Argentic Nitrate.—

Synonyms: lunar caustic, lapis infernalis. Official name, Argenti Nitras.

Theoretical constitution: $AgNO_3$, one atom of silver, one of nitrogen, three of oxygen; by weight, silver 107.7 parts, nitrogen 14, oxygen 48. Molecular weight, 169.7.

Properties and uses: on evaporating a solution of silver in nitric acid and water, nitrate of silver is obtained in the form of colorless, heavy, shining, rhombic plates. It is blackened by exposure to light, and by contact with organic matter. It is also prepared in stick form, by fusing and pouring into moulds. It is very soluble in water, and slightly in alcohol. It is used in dentistry as an astringent, styptic, and obtunding agent. It blackens tissues with which it comes in contact, and is a powerful escharotic. Should be kept in amber bottle with glass stopper.

Toxicology: silver nitrate is an irritant, corrosive poison. The antidote is common salt or sal-ammoniac. Emetics should be given, and white of egg administered freely.

Silver Sulphide.—Silver has a strong affinity for sulphur, the sulphide, Ag_2S, being formed in the mouth by action of sulphuretted hydrogen on an alloy containing silver. Silver can, therefore, not be used in connection with substances containing sulphur, as rubbers. Silver sulphide is soluble in nitric acid, is soft and malleable.

Silver Chloride, $AgCl$, is formed when either common salt or hydrochloric acid is added to a solution of silver nitrate.

Silver Oxide, Ag_2O, is obtained as a brown precipitate, when solution of silver nitrate is decomposed by potash. Take of silver nitrate 100 Gm., of distilled water 200 C.c., of solution of potassa (official) 600 C.c. Dissolve the silver nitrate in water and add solution of potassa as long as any precipitate is produced by it. Wash the precipitate with distilled water, until washings are nearly tasteless. Dry the product and keep it well protected from the light.

It parts with its oxygen easily and must not be heated nor brought into contact with ammonia. Should be kept in a well-closed bottle and in a cool place. It is used as a coloring matter for artificial teeth.

176. Hydrogen.—

Symbol: H. *Atoms in molecule*: H_2. *Atomic weight*: **1.**

Molecular weight: 2. *Density*: 1. *Specific gravity*: 0.0692. *Weight of one litre* of hydrogen gas: 0.0896 gramme. *How liquified*: by pressure of 650 atmospheres at—140° C.

Occurrence in Nature.—In volcanic gases and sun's atmosphere.

How made.—By decomposing an acid with a metal: thus, sulphuric acid with zinc: $H_2SO_4 + Zn = ZnSO_4 + H_2$.

Properties.—Has affinity for chlorine only; at higher temperatures for oxygen. Is a gas, colorless, tasteless, odorless, transparent, and but slightly soluble in water. Is the lightest known substance and burns with the hottest flame.

Use in dentistry.—Used in connection with oxygen in the *oxyhydrogen blow pipe* for fusing refractory substances. (See Oxygen). In combination with carbon alone forms *hydrocarbons*, among which are the volatile oils, as oil of cloves. (See Organic Chemistry).

177. Compounds of hydrogen: hydrogen monoxide or water.—

Synonyms: Aqua; distilled water, *Aqua Destillata*. Theoretical constitution: H_2O, hydrogen monoxide, composed of two atoms of hydrogen and one of oxygen, by weight 8 parts of oxygen to 1 of hydrogen. Molecular weight, 18. Specific gravity, 1.

Origin: occurs in nature in lakes, rivers, etc., and in three states the solid as ice, the liquid, and the gaseous as steam or vapor. In the air it is in form of vapor. Seven-eighths of the human body is water. Is always formed when hydrogen or any substance containing hydrogen burns in the air.

The freezing point of water is 32° on the Fahrenheit scale of thermometers, but zero on the Centigrade; the boiling point is 212° on the Fahrenheit, but 100° on the Centigrade. *Water is expanded by heat* and contracts on cooling, but after reaching 39° F. begins to expand again so that the volume of a given weight of water is less than the volume of ice formed from it. *Ice contracts*, then, *on melting*. On the other hand when water is converted into steam there is great expansion, one volume of water yielding 1700 volumes of steam. *The capacity of water for heat* is greater than that of all bodies except hydrogen. Adopting for the unit of measure that quantity of heat which will raise the temperature of one gram of water through one Centigrade degree those fractions of the unit of heat which will raise various substances, other than hydrogen, as iron, lead, or glass one degree are called the specific heats of the substances. (See Table 1). The specific heat of hydrogen is 3.4, that of iron 0.1138, that of lead 0.0314. (See Section 59.)

Water has a very general solvent power which, however, is limited and varies with temperature, some substances being much more soluble in hot water than in cold water. Among substances very soluble in water we find potassium carbonate and zinc chloride. (See Section 68).

Well waters on being evaporated yield a residue composed usually of compounds of calcium, magnesium, etc., which have previously been held in solution.

Water enters into the formation of crystals, readily shown by preparing a saturated solution of such salts as alum, potassium ferrocyanide, potassium nitrate, magnesium sulphate, and letting stand in a shallow dish until evaporation has taken place.

Water is the medium of chemical change. (See Section 141.)

Water combines with certain substances, forming *hydrates* with oxides of positive elements, and *anhydrides* with oxides of negative elements. Examples: quicklime and water form slaked lime; that is, calcium oxide and water form calcium hydrate; sulphurous oxide and water form sulphurous anhydride.

In general water is a limpid, colorless liquid, odorless, tasteless, neutral, poor conductor of heat and electricity, 773 times heavier than air, standard of specific gravity. The purest natural water is rain water. This, however, is somewhat contaminated with matters washed from the air. River and lake waters, especially those found in granitic regions, are the purest *potable* waters. *Mineral* waters are called alkaline, sulphurous, chalybeate, etc., according to prevailing constituents, and contain *usually* large amounts of solids in solution.

Use in dentistry: distilled water is used in the preparation of many dental formulæ. It is prepared by taking 80 pints of water, distilling two pints which are rejected, then distilling 64 pints. The term **aqua,** U. S. P., is used as a name for a solution of some gaseous or volatile body in water. Thus, **aqua chlori;** the term **liquor** is used when the substance dissolved is fixed or solid, as **Liquor Plumbi Subacetatis.**

178. **Hydrogen Dioxide.**—

Synonyms: hydrogen peroxide, hydric dioxide or peroxide, oxygenated water.

Theoretical constitution: H_2O_2, hydrogen dioxide, composed of two atoms of hydrogen and two of oxygen; by weight, 32 of oxygen to 2 of hydrogen, or 16 to 1. Molecular weight, 34.

Preparation: pass a stream of carbon dioxide through water containing barium dioxide in suspension:

$$\underset{\text{Barium dioxide}}{BaO_2} + \underset{\text{carbonic dioxide}}{CO_2} + \underset{\text{water}}{H_2O} = \underset{\text{barium carbonate}}{BaCO_3} + \underset{\text{hydric dioxide.}}{H_2O_2}.$$

Properties: in the purest form it is a syrupy colorless liquid, having an odor like chlorine or ozone, and a tingling, metallic taste. It is never used in the purest undiluted form in dental operations owing to the readiness with which it decomposes and gives off its oxygen. It is a powerful antiseptic, colorless, odorless, cleansing and stimulating, does not stain or corrode, and is not poisonous. It gives off its oxygen with effervescence in contact with many substances and notably with pus. Application to dentistry: it effervesces with pus, giving off nascent oxygen, which is a powerful bactericide; being one of the most cleansing of agents, it is used to clean cavities. Combined with weak alkali it bleaches. A "ten volume" solution of it is one which will give off ten parts by volume of oxygen; that is, one measure of it gives off ten measures of oxygen. A "two volume" solution contains 0.4 per cent. of the pure dioxide. A little acid is added to the solutions of the dioxide commonly used in dentistry as an aid to their stability.† Hydrogen dioxide should be kept in a cool place in a glass-stoppered bottle. Hydrogen dioxide is sometimes used in solution in glycerine instead of in water. It gives off its oxygen more slowly than when in aqueous solution.

179. **Iodine.**—*Symbol:* I. *Atoms in molecule:* I_2. *Atomic weight:* 127. *Molecular weight:* 254. *Density:* 127. *Specific gravity:* 4.95. *Weight of one litre of gas:* 11.37 grammes. *How liquefied:* at 225° F. *Solubility in water:* 7000 parts of water dissolve 1 of iodine. Freely soluble in alcohol and in aqueous solution of potassium iodide. *Occurrence in nature:* in combination, as iodides, etc, *How made:* from ashes of sea-weed. By action of chlorine

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†Rollins has found that as ordinarily obtained it acts perceptibly on the teeth, and hence should be used with caution.

and heat on liquor obtained by leaching sea-weed ashes. *Properties:* solid, in brilliant scales, of gray metallic color. Gives off violet vapors. Imparts yellowish-brown stain to skin. Solutions when cold give blue color to boiled starch. Not so corrosive or poisonous as bromine, but yet poisonous in sufficient quantity. Antidote, starch.

Preparations used in dental pharmacy.—Tincture of iodine, *Tinctura Iodi*, is made of 80 grams of iodine in 920 grams of alcohol. Compound solution of iodine, *Liquor Iodi Compositus* is iodine 50 grams, potassium iodide 100 grams, distilled water 850 C. c. Decolorized tincture of iodine, *Tinctura Iodi Decolorata*, is iodine 40 grams, alcohol 400 C. c., stronger water of ammonia 90 C. c. Carbolized iodine solution, *Liquor Iodi Phenolatus*, is tincture of iodine 1 gram, phenol (carbolic acid) 12 centigrams, glycerine 8 grams, water 45 C. c.; it is a colorless liquid.

The antidote for iodine is starch.

Bromine.—*Symbol:* Br. *Atoms in molecule:* Br_2. *Atomic weight:* 80. *Molecular weight:* 160. *Density:* 80. *Specific gravity:* 3.187. *Weight of one litre of gas:* 7.15 grammes. *How liquefied:* at ordinary temperatures. *Solubility in water:* 33 parts water dissolve one of bromine.

Occurrence in nature: in combinations as bromides, etc. *How made:* action of sulphuric acid on bittern in presence of manganese dioxide. *Properties:* liquid, heavy, dark, brownish-red, less active than chlorine, bleaches, burns, is poisonous, colors starch yellow. Fumes violently. Is heavier than some metals, as aluminium.

180. **Chlorine.**—*Symbol:* Cl. *Atoms in molecule:* Cl_2.

Atomic weight: 35.4. *Molecular weight:* 71. *Density:* 35.4. *Specific gravity:* 2.47. *Weight of one litre of gas:* 3.17 grammes. *How liquefied:* 4 atmospheres or—40° F. *Solubility in water:* 1 part, by volume, of water dissolves nearly three volumes of chlorine gas. *Occurrence in nature:* always in combination, usual source common salt. *How made:* (*a*) action of H_2SO_4 on NaCl in presence of MnO_2; (*b*) action of air on moistened "chloride of lime." *Properties:* is a gas, greenish-yellow, of pungent taste and suffocating odor, wholly irrespirable, powerful bleaching agent and disinfectant. Combines with all elements except oxygen, nitrogen, and carbon.

Use in dentistry.—Chlorine gas has been used to bleach discolored teeth. It may be prepared as follows:

Place 20 parts, by weight, of commercial hydrochloric acid (sp. gr. about 1.16) in a flask, add 8 parts manganese dioxide, agitate, and after a time heat the flask on a sand bath (safety-tube may be used, which is a funnel-tube bent twice on itself). The equation is as follows:

$$4HCl + MnO_2 = MnCl_2 + 2H_2O + Cl_2.$$

The flask should be closed by a cork perforated by two holes, through one of which the safety-tube may be inserted, its lower end dipping below the surface of the acid; through the other hole a short glass tube bent at right angles should be inserted, its lower aperture being about an inch below the cork. The gas escapes through this second tube, called *deliv-*

ery tube, and may be collected in any way desired.

Chlorine water is used in dental practice as a local application. It is prepared by passing the gas into water in which it is readily soluble, one volume of water dissolving three volumes of chlorine gas. The solution *Aqua Chlori*, U. S. P., is a greenish-yellow liquid, slowly changing in the light to hydrochloric acid. It should not redden litmus but bleach it. It should be kept in a glass-stoppered bottle away from the light and in a cool place. It should contain 0.4 per cent of chlorine.

Toxicology.—Chlorine gas is an irritant poison, and is irrespirable, causing inflammation of the air passages. The treatment is instant removal to fresh air, inhalation of ammonia or very dilute sulphuretted hydrogen or ether-vapor. The inhalation of steam is said to be beneficial.

181. Compounds of chlorine.—

Hydrogen Chloride or Hydrochloric Acid.

Synonyms: muriatic acid, chlorhydric acid, Acidum Hydrochloricum.

Theoretical constitution: HCl, a hydracid, binary compound composed of one atom of hydrogen and one of chlorine; by weight 35.4 parts chlorine to 1 of hydrogen. Molecualr weight 36.4. Density of the gas, 18.25; sp. gr. 1.264. Absolute HCl contains 97.26 per cent. of chlorine and 2.74 per cent. of hydrogen.

Preparation: found free in small quantities in gastric juice. Made from common salt and sulphuric acid:

$$\underset{\text{Sulphuric acid}}{H_2SO_4} + \underset{\text{sodium chloride}}{2NaCl} = \underset{\text{hydrochloric acid}}{2HCl} + \underset{\text{sodium sulphate.}}{Na_2SO_4}$$

Properties: colorless, transparent gas of pungent odor, strongly acid reaction, very soluble in water, one volume of which dissolves 450 volumes of the gas forming the ordinary **muriatic acid.** Commercial muriatic acid is yellow, and the strongest contains 25 to 30 per cent. of the gas. *Acidum Muriaticum* or *Acidum Hydrochloricum*, U. S. P., is colorless, sp. gr. 1.16, contains 31.9 per cent of the gas. *Acidum Muriaticum Dilutum*, U. S. P.: strong acid 6 parts, distilled water 13 parts; sp. gr., 1.049.

Use in dentistry: it is used as a solvent for zinc, and sometimes as a local application. It dissolves iron and zinc readily and, when warmed, attacks tin.

Toxicology.—Hydrochloric acid is a corrosive poison, caustic and escharotic. It stains the skin at first white, then produces discoloration. The stain on black cloth is red, gradually disappearing in course of time. Burns by the acid should be treated first by washing the acid off well, then by application of sodium bicarbonate solution and oil. If the acid be taken internally, give at once magnesia or bicarbonate of sodium in milk at short intervals, then bland liquids as raw eggs, gruel, or oil.

182. **Fluorine.**—*Symbol*: F or Fl. *Atoms in molecule*: Fl_2. *Atomic weight*: 19. *Revised weight*: 18.9840. *Molecular weight*: 38. *Density*: 19. *Weight of one litre of gas*: 1.7

grammes. *Occurrence in nature*: in combination as in fluor-spar and cryolite which are fluorides. *How made*: cannot be readily isolated. *Properties*: colorless gas.

183. **Dyads.**—The dyads of importance will be studied in the same relative order as the monads.

TABLE 16. DYADS OF IMPORTANCE.

Barium	Dyads positive to hydrogen.
Calcium	
Magnesium	
Zinc	
Cadmium	
Lead	
Uranium	
Copper	
Mercury	
Tellurium	Dyads negative to hydrogen.
Sulphur	
Oxygen	

184. **Barium.**—*Symbol:* Ba; *Latin name:* Barium. *Equivalence:* II. *Specific gravity*: 4. *Atomic wt.* (*approx.*)*:* 136.8. *Atomic wt.* (*revised*)*:* 136.763. *Electrical state:* +. *Fusing point:* below red heat. *Properties:* malleable, decomposes water, gradually oxidizes.

Compounds of barium.—Barium chloride, $BaCl_2$, and barium nitrate, $Ba(NO_3)_2$, are both soluble in water and are used in laboratory work in testing for sulphuric acid and sulphates.

185. **Calcium.**—*Symbol:* Ca; *Latin name:* Calcium. *Equivalence:* II. *Specific gravity:* 1.58. *Atomic weight* (*approx.*)*:* 40. *Atomic weight* (*revised*)*:* 39.99. *Electrical state:* +. *Fusing point:* burns when heated. *Properties:* light yellow metal, about as hard as gold, very ductile, tarnishes slowly, decomposes water.

186. **Calcium compounds. Calcium Sulphate.—**

Synonyms: sulphate of calcium, sulphate of lime, plaster-of-Paris, calcic sulphate. Official name, Calcii Sulphas.

Theoretical constitution: $CaSO_4.2H_2O$, one atom of calcium, one of sulphur and four of oxygen; by weight 40 parts calcium, 32 parts sulphur, 64 parts oxygen. Molecular weight, 172.

Preparation: calcium sulphate occurs in nature as a mineral called gypsum. Gypsum, however, differs from the dried calcium sulphate of commerce in that it contains two molecules of water of crystallization; the full formula for gypsum is, therefore, $CaSO_4$, $2H_2O$. Ground gypsum is called *terra alba*. Gypsum when heated to 392° F. loses its water of crystallization, becoming changed into a white, opaque mass having $CaSO_4$, without any H_2O, for its formula. This substance when ground is known as plaster-of-Paris and is anhydrous calcium sulphate; it readily recombines with water, becoming a hard mass on the addition of H_2O.

Properties and uses: the anhydrous sulphate, $CaSO_4$, plaster-of-Paris, is a hard, white, nearly insoluble substance. After taking up water it "sets" into a stone-like solid, and hence is useful in making moulds, casts, and immovable surgical dressings. If alum and gelatine be mixed with the plaster-of-Paris before addition of water, it forms a harder and less porous mass than the plaster alone, and presents a smooth surface which can be washed with water containing the various disinfecting agents.

187. **Calcium Carbonate.**—

Synonyms: calcic carbonate, Calcis Carbonas, carbonate of lime. Official name, Calcii Carbonas Præcipitatus.

Theoretical constitution: $CaCO_3$, one atom of calcium, one of carbon, three of oxygen; by weight 40 parts calcium, 12 carbon, 48 oxygen. Molecular weight, 100.

Origin and method of preparation: it occurs more or less pure in nature as chalk, limestone, marble, Iceland spar, coral, shell, etc. It is found in the bones, teeth, saliva, and in calculi and tartar.

It is obtained for dental uses (1) by precipitation, by mixing solutions of calcium chloride and sodium carbonate:

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} \underset{+}{+} \underset{\text{Calcium chloride}}{CaCl_2} \underset{=}{=} \underset{\text{Calcium carbonate}}{CaCO_3} \underset{+}{+} \underset{\text{Sodium chloride}}{2NaCl}$$

(2) as prepared chalk (Creta Præparata) by grinding a native chalk in water, allowing the mixture to settle, decanting the upper portion, collecting and drying the finer particles.

Properties and uses: precipitated calcium carbonate is a neutral, white, tasteless, impalpable powder; it is insoluble in pure water and in alcohol, but soluble in water containing carbonic dioxide (carbonic acid). It is found as acid carbonate, dissolved in almost all natural waters, causing *hardness*, which may be removed by boiling, hence called "temporary" hardness.

It is used in dentistry as a polishing powder, as an ingredient of dentifrices, and as an antacid. It is useful as an antidote in cases of poisoning by acids.

188. **Calcium Oxide.**—

Synonyms: calcic oxide, lime, Calx, quicklime, burned lime. Official name, Calcii Oxidum.

Theoretical constitution: CaO, calcium oxide, one atom of calcium and one of oxygen in its molecule; by weight, 40 parts of calcium to 16 of oxygen. Molecular weight, 56.

Preparation: lime is obtained on a large scale by heating limestone or other calcium carbonate in a lime kiln:

$$\underset{\text{Calcium carbonate}}{CaCO_3} = \underset{\text{Calcium oxide}}{CaO} + \underset{\text{Carbon dioxide.}}{CO_2}$$

For pharmaceutical purposes it is made by heating marble in a Hessian crucible.

Properties and uses: lime is a grayish-white amorphous solid, odorless, infusible, of alkaline taste and reaction. It becomes incandescent in the oxy-hydrogen flame, emitting a very intense white light. Made from marble it should be pure white.

189. **Calcium Hydrate.**—Slaked lime, Calcii Hydras. Formula, $Ca(HO)_2$. Molecular weight, 74. Prepared by adding 10 parts water to 16 of lime, letting cool, and straining. Dry, white, odorless, tasteless, alkaline pow-

der. None but recently prepared calcium hydrate should be used, as it soon becomes carbonate, absorbing carbonic dioxide from the air.

Mortar is a mixture of sand, water, and slaked lime; as the water evaporates mortar hardens, because part of the lime becomes a *carbonate*, absorbing carbon dioxide from the air, and part a *silicate* combining with the silicic acid of the sand.

Cement or hydraulic mortar is a mixture of powdered quartz, lime, and aluminium silicate; its hardening is due to the formation of calcium and aluminium silicates.

Lime Water or Liquor Calcis is a *clear* solution of calcium hydrate in water. Sugar increases the solubility of the calcium hydrate. Lime water is a colorless, nearly odorless liquid, of feebly caustic taste and alkaline reaction. It is a solution of about 15 parts calcium hydrate in 10,000 of water.

Milk of lime is lime water containing an excess of calcium hydrate, rendering it turbid.

Lime water is used in dentistry in form of gargle as an antacid, astringent, etc.

190. **Calcium Fluoride.**—

Synonyms: fluor-spar, fluoride of lime, Calcii Fluoridum.

Theoretical constitution: $CaFl_2$, one atom of calcium and two of fluorine, 40 parts by weight of calcium, and 38 of fluorine. Molecular weight, 78.

Preparation: calcium fluoride occurs in nature as fluor-spar; it is made artificially by treating a salt of calcium with potassium fluoride.

Properties: human bone contains about two per cent. of calcium fluoride; the enamel of teeth contains it also.

It is a very hard substance, insoluble in water, but decomposed by sulphuric acid, hydrofluoric acid being formed.

191. **Calcium Sulphite.**—Sulphite of lime, Calcii Sulphis. Formula $CaSO_3$, $2H_2O$. Molecular weight, 156. Made by saturating milk of lime with sulphurous oxide, collecting, and drying the precipitate. It is a white powder, slightly soluble in water, soluble in sulphurous acid. It gradually becomes converted to sulphate. Used as an antiseptic.

192. **Chlorinated Lime.**—Official name, Calx Chlorata. Contains probably $Ca(ClO)_2$, calcium hypochlorite. It should yield 25 per cent. chlorine on addition of acid. It is prepared by the action of chlorine on calcium hydrate. It is a white or grayish-white, dry or but slightly damp powder or friable lumps, of feeble chlorine-like odor, and disagreeable, saline taste. It should be kept in well-closed vessels, in a cool, dry place. It is partially soluble in water and in alcohol. It is a disinfectant and a bleaching agent. It is used in dentistry as a deodorizer, disinfectant, antiseptic, and bleaching agent. It is poisonous in large doses.

193. **Calcium Phosphate.**—$Ca_3(PO_4)_2$, basic phosphate, tricalcic phosphate, bone phosphate: found in whole organism, constitutes two-thirds of the teeth, found in bones and in calculi; in the ash of albuminous substances; white, insoluble. Readily soluble in acid solutions.

194. **Calcium Hypophosphite.**—$Ca(H_2PO_2)_2 = 170$. Prepared by dissolving phosphorus in milk of lime by aid of heat. Is a white salt, permanent in air, soluble in water, insoluble in alcohol.

195. **Magnesium.**—*Symbol*: Mg.; *Latin name:* Magnesium. *Equivalence*: II. *Specific gravity*: 1.70 to 1.74. *Atomic wt.* (*approx.*): 24. *Atomic wt.* (*revised*): 23.959. *Electrical state*: +. *Fusing point*: melts at red heat. *Properties*: magnesium is a brilliant, silver-white metal, lighter than silver or aluminium, tarnishing in damp air, burning easily and with a flame of dazzling brightness. It is soluble in dilute acids and unites directly with most of the negative elements.

TABLE 17.—COMPOUNDS OF MAGNESIUM.

Name.	Formula.	Properties, Uses, etc.
Chloride	$MgCl_2$	White, soluble, very bitter.
Oxide	MgO	Known as magnesia or calcined magnesia. White, infusible, antacid, antidote to arsenic and caustic acids.
Sulphate	$MgSO_4$	"Epsom salts." White, soluble, very bitter.
Phosphate	$Mg_3(PO_4)_2$	Found in body along with calcium phosphate.
Ammonio-magnesium phosphate	$MgNH_4PO_4$	Called triple phosphate. Very soluble in acids, insoluble in alkalies.
Hypochlorite	$Mg(ClO)_2$	Used for bleaching purposes.

196. **Magnesium Carbonate.**—

Synonyms: carbonate of magnesia, magnesia alba, salis amari. Official name, Magnesii Carbonas.

Formula, $4MgCO_3.Mg(HO)_2.H_2O$.

Two kinds are known to pharmacy, the "heavy" and the "light." Both are prepared by dissolving 25 parts of magnesium sulphate and 20 of sodium carbonate, each separately, in water, but the "light" carbonate is the result of mixing the solutions when cold, the "heavy" by dissolving in hot water and mixing while hot. There are certain other differences also in the methods of preparation, the light carbonate solution being much more dilute than the heavy. The light carbonate contains more carbonate and less hydrate, is about three times as bulky, and is partly crystalline. The heavy carbonate is wholly amorphous. Both form a light, white mass or powder, nearly insoluble in water, but readily soluble in dilute acids.

197. **Zinc.**—

Symbol: Zn.; *Latin name*: Zincum. *Equivalence*: II. *Specific gravity*: 7.10 to 7.20. *Atomic weight*: 65. *Revised atomic weight*: 64.904. *Electrical state*: +. *Fusing point*: 773° F. *Length of bar, etc.*: 1.0029; (2d in rank, cadmium = 1). *Wt. of cubic ft. in lbs.*: 445.7. *Tensile strength*: 3.3 to 8.3. *Tenacity*: 2; (8th rank). *Malleability*: 7; (7th rank). Brittle, until heated to between 248° and 302° F. *Ductility*: 8; (8th rank). *Conducting power* (*heat*): 5; (5th rank). *Conducting power* (*electricity*): 290 (silver = 1000); (4th rank). *Resistance to air, etc.*: tarnishes slowly; in moist air becomes coated with carbonate. *Solubility*: soluble in dilute acids, and in solutions of alkaline hydrates; slowly corroded by water, milk, and wine.

Direct combinations: oxygen, chlorine. With iron, when heated to fusion. *Color and appearance*: bluish-white. *Structure*: crystalline; form of crystals, rhombohedral. *Consistence*: brittle. *Compounds*: zinc as zinc sulphide, zinc chloride, etc. *Alloys*: brass, bronze, bell metal, German silver, Aich's metal, arguzoid, Dutch metal, electrum, Muntz's metal, solders, sterro-metal, tutenag.

Occurrence: zinc is found usually either as sulphide, zinc-*blende*, ZnS. or as carbonate, *calamine*, $ZnCO_3$. It is also found as silicate and as oxide. Blende is found in Great Britain, Saxony, Aix-la-Chapelle, and in North America. Calamine occurs in Great Britain, Aix-la-Chapelle, Silesia, Spain, and in many other places. Red zinc ore or oxide is found chiefly in New Jersey.

Preparation: zinc is converted into vapor with comparative facility; it boils and distills at bright red heat. Hence, in order to extract zinc from its ores, the latter are first *calcined*, that is ignited in the air so as to burn off any oxidizable material, and the zinc obtained in form of oxide. The latter is then mixed with carbon and distilled, carbonic acid gas and zinc vapor being formed; the zinc vapor is condensed in suitable receivers.

Properties: under ordinary circumstances zinc is brittle, but when heated to about 300° F., it becomes malleable and ductile, and may be rolled into thin sheets. At about 400° F., it becomes brittle, melts at 775° and at 1842°

boils, volatilizes, and burns, if air be not excluded, with a fine greenish-white light, the oxide being formed.

Galvanized iron is iron covered with a coating of metallic zinc.

Dental uses: according to Flagg, zinc, in proportion of from 1 to 1½ parts in 100, if added to the usual 40 silver 60 tin alloys, seems to control shrinkage, imparts a "buttery" plasticity to the amalgam, adds to the whiteness of the filling, and assists in maintaining its color.

Zinc is used in making dies for swaging plates. It may be used, according to Essig, in making counter-dies.*

198. **Alloys of Zinc.**—

Zinc and tin alloy for casting dies for swaging plates is, according to Richardson, zinc 4, tin 1.

Zinc in Solders.—Solders made of the common commercial zinc are brittle, and are rolled with difficulty. They cause also a strong, brassy taste in the mouth, and should therefore be dissolved out of the finished work by pickling in nitric acid, the surface afterwards being burnished. *Pure* zinc in solders gives a plate that rolls easily,

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*Dies for making artificial teeth. [Rollins in *Boston Medical and Surgical Journal*, 1884].

Metal plates are not as firm as rubber because they do not represent so perfect a reverse of the mouth. This is mostly due to the imperfect character and softness of the metal dies on which they are struck. A perfect die can be made by preparing the surface of the impression for electrotyping and then depositing copper on it which, if the die is to be used for striking, can be backed with a harder metal to the right firmness and form. Such a die is perfect and harder than any now in use.

makes a handsome solder and causes much less of the brassy taste, so little indeed that most people do not perceive it. (Chandler.)

199. Compounds of Zinc: Zinc Chloride.

Synonyms: butter of zinc, muriate of zinc. Official name, Zinci Chloridum.

Theoretical constitution: $ZnCl_2$, one atom of zinc and two of chlorine in the molecule; by weight, 64.9 parts of zinc to 70.8 of chlorine. Molecular weight, 135.7. It contains 47.83 per cent of zinc.

Preparation, properties, and uses: zinc chloride is made by heating zinc in a current of chlorine, or by the action of hydrochloric acid on granulated zinc or zinc carbonate, and evaporation of the solution to dryness.

It occurs in the form of hard, dirty-white masses, very deliquescent, and forming a clear solution with water.* Zinc chloride has a caustic, sharp taste, and is acid in reaction. It is soluble in alcohol and in ether. "Burnett's Disinfecting Fluid" contains zinc chloride, in proportion of from 205 to 230 grains to the ounce of water. The official solution of chloride of zinc, Liquor Zinci Chloridi, is an aqueous solution of zinc chloride containing 50 per cent. of the latter, or 23.92 per cent. of zinc.

It is made from 20 parts of granulated zinc, 1 part of nitric acid, 1 part of precipitated carbonate of zinc, and

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*It is one of the most soluble substances known.

sufficient hydrochloric acid and distilled water. To the zinc, enough hydrochloric acid is added to dissolve it; the solution is filtered, nitric acid added, the whole evaporated to dryness, and the dry mass brought to fusion. After cooling, it is dissolved in 15 parts distilled water, the precipitated carbonate of zinc added, and the mixture agitated occasionally during the 24 hours. Finally it is filtered through washed asbestos free from iron, and enough distilled water added to it, through the filter, to make the product weigh 80 parts. The reaction is as follows:

$$\underset{\text{Zinc}}{Zn} + \underset{\text{hydrochloric acid}}{2HCl} = \underset{\text{zinc chloride}}{ZnCl_2} + \underset{\text{hydrogen}}{H_2}.$$

The solution is evaporated to dryness, and the dry mass fused in order to remove any excess of nitric acid. Zinc chloride solution cannot be filtered through paper; powdered washed glass or purified asbestos must be used.

The solution is a heavy, strongly caustic liquid, which should mix with alcohol without precipitation. Its sp. gr. is 1.555.[†]

If of a sp. gr. of 1.1275 at 68° F., it contains only 13.876 per cent of zinc chloride; if its sp. gr. is 1.2466 it contains 25.819 per cent; if 1.3869, 37.483 per cent.

Use in dentistry: zinc chloride is used in dental medicine for various purposes as an antiseptic, disinfectant, and deodorizer. A solution of it is used in connection with the oxide, to make a plastic filling (see zinc oxychloride).

Toxicology: chloride of zinc rapidly coagulates albumin. It is a caustic and irritant. Externally applied, it penetrates deeply into tissues and spreads, producing a white, thick, and hard eschar. In cases of poisoning from

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[†] A solution of this strength is used in making the oxychloride cement.

internal administration, carbonate of sodium in milk, white of egg, or soap are the antidotes.

200. **Zinc Oxide.**—Official name, Zinci Oxidum. $ZnO = 80.9$. Made on a large scale by heating metallic zinc in a current of air. To make a pure white zinc oxide for pharmaceutical purposes, pure precipitated zinc carbonate should be heated at low red heat until the water and carbonic oxide are wholly expelled. This can be done below 500° F. The reaction is as follows:

$$\underset{\text{Zinc carbonate}}{2(ZnCO_3).3Zn(HO)_2} = \underset{\text{zinc oxide}}{5ZnO} + \underset{\text{carbonic acid}}{2CO_2} + \underset{\text{water}}{3H_2O}$$

Too high heat will give the product a yellow color, and make it feel harsh. A small quantity should be used in heating. A good quality of zinc oxide should come in the form of a soft, flaky, impalpable powder of sp. gr. 5.6. It should turn yellow when heated in a test tube, and become white again on cooling.

It is insoluble in water but completely soluble in dilute acids. It is not darkened by sulphuretted hydrogen.

201. **Zinc Oxyphosphate.**—By the combination of zinc oxide with phosphoric acid a substance is obtained known familiarly as *oxyphosphate of zinc*. As known to dentists it comes in the form of a powder and a liquid. The powder is zinc oxide, and the liquid some variety of phosphoric acid. The two mixed, in propor-

tions, found by trial to be suitable for setting purposes, form the *oxyphosphate cement.*

When glacial phosphoric acid is used, the cement is termed oxy*meta*phosphate. The *pure* glacial phosphoric acid is preferred for use, as cements made from the commercial glacial acid have been found less durable.*

202. Zinc Oxychloride.—

Theoretical constitution: oxychlorides differ from chlorides, in that the former are *chlorides of the oxide of a metal*, while the latter are chlorides of the metal itself only.

There are various oxychlorides of zinc, whose formulæ are as follows:

(*a*) $ZnCl_2.6ZnO.6H_2O$;
(*b*) $ZnCl_2.3ZnO.4H_2O$;
(*c*) $ZnCl_2.9ZnO.3H_2O$.

It will be seen, therefore, that the general formula for the three is $ZnCl_2 nZnO.nH_2O$, *n* denoting any number.

Method of Preparation.---The oxychloride is prepared from a powder and a liquid, as in

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*Rollins's process for making the oxymetaphosphate is as follows: Dissolve pure zinc in C. P. nitric acid to saturation, then evaporate to dryness, pack in a crucible, and heat till no more fumes are given off. Break up the crucible and, after separating the oxide of zinc, pulverize it to a very fine powder.

Take a pure solution of orthophosphoric acid (Section 266–1) which can easily be obtained of a strength of sixty per cent.; evaporate it in a platinum evaporating dish till white fumes come off. Then heat it to bright redness to be sure that it is all converted; cool, and make into a thick syrup, To make the filling, mix the powder and fluid in suitable proportions.

Slow-setting cements are less durable than those which set more rapidly The powder should be worked into the acid gradually until the mass is stiff, the chief point being not to add too much powder at a time.

the case of the oxyphosphate. The powder is oxide of zinc, and the liquid a solution of zinc chloride in distilled water.*

Properties and uses: zinc oxychloride is a white substance, plastic when first mixed, but rapidly hardening with age.

It is used in dentistry for filling, "lining," and restoring color to discolored teeth.

203. **Zinc Oxysulphate.**—

Theoretical constitution: the mixture used in dentistry under this name is composed of a powder, consisting of one part of calcined zinc sulphate to two or three parts of calcined zinc oxide. Dissolved in a solution containing gum arabic and a little sulphite of lime, it forms a plastic mass soon setting and very dense when hard. (Flagg).

Uses in dentistry: zinc oxysulphate is used in dentistry as an adjunct to filling materials.

204. Other compounds of zinc.—

Zinc sulphate, $ZnSO_4, 7H_2O$: white vitriol, white copperas, Zinci Sulphas. Occurs in small, colorless, transparent, efflorescent crystals, often mistaken for Epsom salt, astringent, emetic, irritant poison. Freely soluble in water, insoluble in alcohol. Disagreeable, metallic, styptic taste. Made by dissolving zinc in sulphuric acid: $Zn + H_2SO_4 = ZnSO_4 + H_2$.

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*Various methods of preparing the oxychloride have been suggested and as the zinc chloride is *very* soluble in water various strengths of solution have been used, such as 1 part to 2 of water, equal parts, etc., etc. According to Feichtinger (*Dingler's Pol. Journal*) a good method is to add 3 parts of zinc oxide and 1 part glass powder to 50 parts of a solution of zinc chloride of specific gravity, 1.5 to 1.6 to which is further added 1 part of borax dissolved in the smallest possible quantity of water.

Flagg heats oxide of zinc with borax, adds gradually more calcined oxide of zinc, and finally mixes with the zinc chloride solution.

Zinc iodide, $ZnI_2 = 318.1$. Official name, Zinci Iodidum. Made by digesting granulated zinc 30 Gm. (465 grains) iodine 100 Gm. (1550 grains) water 200 C. c. (6¼ fluid ounces) until colorless and free from odor of iodine, subsequently filtering through asbestos or powdered glass and evaporating filtrate rapidly to dryness at moderate heat. Zinc iodide is a white, granular substance, very readily soluble in alcohol and in water.

Zinc iodo-chloride has also been used in dentistry.

Toxicology of zinc compounds: the general antidotes are alkaline carbonates, as sodium carbonate; white of egg, soap and water, and mucilaginous drinks.

205. **Cadmium.**—

Symbol: Cd. Latin name: Cadmium. Equivalence: II. *Specific gravity:* 8.69. *Atomic weight:* 112. Molecule composed of one atom. *Revised atomic weight:* 111.835. *Electric state*: +. *Fusing point*: 442° F. *Length of bar*, etc.: 1.0031; (first in rank, most expansible). *Wt. of cubic ft. in lbs.*: 542.5. *Tenacity*: greater than tin. *Malleability*, *Ductility*: flexible, malleable, and ductile. *Conducting power* (electricity): somewhat lower than zinc. *Resistance to air*: gradually tarnishes in air; stained yellow by sulphuretted hydrogen. *Solubility*: soluble in nitric acid, in dilute hydrochloric, and sulphuric, but not in caustic alkalies. *Direct combinations*: oxygen, chlorine, sulphur. *Color and appearance*: like tin; white tinged with blue; lustrous. *Structure*: crystallizes in regular octahedrons on cooling. *Consistence*: harder than tin; not so hard as zinc; soft enough to mark paper. *Compounds*: cadmium, as cadmium sulphate. *Alloys*: fusible metal,amalgam alloys.

Occurrence: cadmium often accompanies zinc in its ores, and occurs as an impurity in commercial zinc. It is found in small quantities, not over 2 or 3 per cent., in ores of zinc. It occurs most abundantly as sulphide.

Preparation: the metal is obtained by converting the sulphide into oxide by heat, and then reducing this with coal or charcoal.

Uses in dentistry: cadmium is a constituent of easily fusible alloys. It resembles tin in color and appearance, and *creaks* like the latter when bent. It is unalterable in the air. It has been used in dental amalgam alloys.

206. Compounds of Cadmium.

Cadmium Sulphate: $3(CdSO_4).\ 8H_2O$. Obtained by dissolving metallic cadmium, its oxide, or carbonate in sulphuric acid; if metallic cadmium is used, a little nitric acid is added to hasten the reaction, and afterwards driven off by evaporation. Cadmium sulphate occurs in form of colorless, transparent crystals, resembling sulphate of zinc. In dentistry it has been used in various injections and lotions. It is poisonous. Percentage of cadmium, 43.74.

207. Lead.

Symbol: Pb. *Latin name*: Plumbum. *Equivalence*: II and IV. *Specific gravity*: 11.33 to 11.39. *Atomic weight*: 206.5. *Revised atomic weight*: 206.4710. *Electrical state*: +. *Fusing point*: 617° F. *Length of bar*, etc.: 1.0028 (3d rank, cadmium = 1, most expansible). *Wt. of cubic ft. in lbs.*: 709.2. *Tensile strength*: 0.8 to 1.5. *Relative tenacity*: 1 (lowest in rank). *Malleability*: 6; (6th rank). *Ductility*: 10; (10th rank). *Conducting power* (heat): 9; (9th rank). *Conducting power* (electricity): 83; (silver = 1000); (10th rank). *Resistance to air*, etc.: soon tarnishes; corroded by air in presence of carbonic acid. Discolored by sulphuretted hydrogen. *Solubility*: soluble in dilute nitric acid; attacked by hot sulphuric. *Direct combinations*: oxygen, chlorine, bromine, iodine, sulphur. Amalgamates readily. *Color and appearance*: bluish-white, brilliant. *Structure*: crystallizes in regular octahedrons, or in pyramids with four faces. *Consistence*: soft, leaves mark on paper. *Compounds*: mostly plumb*ic*, so-called, Pb^{II}. *Alloys*: solder, type metal, pewter, fusible metal; has affinity for platinum and palladium.

Occurrence: lead occurs in nature chiefly as galena or galenite, which, like cinnabar, is a sulphide, PbS; 100 parts of the pure ore contain 86½ of lead. Another ore is *white-lead ore* or carbonate of lead. Galena is found in Great Britain, Spain, Saxony, and the United States. White lead ore is found in the valley of the Mississippi; in Australia, an ore called Anglesite, which is a sulphate of lead, is found. Other ores are crocoisite (a chromate), Wulfenite (a molybdate), and pyromasphite (a phosphate).

Preparation: galena is roasted, during which process two products, lead oxide and lead sulphate, are formed; the two products thus obtained are then strongly heated in a reverberatory furnace, metallic lead and sulphurous oxide being formed.

Dental uses: lead alloys with other metals, and is an ingredient of various solders: common solder is 50 parts lead and 50 parts tin. Lead is used in dentistry chiefly in making counter-dies. [Thin sheets of it are used for making patterns by which gold or silver plate is cut, so that bits of it may be found in the dentist's gold drawer; a very small amount of it will greatly impair the ductility of gold].

Compounds of lead: oxides of lead are used as coloring matters for artificial teeth. Plumbic peroxide (dioxide) PbO_2, is a chocolate-brown or puce-colored powder, which gives off its oxygen on being heated.

Litharge is plumbic oxide, PbO, prepared by heating melted lead in a current of air. It is pale yellow or orange yellow in color. By oxidizing litharge in a current of air and cooling slowly, a substance used in the arts as a pigment and called plumbic meta-plumbate, $Pb^{II}Pb^{IV}O_3$, or Pb_2O_3, is formed. The plumbic plumbates form the substances known as *red-leads.*

208. Compounds of Uranium.—

An *oxide* of uranium is used by dentists as a coloring matter for artificial teeth.* Its formula is U_2O_3, uranic oxide, or uranyl oxide as it is sometimes called. Uranic nitrate heated in a glass tube till it decomposes yields pure uranic oxide in the form of a yellowish powder.

Another oxide of uranium is uranous oxide, UO, a brown powder.

209. Copper.

Symbol: Cu. *Latin name*: Cuprum. *Equivalence*: $(Cu_2)^{II}$ and II. *Specific gravity*: 8.914 to 8.952. *Atomic weight*: 63.2. *Revised atomic weight*: 63.173. *Electrical state*: +. *Fusing point*: 1996°F. *Length of bar*, etc.: 1.0017; (7th in rank). *Weight of cubic foot in lbs.*: 558.1.

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*Rollins uses such oxides as contain the most oxygen, that is, uranic rather than uranous, plumbic dioxide rather than protoxide, etc., etc., because the coloring matters sometimes lose oxygen in firing.

Tensile strength: 13 to 15. *Tenacity*: 18, (Lead = 1); (3d rank). *Malleability:* 3; (3d rank). *Ductility:* 5; (5th rank). *Conducting power* (heat): 3; (3d rank). *Conducting power* (electricity): 999, (Silver = 1000); (2d rank). *Resistance to air*, etc.: in moist air becomes coated with green carbonate. Tarnished by sulphuretted hydrogen. *Solubility:* soluble in hot mineral acids, and attacked by vegetable acids in presence of air and moisture. Attacked by chlorine and nitric acid, and by sulphur when heated; slowly attacked by weak acids, alkalies, and saline solutions. *Direct combinations:* sulphur, chlorine, bromine, iodine, silicon, and various metals at red heat. *Color and appearance:* lustrous, flesh red. *Structure:* crystallizes in isometric forms. *Consistence:* somewhat softer than iron. *Compounds:* cuprous $(Cu_2)^{II}$ and cupric. *Alloys:* Aich's metal, aluminium bronze, arguzoid, bell-metal, brass, Britannia metal, bronze, Dutch-metal, electrum, German silver, gold coinage, gun-metal, Muntz's metal, pewter, silver coinage, some solders, speculum metal, sterro-metal, tutenag.

Occurrence: native copper exists near Lake Superior; in its ores it is found as oxide, sulphide, carbonate, and in combination with sulphide of iron, forming copper pyrites. The metal is found in England, Sweden, Saxony, Siberia, Australia, Chili, and in the United States.

Preparation: the ores are first roasted in air, then with silica fluxes and carbon, and finally a substance called copperstone is obtained, which contains both oxide and sulphide of copper. By repeating the roasting and heating, the oxide reacts on the sulphide, and metallic copper is obtained.

Pure Copper may be obtained by electrolysis. A solution of cupric sulphate is used, and the negative wire of a battery attached to a copper plate which is immersed in the solution. Pure copper is deposited on the plates, and may easily be stripped off.

Use in dentistry: copper is used as a constituent of some dental amalgam alloys.*

Alloys of Copper:

Babbitt Metal is an alloy of copper, 3 parts; antimony, 1 part; tin, 3 parts. The copper is fused and then antimony and tin are added to it. It melts at a moderately low heat; contracts but little; is brittle, but may be rendered less so by adding tin.

210. **Brass** is an alloy of copper and zinc. Common brass is made of 66.6 parts copper and 33.3 zinc; best brass, 71.4 copper to 28.6 zinc. Yellow brass is 60 copper to 40 zinc. Brass melts at 1869° F.

211. **Bell metal** is an alloy of 6 parts copper to 2 parts tin; some varieties are 78 copper to 22 tin. Cannon metal is 90 copper to 10 of tin.

212. **Bronze** is an alloy of copper and tin. **Aluminium bronze,** 900 parts copper to 100 of aluminium. The latter has been used for the under layer of teeth plates, and is said to be free from injurious oxidation and to be more easily manipulated than gold alloys or silver. It may be stamped and pressed, almost as easily as pure silver, while possessing the elasticity of steel. Its melting point is higher than that of pure gold, so that it may be made red hot without danger of melting, and can be manipulated

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*See Copper Amalgam under Mercury.

with hard solder. Sauer solders it with from 14 to 16 carat red gold. Aluminium bronze is one-half lighter than 12 carat silver and almost half the weight of 14 carat gold. It oxidizes, superficially only, in the mouth; it is affected, superficially, by a 1 in 1,000 solution of corrosive sublimate, but not by carbolic acid.

213. **Gold aluminium bronze** oxidizes more readily, is softer, and not so elastic.

214. **Phosphor bronze** is copper, combined with from 3 to 15 per cent. of tin, and from ¼ to 2½ per cent. of phosphorus.

215. **Speculum metal** is an alloy of copper and tin; 66.6 copper and 33.3 tin.

216. **Compounds of Copper.**—

Cupric Sulphate: $CuSO_4, 5H_2O$. Known as sulphate of copper, blue vitriol, Roman vitriol, blue stone, blue copperas, vitriol of copper. Official name, Cupri Sulphas. Made on a large scale by dissolving copper in sulphuric acid, evaporating, and allowing to crystallize:

$$\underset{\text{Copper}}{Cu} + \underset{\text{sulphuric acid}}{2H_2SO_4} = \underset{\substack{\text{cupric}\\\text{sulphate}}}{CuSO_4} + \underset{\text{water}}{2H_2O} + \underset{\substack{\text{sulphurous}\\\text{oxide}}}{SO_2}.$$

It occurs in the form of blue, prismatic crystals, efflorescent, of astringent, metallic taste, soluble in 4 parts water, insoluble in alcohol. In dentistry it is used externally, dissolved in ammonia, as an astringent and styptic. It is poisonous; antidotes: milk, white of egg given freely.

217. Mercury (quicksilver).

Symbol: Hg. *Latin name:* Hydrargyrum. *Equivalence:* $(Hg_2)^{II}$ and II. *Specific gravity:* 13.596. *Atomic weight:* 199.7. Molecule composed of one atom. *Revised atomic weight:* 199.7120. *Electrical state:* +. *Fusing point:* liquid at ordinary temperatures. Boils at 660° F. *Length of bar* total expansion, 1.0180. Malleable at—40° F. *Resistance to air,* etc.: unaltered in air; does not leave streak on paper.

Solubility: soluble in dilute nitric acid and hot sulphuric; insoluble in hydrochloric acid. *Direct combinations:* dissolves all metals but iron; combines directly with halogens and sulphur. *Color and appearance:* opaque, with metallic lustre; brilliant silver-white. *Structure:* octahedral crystals at—40° F. *Consistence:* liquid; slightly volatile. *Compounds:* mercurous $(Hg_2)^{II}$ and mercuric. *Alloys:* amalgams. *Use in dental amalgam alloys:* mercury amalgamates readily with gold, zinc, tin, and silver; also with copper, platinum, palladium, and cadmium.

Occurrence and preparation: mercury is found in the form of **Cinnabar,** which is native mercuric sulphide. Large quantities of it are obtained in California; it is also found in Spain, Austria, Mexico, Peru, China, Japan, Borneo. Mercury is obtained from cinnabar, either by roasting the latter or by heating it with lime, which combines with the sulphur of the cinnabar, while the metal volatilizes and is condensed in suitable coolers.

The equation of the preparation of mercury is

$$\underset{\text{Mercuric sulphide.}}{HgS} + \underset{\text{Oxygen.}}{2O} = \underset{\text{Mercury.}}{Hg} + \underset{\text{Sulphurous oxide.}}{SO_2}$$

Dental uses: amalgams. Mercury readily alloys with other metals, forming combinations called *amalgams.*

This property of mercury may be readily shown by the following experiment: clean a copper cent with a little nitric acid, wash well with water, and on it place a globule of mercury; the latter soon covers the whole surface of the cent, giving it a white color. Heat the cent and its original color will be restored, the mercury volatilizing. Many of the alloys of mercury with other metals are soft when freshly formed, but harden with time, hence their value for fillings.

The combinations formed are, in the case of solid amalgams, definite compounds in which, however, there is but feeble chemical affinity between the constituents. Liquid amalgams are merely solutions of the various metals in mercury, and not, as a rule, definite chemical compounds. Many liquid amalgams become, however, after a time, white, solid, and crystalline. There is usually little or no contraction in volume, but in the case of silver and copper amalgams there is considerable, and in tin and lead slight, though perceptible. (Watts).

Amalgams are decomposed by heat.

218. The methods by which amalgamation may be made to take place are as follows:

1. Direct contact on part of the metal, either as a solid or in the finely divided state, with mercury, either at ordinary temperatures or at higher temperatures. Heat is evolved during the amalgamation.

2. Introduction of metallic mercury, or of sodium-amalgam, into a solution of a salt of a metal.

3. Introduction of a metal into a solution of a salt of mercury.

4. Contact of a metal with mercury and addition of a dilute acid.

In the last two cases a weak electric current is sometimes developed.

Electricity is often used to facilitate the union of mercury with a metal precipitated from a solution of one of its salts. (See *Copper Amalgam*).

219. **Antimony amalgam:** triturate 3 parts heated mercury with 1 part fused antimony; or triturate 2 parts antimony in a mortar, add a little hydrochloric acid, and gradually drop in 1 part of mercury. The amalgam is soft, decomposed by contact with air or water, and the antimony separates.

Amalgams containing antimony in notable quantity are fine grained, plastic, and do not shrink, but are excessively dirty to work. Used in small proportions in amalgams it is said to be of possible value in controlling shrinkage.*

220. **Cadmium amalgam:** cadmium amalgamates at ordinary temperatures. When complete saturation takes place, as through agency of sodium-amalgam in a solution of salt of cadmium, a compound of 78.26 Hg to 21.74 Cd is formed, having for its formula, therefore, Hg_2Cd, and being silver-white, granular, hard, brittle, heavier than mercury, and in octahedral crystals. (Watts).

Cadmium amalgamates easily, sets quickly, and resists sufficiently, but fillings containing it gradually soften and disintegrate, and, if there is a large proportion, the dentine becomes decalcified and stained bright orange-yellow from formation of cadmium sulphide.

221. **Copper amalgam:** there are various processes

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*Dr. Chase's "alcohol tight" amalgam contains nearly five per cent. of antimony. (Weagant).

for making copper amalgam. Rollins, Ames, and others make it by *electrolysis*.

Rollins's method is as follows:*

Distilled water, five gallons; sulphate of copper, enough to saturate; sulphuric acid, one pound. Mix, filter, and pour into a wooden firkin with wooden hoops. All the chemicals should be absolutely pure. Place ten pounds of pure mercury in a glass jar and immerse in the copper solution. To the zinc plate of a galvanic battery attach a gutta-percha-covered wire, having one end bare for about an inch. This exposed end is to be immersed below the level of the surface of the mercury. Tie granulated pure copper in a bag and hang it in the copper solution, connecting with a wire to the carbon of the battery. The battery is to be kept in action till the mercury has absorbed enough copper to make a thick paste. Then remove and wash thoroughly in hot water till all of the sulphate solution has been removed. Squeeze out the softer amalgam and allow the remainder to harden. When it is hard, heat it, and renew the squeezing as before. This new method insures an amalgam of perfect purity, and is simpler than any of the old and faulty ways in use. Copper amalgam dissolves rapidly in mouths where the saliva is acid, and in this way serves as an indicator of the condition of the oral fluids. It stains teeth in a certain proportion of cases, particularly when teeth have lost their pulps, or when the dentine is of an open structure. A battery answers for home manufacture, but on a larger scale a dynamo should be used.

Dr. T. H. Chandler, of Boston, has described to me the following processes for making copper amalgam, which he calls "No. 1" and "No. 2." He thinks "No. 1" an excellent filling:

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*Boston *Medical and Surgical Journal*, February, 1886.

No. 1.—To a hot solution of sulphate of copper add a little hydrochloric acid, and a few sticks of zinc, and boil for about a minute. The copper will be precipitated in a spongy mass. Take out zinc, pour off liquor, and wash the copper thoroughly with hot water. Pour on the mass a little dilute nitrate of mercury, which will instantly cover every particle of the copper with a coating of the mercury. Add mercury two or three times the weight of the copper, triturate slightly in a mortar and finish by heating the mixture a few moments in a crucible.

No. 2.—Take finely divided copper (copper dust) obtained by shaking a solution of sulphate of copper with granulated tin. The solution becomes hot, and a fine brown powder is thrown down. Of this powder take 20, 30, or 36 parts by weight and mix in a mortar with sulphuric acid, 1.85 specific gravity, to a paste, and add 70 parts of mercury with constant stirring. When well mixed, wash out all traces of acid and cool off. When used, heat to 1300° F; it can be kneaded, like wax, in a mortar.

While in this plastic state, it is an excellent solder for metals, glass, etc., used by applying it to surfaces to be joined, pressing hard together and allowing it to set.

Weagant's process for making copper amalgam is as follows:

Nearly fill a vessel with a solution of copper sulphate, one part of a saturated solution to two or three parts water. Pour into it enough mercury to cover well the bottom of the glass, and stand a clean strip or plate of iron in the mercury, allowing the end to project above the glass. Pure precipitated copper in finely divided state will at once become deposited on the iron, and the mercury will gradually unite with the copper, creeping up the iron until the whole surface is covered with a film of amalgam. If the iron is placed for a moment in a weak solution of sulphuric acid just before being immersed in the copper bath, amalgamation takes place more rapidly.

It must be allowed to stand undisturbed until the change in the color of the solution shows that all the copper is precipitated. Then with a siphon draw off the liquid and renew the sulphate of copper. This proceeding may be repeated as long as the mercury takes up the copper. When all the mercury has become amalgamated, scrape off whatever amalgam adheres to the strip of iron, pour off the liquid, and turn the mass of amalgam into a mortar. Rub and wash it thoroughly, allowing a stream of water to fall upon it from a tap, cleaning out all the free metallic copper and scales of oxide of iron. As soon as it is as clean as it can be made, place it in a chamois skin and squeeze out the surplus mercury. Then the washing and grinding in the mortar must be repeated until the mass again becomes soft, when more mercury can be removed. The greatest care must be taken to remove all the little scales and grains of iron, or the amalgam will be dirty to work, and the best results from it cannot be obtained. When the amalgam has been well worked and all the mercury possible squeezed out, heat it gently in an iron vessel. The first time this must be done carefully, as steam from water which is retained in it becomes generated, and the mass will explode, flying in all directions. When the amalgam begins to get soft, rub in a mortar, and again squeeze out mercury. This heating, rubbing, and squeezing must be repeated again and again, until very little mercury can be removed and the amalgam is found to set instantly, and become very hard. It may then be made into little sticks or pellets, and laid away for use. To use it, place the quantity required in an iron spoon and heat it over a flame until mercury begins to show like sweat upon the surface. Then crush and grind the mass in a small mortar, and work together in the hand. If too soft, squeeze in a piece of chamois skin, using a pair of pliers if necessary. One soon learns how soft or dry to make it in order to get the best results. Do not throw away any of the scraps remaining, as they may be used over and over again an indefinite number of times, seeming to improve by age. Be careful not to heat too much, as some of the mercury volatilizes, leaving pure copper, which becomes oxidized by the heat and makes the amalgam dirty.

A weak solution of sulphate of copper is used instead of the saturated solution, as the precipitate is much finer and the amalgam requires less rubbing to bring it to shape.

Copper amalgam is composed of pure copper and pure mercury in variable proportions. The less mercury it contains the more quickly it sets and the harder it becomes. When properly made it is exceedingly pleasant to work, fine-grained and plastic, and sets either slowly or rapidly, as we desire it and are pleased to prepare it. It becomes very hard—harder in fact than any amalgam made from alloys. It is not known to shrink or expand in the least degree. It does not ball up nor change its shape in any way during the setting or afterwards, and finally, instead of having any injurious effect upon the teeth or surrounding tissues, it is decidedly beneficial to them, acting as an antiseptic or germ destroyer. But, although it does not cause discoloration of the teeth, the filling itself will quickly and emphatically become black —very black—upon the surface. It should always be carefully polished when hard, for, although polishing does not prevent its turning black, it is a polished black, and not so disagreeable and dirty looking as when left with a rough surface. (Weagant).

The sulphide of copper formed by the action of the sulphuretted hydrogen of the mouth on the copper of the amalgam is, according to Tomes, readily converted, on exposure to air and moisture, into copper sulphate, hence it is almost certain that the latter is formed on the exposed surface of the filling. Cupric sulphate is freely soluble, and hence is likely to permeate the dentine. Sulphides of the other metals are not so readily converted into soluble salts, hence will not permeate the dentine so thoroughly.*

222. **Gold amalgam:** gold, in leaf or filings, amalgamates readily with mercury at ordinary temperatures. For rapid amalgamation, heat should be used, and the gold be in the finely divided state.

Gold added to amalgams of tin and silver is valuable in that it controls shrinkage, balling, and discoloration, facilitates setting, and adds to edge-strength. Amalgams containing it are smoothly and easily worked. Some dentists use amalgams containing a very large proportion of gold.

223. **Palladium amalgam:**—

Palladium has been recently brought to notice as forming with three times its weight of mercury a desirable dental amalgam, especially useful in the sixth-year molars of young patients.†

Some care is necessary in the mixing, as palladium forms a true chemical compound with mercury, and the action is so intense that under certain circumstances an explosion may result. Palladium fillings become black, but do not discolor the tooth-substance.

The amalgam sets with such great rapidity that it is necessary to mix it quite soft in order to make a filling

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*Copper sulphate has been successfully used abroad as a preservative for telegraph poles.

†Dr. E. A. Bogue has used palladium amalgam. In the proportion of seventy-five per cent. mercury to twenty-five per cent. of pure precipitated palladium the expense is greatly reduced.

before it is too hard to use.* It must be worked very quickly, and with heated instruments.

224. **Platinum amalgam:** metallic platinum does not unite readily with mercury. Spongy platinum unites with mercury, when triturated in a warm mortar with the latter, or in contact with acetic acid; or sodium-amalgam containing 1 per cent. sodium, if introduced into a solution of platinic chloride, will form an amalgam of silvery appearance. The amalgam containing 100 parts mercury, to 15.48 platinum, has a sp. gr. of 14.29, and has metallic lustre when rubbed; 100 mercury to 21.6 platinum is a dark gray solid; 100 mercury to 34.76 platinum is of 14.69 sp. gr., dark gray, but of no lustre; 100 mercury to 12 platinum is bright, but soft and greasy. The solid amalgam containing the most mercury is probably $PtHg_2$. Mercury exposed for some time to the action of platinic chloride forms a thick, pasty amalgam.

In general, it may be said that an amalgam of mercury and platinum alone does not harden well.†

Platinum, according to Essig, is of value only when combined with tin, silver, and gold, with the proper amount of mercury; under such circumstances, it seems to confer on the alloy the property of almost instantly setting, and of being much harder. According to Fletcher, the amalgam should be used immediately, before the platinum and mercury have time to set.

225. **Silver amalgam:** amalgamation takes place quickly, if the silver is in thin plates, or in powder, and dropped at red heat into heated mercury. The amalgam varies according to circumstances of formation, composition, etc., and is soft, or crystalline, or granular. The

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*Dr. Chandler mixes gold in large proportion in order to render the palladium more tractable.

†Dr. Ames, of Chicago, has prepared platinum amalgam by electrolysis.

amalgam most readily formed has for its formula AgHg. [Amalgams of mercury and silver are said by Watts to *contract* considerably, but by others to expand. The *proportions* are undoubtedly of importance].

Amalgams composed of silver and mercury alone tend, when used as fillings, to change their shape. But silver used in connection with other metals is the most important element in a good amalgam for filling teeth.* Silver forms silver sulphide in contact with the sulphuretted hydrogen of the mouth, and both tooth and filling are blackened in consequence; but the tendency is toward preservation of the tooth.

226. **Tellurium** and mercury are said to unite directly, forming a tin-colored amalgam.

227. **Tin amalgam:** made readily and quickly by pouring mercury into melted tin, but readily enough by mixing the filings with mercury at ordinary temperatures. Tin amalgam has a white color, and, if there is not too much mercury, occurs in form of a brittle, granular mass of cubical crystals. In most cases there is *condensation*, but in the amalgam composed of 1 part tin to 2 mercury (melted and by volume) the condensation is scarcely perceptible.

Amalgams composed of mercury and tin alone do not harden sufficiently. In an alloy with other metals, tin is valuable in that it facilitates amalgamation, prevents discoloration, and diminishes conductivity.

228. **Zinc amalgam:** usually made by cooling melted zinc to as low a temperature as possible without letting it solidify, then pouring in mercury in a fine stream, and stirring constantly.

Amalgams of mercury and zinc alone are not common-

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*Silver is the largest component of most of the reliable amalgam alloys on the market.

ly used. Added to alloys of tin and silver in as small proportion as one per cent., zinc controls shrinkage, adds to the whiteness of the filling, and tends to maintain color.*

229. **Dental amalgam alloys:** it will readily be perceived from a study of common **amalgams** that but few of them would be of service to the dentist. On the other hand combinations of metals, often first melted in tin, brought about through the agency of mercury—that is, amalgams of *several metals at once*,—alloy amalgams—have been found very useful, so that now large quantities are used. Amalgams for dental purposes are chiefly composed of tin and silver, in different proportions, of which Townsend's alloy of 60 tin to 40 silver may be taken as the type. Some dental amalgam alloys, as Hardman's and Lawrence's, contain copper in addition to tin and silver; some contain zinc, gold, etc. The list of metals used in the dental amalgam alloys comprises tin, silver, copper, zinc, gold, platinum, cadmium, antimony, palladium. The so-called "gold and platina alloys," according to Flagg, contain 50 per cent. of tin, more than 40 of silver, and from 2 to 7 of gold and platinum.

[In regard to the average proportions of tin and silver, Flagg finds 40 tin to 60 silver the best working formula, modified by additions of copper, gold, and zinc].

230. **Qualities desirable in dental amalgam alloys:** strength and sharpness of edge, freedom from admixture with any metal favorable to the formation of soluble salts of an injurious character in the mouth, capability of maintenance of color and shape, and non-liability to undue expansion. N. B.—Absolute freedom from discoloration can not often be obtained, nor is it always desirable, according to Flagg.

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*Chandler's experiments with zinc lead him to prefer sifting in a small percentage of *pure* zinc dust at the "mix" rather than melting it with the other ingredients of an amalgam alloy.

231. **Discoloration of amalgam fillings:** the formation of sulphides, due to the sulphuretted hydrogen resulting from the decomposition of the food, is the main cause of the discoloration of amalgam fillings; black discoloration is found in fillings containing *silver* or *copper;* yellowish discoloration in those containing *cadmium.* According to Essig, it is not safe to suppose that a metal not of itself blackened by sulphuretted hydrogen—as gold or platinum—will secure the same immunity to alloys containing silver and mercury. It has been noticed that plugs, which apparently exclude the passage of a solution of indigo or ink, will show peripheral discoloration when exposed to the action of a sulphuretted hydrogen solution, though the surface directly exposed to the action of the sulphur was but slightly clouded.* (Essig).

Discoloration of gold fillings: Chandler takes the ground that the discoloration of gold in the mouth is due to oxidation of the steel worn from pluggers.

232. **Compounds of Mercury:—**

Mercuric chloride or **corrosive sublimate:** Synonyms: corrosive chloride, bichloride of mercury, "oxymuriate" of mercury, perchloride of mercury, deuto-chloride of mercury, Hydrargyri Perchloridum. Official name, Hydrargyri Chloridum Corrosivum.

Theoretical constitution: $HgCl_2$ or mercuric chloride. Mercury as a *dyad.* The molecule is composed of one atom of mercury to two of chlorine; by weight, mercury 200 parts, chlor-

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*Chandler suggests that the discoloration and destruction of amalgam fillings may be due to galvanic action, the ingredients of fillings forming minute batteries, as it were, and destroying one another.

ine 70.8. Molecular weight, 270.8. Percentage of mercury, 73.85.

Preparation (pharmaceutical): made by taking 20 parts of mercuric sulphate and 16 of sodium chloride, reducing each to fine powder, mixing well, adding 1 part of black oxide of manganese in fine powder, triturating thoroughly in a mortar, and subliming:

$$\underset{\text{Mercuric sulphate.}}{HgSO_4} + \underset{\text{Sodium chloride.}}{2NaCl} = \underset{\text{Mercuric chloride.}}{HgCl_2} + \underset{\text{Sodium sulphate.}}{Na_2SO_4}.$$

The manganese oxide is added to oxidize any mercurous salt which may be present in the mercuric sulphate.

Properties: corrosive sublimate occurs as a white, heavy powder, or as heavy, colorless, rhombic crystals or crystalline masses. It has a metallic, acrid taste, an acid reaction, and is a violent poison. Specific gravity, 5.4. It is soluble in 16 parts of cold water, and 2 of boiling, in about 2 of alcohol, and 4 of ether. Its ready solubility in alcohol should be noted, as many compounds of the metals are insoluble in alcohol, or less soluble in it than in water. It is a powerful germicide, an aqueous solution of 1 in 20000 destroying the spores of bacilli in ten minutes. A solution of 1 in 5000 is used as a disinfectant. Aqueous solutions gradually decompose on exposure to light, or in contact with organic substances, such as sugar, gum, extracts, resin, etc. When mercuric chloride is being powdered, it should be kept moist with alcohol to prevent the poisonous dust from rising.

Dental uses: mercuric chloride in 1 in 20000 solution—half a grain in twenty-one fluid ounces of water (metric, 0.032 grammes in 620 C.c.)—is used as an antiseptic. As a germicide, 1 part in 2500 of water; 1 in 5000 as a disinfectant. It is used as a lotion, injection, or gargle.

Toxicology: corrosive sublimate is a powerful, irritant poison, and external application of it has been often attended by fatal results. In poisoning from internal administration, white of egg in milk, or else wheat flour mixed with milk, should be given; vomiting should be encouraged by emetics. White of egg in milk should be administered two or three times daily for some weeks. If salivation is troublesome, gargles of chlorate of potash and of alum should be used. In chronic poisoning, ptyalism is a prominent symptom.

In chronic mercurial poisoning the teeth are said to become brittle.

233. **Mercurous chloride or calomel:—**

Synonyms: mild chloride of mercury, subchloride of mercury, submuriate of mercury, Hydrargyri Subchloridum, protochloride of mercury. Official name, Hydrargyri Chloridum Mite.

Theoretical constitution: Hg_2Cl_2, two atoms of mercury (together bivalent) and two of chlorine; 400 parts by weight of mercury, and 70.8 by weight of chlorine. Molecular weight, 470.8. Its formula is sometimes written HgCl.

Preparation: either (1) by subliming mercuric sulphate 10 parts with sodium chloride 5 parts, 7 parts of metallic mercury having been previously triturated with the moistened mercuric sulphate.

$$HgSO_4 + Hg = Hg_2SO_4;\text{ then}$$
$$Hg_2SO_4 + 2NaCl = Hg_2Cl_2 + Na_2SO_4.$$

Mercurous sulphate and sodium chloride yield mercurous chloride and sodium sulphate. Or (2) by precipitating by hydrochloric acid a solution of 300 grams of mercury in 270 C.c. of suitably diluted nitric acid.

Properties: sublimed calomel is a fine, white powder with very slight tinge of yellow. Tasteless, insoluble in both water and alcohol. Sp. gr., 6.56. Completely volatilized by heat. Precipitated calomel is bulkier than sublimated calomel. Exposed to sunlight, it acquires a grayish tinge becoming partially decomposed into metallic mercury and corrosive sublimate; boiled with water, the same change takes place slowly, and a mixture of it with sugar contains, after some time, an appreciable amount of the mercuric chloride. Mixed with water, it should give no white precipitate with ammonia. Given internally in sufficient quantity it produces salivation; cases are also on record where external application of it has produced salivation.

234. **Mercuric Sulphide.—**

Synonyms: sulphide of mercury, cinnabar, vermilion.

Theoretical constitution: HgS, mercur*ic* sulphide. Molecular weight, 231.7.

Preparation: it occurs as an ore and is then termed *cinnabar*. Made artificially, it is called *vermilion*.

The brilliancy of vermilion depends much on the manner in which it is prepared, and on the purity of the substances used in making it. One method of preparation is to heat to 122°F. the following mixture: mercury, 300 parts; sulphur, 114 parts; potassium hydrate, 75 parts; water, 450 parts. The presence of potassium hydrate facilitates the reaction. The mass, which is at first black, becomes red in the course of several hours; in order to cool it, it is poured into cold water, collected on a filter, washed, and dried. Several kinds of vermilion are found in commerce; the Chinese (made in the dry way by subliming a mixture of sulphur 1 part and mercury 7 parts in small lots) the German, and the French. Vermilion should sublime without residue, if pure.*

235. **Mercuric Iodide.**—

Synonyms: biniodideof mercury, red iodide of mercury, deut-iodide of mercury. Official name, Hydrargyri Iodidum Rubrum.

Theoretical constitution: HgI_2, mercuric iodide. Molecular weight, 453.2.

Preparation: formed when solution of potassium iodide is cautiously added to solution of mercuric chloride,

$$\underset{\text{Mercuric chloride.}}{HgCl_2} + \underset{\text{Potassium iodide.}}{(KI)_2} = \underset{\text{Mercuric iodide.}}{HgI_2} + \underset{\text{Potassium chloride.}}{2KCl.}$$

Properties: occurs as a fine, heavy, crystalline, scarlet-red powder. Nearly insoluble in water. but soluble in hot alcohol, in solution of potassium iodide and of sodium chloride. Is a powerful irritant poison.

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*Shown by heating *dry* in a tube called a *reduction tube.*

236. **Mercurous Iodide.**—

Synonyms: protiodide of mercury, yellow iodide, green iodide.

Theoretical constitution: Hg_2O_2 or HgI (like HgCl).

Preparation: made by triturating together with a little alcohol 127 parts of iodine and 200 of mercury.

$$Hg_2 + I_2 = Hg_2I_2$$

The trituration is continued until there is obtained a green mass, which, after washing in boiling alcohol, is dried.

Properties: mercurous iodide is a green-yellow powder, insoluble in water, alcohol, and ether. Exposed to the action of light, heat, alkaline chlorides or iodides, it is transformed into mercury and mercuric iodide.

237. Tellurium.—

Symbol: Te. *Latin name*: Tellurium. *Equivalence*: II, IV, VI. *Specific Gravity*: 6.18—6.24. *Atomic weight*: 128. *Revised atomic weight*: 127.960. *Electrical state*: — *Fusing point*: little below red heat. *Malleability, ductility*: brittle. *Conducting power* (heat): bad conductor. *Conducting power* (electricity): bad conductor. *Solubility*: soluble in hot sulphuric acid, in hot caustic alkali solutions; attacked by hot nitric acid. *Direct combinations*: hydrogen. oxygen, sulphur, bromine, chlorine, iodine. *Color and appearance*: silver white. *Structure*: crystallizes in rhombohedrons; like As and Sb. *Consistence*: hard and brittle. *Compounds*: tellurides; telluric, tellurous.

Properties and preparation: tellurium is in physical properties a metal, though chemically allied closely to sulphur and selenium. It is found native, though, in Hungary, and in combination with bismuth, lead, gold and silver. It melts at 500° C. When heated in the air it takes fire and burns with a blue flame tinged with green.

238. Sulphur.—

Symbol: S. *Atoms in molecule*: S_2 and S_6. *Atomic weight*: 32. *Molecular weight*: 64. *Density*: of vapor, 32. *Specific gravity*: 2.04. *Weight of one litre of vapor*: 2.86 grammes at 1000° C. *How liquefied*: melts at 114° C (237° F.) *Solubility*: insoluble in water. *Best solvent*: carbon disulphide. Nearly insoluble in alcohol.

Occurrence in nature: occurs free in earth of volcanic regions of Sicily.

How made: distill crude brimstone in retort; vapor conducted into large chamber condenses in form of powder known as *flowers of sulphur*. *Sulphur lotum* is flowers of sulphur which has been washed. Sulphur may be made by precipitation from sulphides by acids.

Properties: affinity for many of the metals, for oxygen, carbon, etc. Forms many compounds. Lemon yellow solid, melting at 234° F., and boiling at 824° F. Brittle, tasteless, odorless. Does not conduct electricity or heat. Precipitated sulphur is almost white in color.

Use in dentistry: flowers of sulphur is used in the manufacture of dental rubbers, as a vulcanizing material. Caoutchouc is heated till soft, then ground with 15 or 20 per cent. of sulphur and subjected to heat, pressure, and moisture.

Sulphurous acid: this substance, H_2SO_3, is made by dissolving sulphurous anhydride, SO_2, in water. [Sulphurous anhydride is made by burning sulphur and collecting the fumes]. Sulphurous acid is an unstable liquid of suffocating odor. Its compounds are *sulphites*. It is used for bleaching purposes, and should always be freshly prepared.

239. Hydrogen Sulphide or Sulphuretted Hydrogen.—

Synonyms: hydric sulphide, sulphydric acid, hydrosulphuric acid, Acidum Hydrosulphuricum.

Theoretical constitution: H_2S, two atoms of hydrogen to one of sulphur; by weight, 16 parts of sulphur to 1 of hydrogen; molecular weight, 34; density, 17.2 · sp. gr., 1.192. Weight of a litre, 1.540.

Origin and manufacture: it is found in volcanic gases, in some mineral springs, and as a result of the decomposition of organic matter containing sulphur, as in the intestines and in teeth. It is usually made by the action of a dilute acid on a sulphide, as for example:

$$\underset{\text{Ferrous sulphide.}}{FeS} + \underset{\text{Sulphuric acid.}}{H_2SO_4} = \underset{\text{Ferrous sulphate.}}{FeSO_4} + \underset{\text{Hydrogen sulphide}}{H_2S}$$

Properties: colorless, fetid gas, combustible, soluble in water, readily recognized by its odor, (that of rotten eggs) valuable as a re-agent, yields precipitates with salts of many metals. Blackens unsized paper saturated with solution of sugar of lead. Poisonous.

Application to dentistry: its odor, if recognized in the breath, indicates that decomposition is going on somewhere in the mouth.

Its action on the various metals and compounds used in dentistry is of the utmost importance. It forms *sulphides* with silver, mercury, lead, copper, bismuth; these sulphides are all dark in color, and the *blackening* observed in amalgam fillings is due to formation of them. It also forms sulphides with arsenic, antimony, cadmium, and tin, but these sulphides are not black; the sulphide of arsenic is yellow, that of antimony orange, cadmium yellow, tin yellow or brown. Sulphuretted hydrogen does not act on *metallic* gold, platinum, palladium, iridium, nor does it blacken iron, cobalt, nickel, manganese, zinc, chromium, or aluminium.

240. **Hydrogen Sulphate or Sulphuric Acid.**—

Synonyms: hydric sulphate, oil of vitriol, dihydric sulphate, vitriol, spirit or essence of vitriol.

Theoretical constitution: H_2SO_4, hydrogen sulphate, an oxacid composed of two atoms of hydrogen, one of sulphur, and four of oxygen; by weight two parts hydrogen, 32 of sulphur, 64 of oxygen. Molecular weight, 98. Its salts are *sulphates*; for example, zinc and sulphuric acid form zinc sulphate.

Preparation: the crude acid is prepared by the action of nitric acid on sulphurous oxide producing sulphuric oxide, which uniting with water forms sulphuric acid. The sulphurous oxide may be made by burning sulphur in air The acid is concentrated by evaporation until a sp. gr of 1.84 is obtained, when it contains about 96 per cent. of pure sulphuric acid.

Properties: colorless, odorless, heavy, oily liquid. Generates heat on addition of water Very caustic. Stains fabrics reddish, and chars organic matter. Stain removed by ammonia. Valuable for drying gases on account of its affinity for moisture. Sp. gr. (pure) 1.848; official, 1.843.

The charring of organic matter by sulphuric acid is due to the fact that it unites with the hydrogen and oxygen in them, leaving behind compounds so carbonaceous that the black color predominates. It corrodes animal tissues. Starch or cellulose boiled with dilute sulphuric acid is converted into glucose, cane sugar into levulose and glucose. Sulphuric acid dissolves most of the metals, but has little action on lead.

Acidum sulphuricum, U. S. P., called the C. P. acid, sp.gr. 1.84. Contains at least 96 per cent. of H_2SO_4.

Acidum sulphuricum dilutum, U. S. P., sp. gr., 1.067; 1 part of sulphuric acid by weight to 9 parts of distilled water.

Acidum sulphuricum aromaticum, about same strength as *dilutum*; contains alcohol, cinnamon oil, and tincture of ginger.

Application to dentistry: in the dental laboratory the acid is used for cleaning metallic plates previous to soldering and after soldering. Its action is more vigorous when it is diluted with water, say with about one-third of water, heat being generated. Its action on hemp paper is to reduce it to pyroxylin, hence it is used in the preparation of celluloid base.

In dental therapeutics, in dilute form, it is used as a local application in various affections of the mouth. It is caustic, and will dissolve thin, carious portions of bone.

Toxicology: the concentrated acid (or the dilute in large doses) is a corrosive poison. Its stain on cloth is usually a dirty brown or reddish brown, and the cloth becomes rotten and damp. It chars wood. Vomited matters will contain a brownish-colored, bloody liquid with free acid. The treatment is to give lime, magnesia, sodium carbonate, preferably in milk. The stomach pump should *not* be used in cases of poisoning from acids. *Burns* from the acid should be treated like those of hydrochloric acid.

241. **Oxygen.**—

Symbol: O. Atoms in molecule: O2. Atomic weight: 16. Molecular weight: 32. Density: 16. Specific gravity: 1.10563, (air = 1). Weight of one litre of gas: 1.43 grammes. How liquefied: pressure of 300 atmospheres and temperature of —140° C. Solubility: water dissolves 3 per cent. of its volume of oxygen gas.

Occurrence in nature: constitutes 20.93 per cent. by volume of atmospheric air. *Combined* with other elements constitutes two-thirds of the entire globe, eight-ninths of all water, one-half the weight of minerals, three-quarters of the weight of animals, and four-fifths of vegetables.

How made: by heating $KClO_3$ and MnO_2:

$$\underset{\text{Potassium chlorate.}}{2KClO_3} = \underset{\text{Potassium chloride.}}{2KCl} + \underset{\text{Oxygen.}}{3O_2}.$$

Properties: has affinity for all elements save fluorine. Is a gas, colorless, odorless, tasteless, transparent. Supports combustion and hence life. *Oxidation* is the term for the combination of substances with oxygen. *Oxidizing agents* are those which part easily with their oxygen as HNO_3, KNO_3, $KClO_3$.

Use in dentistry: a body is called "combustible" when it unites readily with oxygen, heat and light being at the same time liberated. It is the oxygen in the air which supports combustion, and which affords us our artificial heat and light. Substances which burn with difficulty in the air, owing to the latter not being pure oxygen but a mixture of oxygen with nitrogen, will burn in pure oxygen with great readiness. Oxygen blowpipes are those in which the flame is blown with a jet of oxygen; oxyhydrogen blowpipes, those where the hydrogen burns in a stream of oxygen gas, producing a heat which fuses refractory substances such as flint, quartz, etc., and melts the various metals. Some metals, as platinum, which can not be fused in a furnace may be melted by the oxyhydrogen flame.

The Atmosphere.—Under the head of oxygen and nitrogen, air must be considered, which is not a *compound*, but when pure is a *mixture* of 20.93 parts of oxygen by volume to 79.07 of nitrogen. By weight, 23 parts of oxygen to 77 of nitrogen. In the air which we breathe are found small quantities of other substances such as watery vapor, carbon dioxide, ozone, ammonia, nitric and nitrous acids, hydrocarbons, solid particles of dust, sodium chloride, vegetable germs or spores, bacteria, etc., etc. Air in which animals are confined contains some of the organic exhalations from their bodies; in the neighborhood of large cities the air is contaminated by various substances like sulphuretted hydrogen poured forth from manufacturing establishments, furnaces, etc., etc. The air of cities contains more bacteria than that of the country. A cubic metre of Paris air was found to contain

3910 bacteria, as compared with 455 in a cubic metre of country air. Hospital air has been found to contain 40,000 to 79,000 microbes to the cubic metre.

TRIADS.

242. The following is a list of the most important triads:

TABLE 18. IMPORTANT TRIADS.

Bismuth	Triads positive to hydrogen.
Gold	
Antimony	Triads negative to hydrogen.
Boron	
Arsenicum	
Phosphorus	
Nitrogen.	

243. Bismuth.—

Symbol: Bi. *Latin name:* Bismuthum. *Equivalence:* III and V. *Specific gravity:* 9.78—9.80. *Atomic weight:* 207.5. *Revised atomic weight:* 207.5230. *Electrical state:* +. *Fusing point:* 507° F. *Length of bar:* 1.0014. *Weight of cubic ft. in lbs.:* 613.0. *Tensile strength:* 1.5. *Tenacity, malleability, ductility:* brittle. *Conducting power* (*heat*)*:* 11; (11th rank). *Conducting power* (*electricity*)*:* 12; (12th rank). *Resistance to air:* tarnishes in moist air. *Solubility:* soluble in nitric acid; in hot sulphuric acid; in aqua regia. *Direct combinations:* oxygen, chlorine, bromine, iodine, sulphur. *Color and appearance:* white with bronze tint; highly crystalline appearance. *Structure:* crystallizes in rhombohedrons. *Consistence:* hard, brittle. *Compounds:* bismuthous and bismuthic. *Alloys:* fusible metal, pewter, pewterer's solder.

Use in dentistry: for making readily fusible alloys.

Occurrence: this metal occurs native, disseminated through rocks in veins. It is rather rare and is found associated with ores of nickel, cobalt, silver, and copper. Saxony and Bohemia are the chief sources, but it is also found in Transylvania, England, United States, Sweden, Norway, and Peru.

Preparation: to extract the metal the earthy matters containing it are heated and the melted bismuth is collected in suitable receivers.

244. Use in dentistry: the value of bismuth in alloys is due to its low melting point, and to the fact that it *expands* very considerably as it solidifies. Compressed bismuth is lighter than that which has not been so treated. It is more easily vaporized than many metals and boils at moderate white heat. It tends to crystallize from fusion in a remarkable manner, in rhombohedrons of great size and beauty, often mistaken for cubes.

An alloy of tin, lead, and bismuth, is employed for testing the finish of a die. Bismuth is used in the dental laboratory for making readily fusible alloys for dies and counter dies. It lowers the fusing point and imparts hardness when used in alloys.

245. **Compounds of bismuth.—**

Bismuth subnitrate: official name, Bismuthi Subnitras. Formula, $BiONO_3.H_2O$. Molecular weight, 303.5. It is, as will be seen from the formula, the nitrate of the oxide of bismuth. It is called bismu*thyl* nitrate by some authors, also bismuth trisnitrate and oxynitrate. Recent investigators deem it not a fixed and definite compound, but rather a mixture. The chemistry of its preparation is complicated; bismuth is first dissolved in nitric acid, forming the nitrate; next, bismuth subcarbonate is made from the nitrate, by the action of sodium carbonate; the bismuth subcarbonate is next redissolved in nitric acid, to form bismuth nitrate again; finally, the bismuth nitrate is converted into subnitrate by action of ammonia water. Good subnitrate of bismuth is soft, bulky, insoluble in water, soluble in nitric acid. It often contains arsenic as impurity. Treatment in poisoning, as for arsenic. Used in dentistry internally and topically.

246. Alloys of bismuth.—

Fusible alloys are of different compositions, but contain *bismuth.* One is bismuth 2 parts, lead 1 part, tin 1 part; melts at 200° F. Another is 50 bismuth, 12.5 cadmium, 25 lead, 12.5 tin.

Wood's metal, according to Essig, is bismuth 7, lead 6, and cadmium 1. Fuses at 180° F.

247. Gold.—

Symbol: Au. *Latin name*: Aurum. *Equivalence*: I, III. *Specific gravity*: 19.26 to 19.34. Precipitated gold, 19.49. *Atomic weight*: 196.2. *Revised atomic weight*: 196.155. *Electric state*: +. *Fusing point*: 2016° F. *Length of bar*: 1.0015; (8th rank). *Weight of cubic ft. in lbs.*: 1208.6. *Tensile strength*: 9.1. *Tenacity*: 12; (6th rank). *Malleability*: 1; (1st rank). *Ductility* 1; (1st rank). *Solubility*: soluble in aqua regia, free nascent chlorine or bromine, mercury; unaffected by action of single acids, alkalies, or sulphuretted hydrogen. *Direct combinations*: chlorine, bromine, phosphorus, antimony, arsenic, mercury. *Color and appearance*: orange yellow by reflected light, very brilliant, green by transmitted light. Lustre unaffected by high temperatures. *Consistence*: soft. *Compounds*: auric and aurous. *Alloys*: coinage, jewelry, etc., etc. *Structure*: isometric crystals.

248. Occurrence: gold occurs native, that is, uncombined with other metals. It is found almost everywhere, but in most regions in exceedingly small quantities. It occurs in England, Scotland, Ireland, Wales, Hungary, Transylvania, Sweden, Spain, Italy, Siberia, in the Ural Mountains, Japan, Ceylon, Borneo, Thibet, Africa, Brazil, Chili, Peru, Mexico, California, and Australia. The greatest quantities are now found in Africa, California, and Australia. Gold is either in form of *alluvial gold,* that is, washed down by rivers, or *gold-quartz,*the metal being disseminated in thin plates and branch-like fragments, through lumps of quartz-rock.

249. Preparation: *alluvial gold* is extracted by washing the alluvial deposits, the separation of earthy matters being readily effected owing to the high specific gravity of gold (19.3). In California and Australia a wooden trough, six feet long, resting on rockers and called a *cradle*, is used. At the head of it is a grating, on which the alluvial matter is thrown. A stream of water, entering the cradle, flows through and escapes at the lower end, leaving the gold in the trough, but carrying the earthy matters along with it. *Gold-quartz* must first be crushed, either by passing it through rollers or by use of stampers. After pulverization, the gold is dissolved out by mercury. The amal-

gam resulting is then subjected to pressure and excess of mercury thus squeezed out, the remainder being separated by distilling, leaving the gold.

250. **Refined gold** may be obtained in various ways. Chlorine gas has been used as a refining agent, when gold is to be separated from silver. Nitric acid or sulphuric acid may be used. Sulphuric acid converts silver or copper into sulphates, but does not attack gold.

American gold is liable to contain iridium, which may be separated from it by alloying the gold with silver, melting, and either pouring off the gold and silver alloy from the iridium or treating with nitric acid and then with aqua regia.

251. **Chemically pure gold** is obtained from refined gold in various ways: for example, refined gold may be dissolved in aqua regia, excess of acid driven off by heat, then alcohol and potassium chloride added to precipitate any platinum present. The filtered solution is then evaporated over the water bath, the residue dissolved in distilled water, until each gallon contains not more than half an ounce of the chloride, the solution allowed to settle, the supernatant liquid siphoned off, and the gold precipitated in the metallic state by one of the various precipitants, such as oxalic acid or sulphurous anhydride.

252. **Agents used for Precipitating Gold:** gold may be precipitated in the metallic state by various substances.

Oxalic acid precipitates gold from its chloride solution in several forms, spongy or crystalline. Gentle heat favors the process. The equation is:

$$\underset{\text{Auric chloride.}}{2AuCl_3} + \underset{\text{Oxalic acid.}}{3H_2C_2O_4} = \underset{\text{Hydrochloric acid.}}{6HCl} + \underset{\text{Carbon dioxide.}}{6CO_2} + \underset{\text{Gold.}}{2Au}.$$

Sulphurous acid precipitates gold in scales, "not sufficiently coherent or sponge-like for use as a filling material." (Essig).

Ferrous sulphate precipitates gold in form of a light-brown powder.

Phosphorus, when introduced into a heated solution of gold chloride, becomes coated with a film of metallic gold.*

Zinc and other base metals precipitate gold as a brown powder.

Metallic salts, besides ferrous sulphate, and *organic acids* besides oxalic, precipitate gold; the latter best from neutral solutions.

253. **Crystal gold** is obtained by reduction on a platinum pole by the electric current. Plates of pure gold are suspended in a solution of auric chloride. These are connected with a battery, so that, as the solution loses its gold by deposition of the metal, it is re-supplied by the suspended plates.

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*Other non-metals become coated in the same way.

254. **Pure gold** may be **beaten** out so as to present a surface 650,000 times its original area.

Dentists' leaf-gold is usually beaten from fine gold; a very small quantity of any other metal materially injures its malleability. To prepare leaf gold, the metal is first melted in a crucible with a little borax, poured into a mold to form an ingot ¾ inch high, the ingot annealed and hammered with several annealings, until only $\frac{1}{6}$ inch high, passed between rollers until reduced to a thin ribbon, cut into pieces an inch square; 150 of these pieces are piled up, alternately, with pieces of tough paper or vellum 4 inches square rubbed over with a little fine plaster-of-Paris. Twenty vellums are then placed above, and twenty below the pile, which is firmly secured by passing two strong belts of parchment across it. The pile is placed on a heavy block of marble, and beaten with a hammer weighing about 16 pounds. After a time the middle leaves are shifted to the outside, and the beating continued, until the leaves are nearly the size of the vellums, when they are taken out and cut into 4 squares measuring an inch each way. They are then made into packets, with *gold beaters' skins* in alternate layers, and beaten with a ten-pound hammer. When they are 4 inches square they are cut into 4 equal squares, again made into packets with gold-beaters' skin, and hammered again with a seven-pound hammer to about 3½ inches square. They are then lifted off the skin, cut down to one size, and packed between leaves of books. There are, usually 25 leaves in a book, each of which is on an average $\frac{1}{282,000}$ of an inch thick. They are now usually beaten by mechanical power. These leaves show, when held up to the light, a fine green color. Rendered non-lustrous by heat, the color is ruby-red. Weak solution of potassium cyanide slowly dissolves them. *Fine gold, i. e.*, that which is perfectly free from impurities, is about as soft as lead. Its fineness is expressed by use of the term *carats*: gold coin containing 22 parts gold to 2 of alloy is said to be 22 carats fine; pure gold is 24 carats fine.

255. **Cohesive gold,** used for filling operations, may be obtained by heating foil to redness, by which the cohesiveness, which is greatly diminished by compression of the fibres in beating, is restored.

256. **Corrugated gold,** according to Essig, is prepared by placing the sheets of gold between leaves of a particular kind of unsized paper and tightly packing them in iron boxes, which are exposed to a temperature sufficiently high to carbonize the paper. On cooling, the gold is found to be exceedingly soft, non-cohesive, and to present a peculiarly corrugated condition of surface.

Use in dentistry: gold is used by dentists in fine powder, and in foil for filling purposes. It is an ingredient of some amalgam alloys, of alloys for bases for artificial dentures, and of solders. In minute division it is used as a coloring matter for artificial teeth.

Gold containing palladium or platinum is *lighter* in color; if it contains copper it is *redder* in color. Lead or antimony makes gold brittle, even if in minute proportion. Silver whitens the color of gold.

TABLE 19.—EFFECT ON GOLD OF ALLOYING.

Malleability: impaired; seriously by As, Sn, Sb, Bi, Pb. *Ductility:* diminished. *Hardness:* increased. *Tenacity:* usually increased. *Specific gravity:* varies; with Zn, Sn, Bi, Sb, Co, sp. gr. greater than mean of components; with Ag, Fe, Pb, Cu, Ir, Ni, less than the mean. *Fusibility:* usually increased.

Gold and Copper have great affinity for one another and may be alloyed in all proportions. Copper diminishes the ductility of gold when it enters into the combination in a proportion over 10 to 12 per cent. *Pure* copper must be used for alloying. *Gold and Silver* readily mix but do not appear to form true combinations. One-twentieth of silver will modify color of gold. *Yellow Gold, Green Gold,* and *Pale Gold* are alloys of gold and silver. Alloys of gold, copper, silver and palladium are brownish-red in color, hard as iron, and never rust. *Nurnberg Gold* is an alloy of copper 90 parts, gold 2.5, add aluminium 7.5; it has the color of gold and remains unchanged.

The melting of metals constituting alloys is brought about by use of graphite crucibles, the gold being melted first. After it is entirely melted, it is heated as strongly as the furnace permits and the other metals added in as small pieces as practicable. The mixture is stirred with an iron rod sharpened on the point and previously heated to redness. When it is desired to toughen gold, use as a flux the following: one part charcoal to one sal-ammoniac adding to the gold *just before melting.*

Phosphor-iridium, as it is called, has some remarkable properties. It is prepared by Holland's process, in which iridium ore is heated in a Hessian crucible to a white heat, and, after phosphorous, has been added, the heating is continued for a few minutes. It has the power more than any other metal of retaining lubricants. It is slightly magnetic when alloyed with iron and is not attacked by acids or alkalies. The alloy with iron (50 per cent or less), is not affected by the best file.

[For further consideration of the subject of alloys the reader will find it useful to consult special works, among these may be mentioned Krupp's book which has lately been translated into English with additions by Brannt].

TABLE 20.—SPECIFIC EFFECTS OF CERTAIN METALS ON GOLD WHEN ALLOYED WITH IT.

METAL.	EFFECT.
Zinc:	forms hard, white, brittle alloy (when in equal proportions); does not unite so intimately as lead or tin.
Tin:	renders gold intractable to remarkable degree. The combination is attended by contraction(?).
Lead:	renders gold intractable.*
Antimony:	renders gold intractable. One part in 1920 too brittle for successful lamination.
Bismuth:	in almost inappreciable quantities renders gold intractable, as 1 in 1920.
Iron:	does not sensibly affect malleability, in the proportion of 1 to 11.
Mercury:	dissolves gold, and combines with it at all temperatures, but more readily when gold is in state of fine division and when heat is applied.
Arsenic:	malleability of gold affected, even by vapor of arsenic. The color of the gold may not be changed, even when it has become brittle.
Silver:	renders gold more fusible, increases hardness, does not materially affect malleability, makes color lighter.
Palladium:	equal parts: gray color, less ductile. 4 gold, 1 palladium: white, hard, ductile. Merest traces of palladium render gold brittle.
Copper:	hardens and toughens gold, gives deeper color, renders it capable of receiving rich polish, does not practically impair its malleability.
Platinum:	in small proportions hardens, and renders more elastic, without impairing malleability. Makes color pale and dull, if equal weights. Excess of platinum renders alloy infusible in blast furnace.

*A minute quantity of lead will color gold brownish, render it brittle, and reduce its tenacity from resistance to 18 tons per square inch to only 5 tons.

TABLE 21.—APPEARANCE OF GOLD ALLOYS.

ALLOY METAL	COLOR, ETC.
Tin:	Light colored, very brittle.
Lead:	Dull colored, brittle.
Platinum:	Grayish or dull colored, malleable, tough, elastic.
Zinc:	Unequally malleable, brittle in spots.

257. **Gold Alloys and Alloys Resembling Gold:** gold coinage: gold 90, copper 10. Gold jewelry and plate: gold 75 to 92, copper 25 to 8.

Green gold: gold 75, silver 25.

Red gold: gold 75, copper 25.

Dutch gold is merely a species of brass, usually sold in very thin leaves or sheets, It is formed of 11 parts copper with 2 of zinc.

Fool's gold is iron pyrites, a sulphide of iron.

Oreide is a species of brass.

Pinchbeck gold is a kind of brass; *Mannheim gold* and *Similor* are also brass.

Talmi gold is 90 copper, to 10 aluminium, as is aluminium bronze.

Mosaic gold is a definite chemical compound, SnS_2, stannic sulphide, made by heating in a flask at low red heat, 12 parts tin, 6 mercury, 6 ammonium chloride, and 7 flowers of sulphur; everything sublimes except the stannic sulphide which remains in the bottom of the flask. [The name "Mosaic gold" is sometimes given to substances other than stannic sulphide].

Gold base plate: different formulas are in vogue, but the constituents are in the main gold, copper, and silver; some contain platinum as well. 18 carat gold plate is made by two formulas: No. 1 contains 18 dwts. pure gold, 4 fine copper, 2 fine silver; No. 2 is 20 dwts. gold coin, 2 fine copper, 2 fine silver. Gold plate, 22 carats fine, is 22 dwts. pure gold, 1 dwt. fine copper, 18 grains silver, 6 grains platinum.

Gold plate for clasps, wires, etc., etc.: gold used for this purpose should contain sufficient platinum to render it firmer and more elastic. A 20 carat alloy for such purposes is made by 2 formulas: No. 1 is 20 dwts pure gold, 2 fine copper, 1 fine silver, 1 platinum; No. 2 is 20 grains coin gold, 8 grains fine copper, 10 grains fine silver, 20 grains platinum.

Gold solder is 22.2 copper, 66.6 gold, 11.1 silver.

258. Compounds of Gold.—

Auric Chloride or the terchloride of gold, $AuCl_3$. Prepared by dissolving gold in aqua regia, using gentle heat. The solution evaporated to dryness, over the water bath, yields ruby-red, prismatic crystals, deliquescent, soluble in water, alcohol, ether, and of disagreeable, styptic taste; auric chloride stains the skin purple, but the stain is readily removed by potassium cyanide. It is an escharotic and disinfectant, and dissolved in ether is used in dentistry as an obtunding agent. Solutions should be kept in glass stoppered bottles, as the gold tends to deposit from solutions. It is a poison.

Auric Oxide, Au_2O_3, is prepared from the terchloride by digesting magnesia in it, by which magnesium aurate is formed. The latter is decomposed by nitric acid and the residue auric oxide, when dried, is a dark brown, easily decomposing powder.

Purple of Cassius is a compound of gold, tin, and oxygen.

It may be prepared by treating gold chloride with solution of stannous chloride, or by adding stannous chloride to a mixture of stannic chloride and auric chloride, as follows: 7 parts of gold are dissolved in aqua regia, and mixed with 2 parts of tin also dissolved in aqua regia; this solution is largely diluted with water, and a weak solution of 1 part tin in hydrochloric acid is added drop by drop, till a fine purple color is produced. The purple of Cassius remains suspended in water, but subsides gradually, especially if some saline substance be added. Purple of Cassius is a brown, reddish purple or black powder soluble in ammonia. It is used as a coloring for porcelain. Its composition is doubtful, probably $Au_2O.SnO_2.SnOSnO_2.4H_2O.$, that is a double stannate of aurous oxide and stannous oxide.

259. Antimony.—

Symbol: Sb. *Latin name:* Stibium. *Equivalence:* III and V. *Specific gravity:* 6.72. *Atomic weight:* 120. *Revised atomic weight:* 119.955. *Electrical state:* —. *Fusing point:* 842° F. *Length of bar:* 1.0011; (11th in rank). *Weight of cubic feet in lbs:* 419.5. *Tensile strength:* 0.5. *Tenacity, malleability, ductility:* brittle. *Conducting power* (*heat*)*:* 10; (10th rank). *Conducting power* (*electricity*)*:* 46; (silver = 1000); (11th rank). *Resistance to air, etc:* takes fire at red heat, but scarcely tarnishes in air. *Solubility:* in boiling hydrochloric acid to which a little nitric has been added: in fine powder, dissolved by solutions of higher sulphides of Na and K. *Direct combinations:* with chlorine, sulphur, oxygen, bromine, iodine. *Color and appearance:* brilliant bluish-white, like zinc. *Structure:* rhombohedral crystals like arsenic and red phosphorus; there is also an amorphous form. *Consistence:* hard, brittle. *Compounds:* antimonous (III) and antimonic (V). *Alloys:* Britannia metal, pewter, type metal, Babbitt's anti-friction metal.

Occurrence: antimony is found both native and combined. It occurs free in Germany. Gray antimony ore, the *sulphide*, Sb_2S_3, occurs in England, France, Hungary, and Borneo. An *oxide* is found in Algeria. *Red antimony*, which is a compound of the oxide and sulphide is found in Tuscany.

Antimony is also found in the United States and in Mexico.

Preparation: the principal ore (stibnite), which is a sulphide, yields regulus of antimony (metallic antimony) when melted with metallic iron. A purer article is obtained by roasting the crushed ore, converting it into an oxide; the latter is then fused with charcoal.

Properties: the metal is not attacked by hydrochloric acid. Nitric acid converts it into a white, insoluble oxide. Aqua regia dissolves it, forming a chloride called "butter of antimony"; water converts this chloride into an oxychloride.

$$\underset{\text{Autimonous chloride.}}{SbCl_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Antimony oxychloride.}}{SbOCl} + \underset{\text{Hydrochloric acid.}}{2HCl.}$$

This equation illustrates the formation of an oxychloride.

260. Uses in dentistry and the arts: antimony is valuable as a constituent of alloys: to give hardness to other

metals, and to cause them to expand and completely fill moulds on cooling.

It can be distinguished from other metals by its brittleness, crystalline structure, and hardness; it can easily be pulverized, and breaks from a slight tap of a hammer. It is not deemed a metal by some, being classed with arsenic and phosphorus, rather than with the metals. It burns at red heat, with odor of garlic and with white fumes, suggesting arsenic. The amalgam with mercury is soft and decomposed by contact with air or water, antimony separating. It has been used in dental amalgam alloys.

261. Boron.—

Symbol: B. *Latin name:* Boron. *Equivalence:* III. *Specific gravity:* 2.63. *Atomic wt.* (*approx.*)*:* 10.9. *Atomic wt.* (*revised*)*:* 10.941. *Electrical state:* —. *Properties:* amorphous, greenish powder, soluble in melted aluminium. Boron is not used in dentistry.

262. Hydrogen Orthoborate or Boracic Acid.—

Synonyms: boric acid, orthoboric acid, sedative salt of Homberg. Official name, Acidum Boricum.

Theoretical constitution: orthoboric acid, H_3BO_3, graphically, $B'''(HO)_3$. Composed of three atoms of hydrogen, one of boron, and three of oxygen. By weight, 3 parts of hydrogen, 11 of boron, and 48 of oxygen. Molecular weight, 62.

Preparation: boracic acid is made from borax by adding hydrochloric acid to a hot solution of the former, which causes a precipitate of boracic acid:

$$\underset{\text{Borax.}}{Na_2B_4O_7} + \underset{\text{Hydrochloric acid.}}{2HCl} + \underset{\text{Water.}}{5H_2O} = \underset{\text{Boric acid.}}{4H_3BO_3} + \underset{\text{Common salt.}}{2NaCl.}$$

Properties: brilliant, white, shining, odorless, six-sided plates, greasy to the touch, slightly soluble in cold water 1 part in 25, soluble in 3 parts hot water, soluble in 6 parts alcohol, soluble in glycerine. Specific gravity, 1.517 at ordinary temperatures. Is a powerful antiseptic. Saturated with alcohol, burns with a green flame. Its solutions are but faintly acid; turmeric paper moistened with a solution of this acid becomes reddish-brown on drying. Heated with glycerine forms *boroglyceride*. (See Boroglyceride under head of Glycerine).

Use in dentistry: boracic acid is used for various antiseptic purposes. Combined with sodium sulphite it has been used as a bleaching agent for discolored teeth. (See Boroglyceride).

263. **Arsenic.**—.

Metallic arsenic is not used in medicine or dentistry. One of its compounds, *arsenous oxide* or *anhydride*, is of importance, and the term **arsenic** is usually applied to this substance.

Arsenous Anhydride.—

Synonyms: arsenious acid, arsenious anhydride, white arsenic, ratsbane, white oxide of arsenic, Arseniosum Oxidum. Official name, Acidum Arsenosum.

Theoretical constitution: As_2O_3, arsenous oxide, two atoms of arsenic to three of oxygen, by weight 150 of arsenic to 48 of oxygen. Molecular weight, 198. Composed of 75.76 per cent. As and 24.24 per cent. O. [The molecule of vitreous arsenic is thought to be represented by the formula As_4O_6].

Preparation: arsenous oxide occurs in nature as arsenic "bloom," a term derived from the Saxon *bloma*, a lump. It is obtained by roasting ores of other metals containing it in a current of air. The arsenous oxide in the roasting process volatilizes and is condensed in suitable receiving chambers as a white powder.

Properties: it is found in the form of a fine, white, heavy powder or in glassy looking lumps. The powder is somewhat gritty, odorless, tasteless, permanent in air. Condensed from sublimation at 752° F., it is a transparent, vitreous mass, sp. gr., 3.738. When condensed at temperature slightly less, crystallizes in right rhombic prisms. Vitreous arsenic, on keeping, gradually becomes opaque and crystalline. When condensed at 392° F., it occurs in octahedral crystals, sp. gr., 3.69. This form is also obtained on evaporating a saturated aqueous solution. Vitreous arsenic is slightly more soluble than the opaque; 100 parts boiling water dissolve 12 parts of the vitreous; on cooling, about three parts are left in solution. Arsenic is soluble in hot HCl, in solutions of alkalies and of tartaric acid. Dissolved in acids it forms a binary compound of arsenic, as, for example, arsenous chloride when dissolved in hydrochloric acid. Dissolved in alkalies it acts as the negative element forming arsenites of the alkali metals, as K_2HAsO_3, potassium hydro-arsenite.

Locally, it acts as an escharotic, first destroying the vitality of organic structure, decomposition then ensuing.

It is a powerful antiseptic, retarding putrefaction to a marked degree.

Uses in dentistry: arsenous oxide is used to destroy the vitality of tooth pulps; it has also been used as an obtunding agent. It kills a tooth by causing irritation; there is increased flow of blood to the parts, the arteries are enlarged so that there is no return of blood through the veins, hence strangulation at apex of the tooth.

Toxicology: arsenic in doses of from one to two grains is a powerful poison. It is poisonous also even when locally applied. There is danger of absorption when arsenic is applied to the teeth.

The treatment of poisoning by this agent, when administered internally, is to provoke or promote vomiting by giving large quantities of hot milk and water or emetics, as sulphate of zinc (5 grains repeated in 15 minutes) or mustard (teaspoonful or two of ground mustard in water); subcutaneous injection of apomorphine hydrochlorate in doses of $\frac{1}{15}$ to $\frac{1}{10}$ of a grain will speedily bring about emesis. The *antidote* to arsenic is ferric hydrate, conveniently made by adding Aqua Ammoniæ to Tincture of Ferric Chloride. A brownish substance is formed which, separated from the liquid, may be given *ad lib.* The antidote should be given *after* vomiting has been brought about. Finally bland liquids, such as milk and eggs, should be given; sugar and magnesia in milk are highly recommended. When arsenic has been absorbed from local application it is of course useless to give emetics, etc., the only treatment possible being that of treating the symptoms as they appear, promoting elimination by diuretics as potassium nitrate, etc., etc.

Note: in making the antidote for arsenic let the precipitate drain on a wetted muslin strainer until most of the liquid has run off, gather up the cloth, press it with the hands until no more liquid can be squeezed out, then add water and administer. The official hydrate is made from solution of normal ferric sulphate.

264. **Phosphorus.**—

Symbol: P. *Atoms in molecule*: P_4. *Atomic weight*: 31. *Molecular weight*: 124. *Density*, of vapor: 62. *Specific gravity*: yellow 1.83, red 2.14. *How liquefied*: the yellow melts at 111° F. under water. *Solubility*: yellow is insoluble in both water and alcohol, but soluble in carbon disulphide, while the red is insoluble in the latter.

Occurrence in nature: does not occur native, but as phosphates, etc.

How made: from ash of burnt bones by treating with sulphuric acid, and heating with charcoal.

Properties: yellow is translucent, waxy, shines in the dark, readily oxidized, taking fire at 140° F. and must be kept under water. Becomes covered with red or white coat on exposure to light; poisonous. Red does not inflame readily, and is not poisonous. Phosphorus combines with most elements except C, N, and H, and reduces some metallic salts as of Cu, Ag.

Use in dentistry: phosphorus is of value as a deoxidizer in fusing refractory metals such as iridium, nickel, etc.

Toxicology. Carious teeth, swollen and inflamed gums, finally necrosis of the jaws, usually of the lower one, are often noticed in those who work in match factories. Most cases of phosphor-necrosis originate in unsound teeth or where the gums are kept away from the teeth by tartar.

About $\frac{1}{70}$th grain of phosphorus is contained in a match head. In the dipping and packing room the matches are handled the most, and in damp weather the fumes are given off so that no workman with carious teeth should work in these rooms. Alkaline mouth-washes should be used, and workmen should keep their hands clean and not eat in the work rooms. Good ventilation should be secured.

The use of *red* phosphorus instead of yellow is to be advised, as the former is not poisonous.

265. **Anhydrous Phosphoric Acid,** so called, is phosphoric anhydride, *i. e.*, phosphoric oxide or phosphorus pentoxide, P_2O_5, and is formed by the rapid burning of phosphorus in air or in oxygen. It is very deliquescent. It forms with water a solution of the glacial acid, HPO_3.

$$\underset{\text{Phosphoric anhydride.}}{P_2O_5} + \underset{\text{water.}}{H_2O} = H_2P_2O_6 = \underset{\text{Glacial phosphoric acid.}}{(HPO_3)_2 \text{ or } 2HPO_3.}$$

266. Hydrogen Phosphate or Phosphoric Acid.—

There are several kinds of phosphoric acid, but we shall here speak of two only:—

1. **Common Phosphoric Acid**.—[*]

Synonyms: tri-basic phosphoric acid, tri-hydrogen phosphate; (it is sometimes called ortho-phosphoric acid).

Theoretical constitution: H_3PO_4: may be regarded as mono-meta-phosphoric acid, *i. e.*, the acid obtained by removing one molecule of water from ortho-phosphoric[*] acid, Ortho-phosphoric acid has for its formula H_5PO_5, which formula minus H_2O becomes H_3PO_4, rationally $(PO)'''(HO)_3$. The acid contains, then, three atoms of hydrogen, one of phosphorus, and four of oxygen; by weight 3 parts hydrogen, 31 of phosphorus, 64 of oxygen. Molecular weight, 98. Its salts are *phosphates.*[**]

Preparation: made by boiling phosphorus in dilute nitric acid, and evaporating to a syrupy liquid.

Properties: syrupy liquid, which, if evap-

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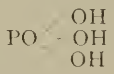
[*] Phosphoric acid is tri-basic, and, therefore, three hydroxyl groups are assumed to be present in it, hence the rational formula is $PO(HO)_3$. The graphic formula is probably



$$PO\begin{array}{l}\;\;OH\\ - OH\\ \;\;OH\end{array}$$

[**] Called often ortho-phosphates.

orated spontaneously over sulphuric acid, gives hard, transparent, prismatic crystals readily deliquescing. It does not coagulate albumin.

Acidum Phosphoricum, U. S. P., is a colorless, strongly acid liquid of sp. gr. 1.347. It does not fume and should not contain arsenic. It contains 50 per cent. acid to 50 of water. It is odorless.

Acidum Phosphoricum Dilutum, U. S. P., contains 10 per cent. of H_3PO_4, and is composed of 1 part of Acidum Phosphoricum, to 4 of distilled water.

Syrupy phosphoric acid: H_3PO_4, syrupy phosphoric acid, contains on an average, about 66 per cent. of H_3PO_4, and as sold by manufacturing chemists is not the glacial acid but merely a strong phosphoric acid of syrupy consistence. It is of different strengths according to the makers.

2. Glacial Phosphoric Acid.

Synonyms: mono-hydrogen phosphate, meta-phosphoric acid, di-meta-phosphoric acid, mono-hydrated phosphoric acid.

Theoretical constitution: HPO_3 or di-meta-phosphoric acid, *i. e.*, derived by subtracting two molecules of water from ortho-phosphoric* acid. $H_5PO_5 - 2H_2O = HPO_3$. Its molecule, therefore, consists of 1 part hydrogen, 1 part

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* Not what is usually called ortho-phosphoric acid, but the maximum hydroxide or normal acid of phosphorus.

phosphorus, and 3 parts oxygen; by weight 1 part hydrogen, 31 of phosphorus, and 48 of oxygen. Molecular weight, 80.

Preparation: it may be made by heating the ordinary acid, which loses a molecule of water and becomes the glacial acid.

$$\underset{\text{Phosphoric acid.}}{H_3PO_4} = \underset{\text{Glacial phosphoric acid.}}{HPO_3} + \underset{\text{Water.}}{H_2O}$$

It is sometimes made by calcining ammonium phosphate, but the product is then likely to contain ammonia.[*]

Properties: on cooling the platinum vessel in which the common acid, H_3PO_4, has been heated to redness, a vitreous mass, HPO_3, is seen, hard, colorless, transparent, not crystallizable, readily soluble in water, forming an intensely acid solution which is slowly converted into the ordinary acid. It coagulates albumin. In commerce it comes in the form of sticks or brittle cakes, odorless, sour to the taste and hygroscopic, more or less contaminated with pyro-phosphoric acid, and containing phosphates of sodium, calcium, magnesium, etc. Solution of the common acid in water when heated becomes first pyro-phosphoric acid, then (at red heat) glacial phosphoric acid.

Use in dentistry: the dilute acid is used as

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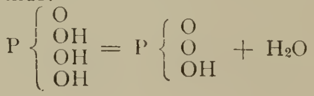
[*] The formation of meta-phosphoric acid from ordinary phosphoric acid is represented thus:—



$$P\begin{cases} O \\ OH \\ OH \\ OH \end{cases} = P\begin{cases} O \\ O \\ OH \end{cases} + H_2O$$

a local application in caries, and has been given internally. It is liable to fungoid growth of a tenacious or mucoid character, diffusible, and of a yellowish-gray color; it loses strength on development of this growth, its specific gravity falling often below 1055.

TABLE 22—PHOSPHORIC ACIDS.

COMMON PHOSPHORIC ACID.	GLACIAL PHOSPHORIC ACID.
H_3PO_4. Called by some ortho-phosphoric acid.	HPO_3. Called metaphosphoric acid.
Syrupy liquid.	Solid.
Evaporated spontaneously yields prismatic crystals.	Does not crystallize, but forms an amorphous, glassy mass, coagulates albumin.
Does not coagulate albumin.	Slowly turns into the common acid.
Strong acid is called syrupy phosphoric acid.	Is volatile at red heat, and when boiled with water is converted into the common acid.
The official acid (50 per cent.) heated above 392° F. is converted gradually into the glacial acid and pyrophosphoric acid.	
Little or no precipitate with solution of silver nitrate.	Abundant precipitate with solution of silver nitrate.

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* Rollins obtains it as a soft solid by the process given in section 201. It is said (*Zeitschrift f. anal. Chemie.*, VI. 187,) that really pure phosphoric acid makes a soft glutinous mass when heated, but on heating strongly for seven or eight minutes after the acid has begun to go off in white fumes a hard mass is obtained.

267. Nitrogen.

Symbol: N. *Atoms in molecule*: N_2. *Atomic weight*: 14. *Molecular weight*: 28. *Density*: 14. *Specific gravity*: 0.971, (air = 1). *Weight of one litre of gas*: 1.256 grammes. *Solubility in water*: 1 part of water dissolves 0.025 part by volume of nitrogen.

Occurrence in nature: nitrogen constitutes 79.07 per cent. by volume of atmospheric air.

How made: obtained from air by burning phosphorus in a confined space.

Properties: affinity for magnesium, borum, vanadium, titanium. Very inert chemically. Colorless, tasteless, odorless, transparent gas. Incombustible and does not support combustion. In combination found in nitroglycerine, poisonous alkaloids as strychnine, and in albuminoid substances.

268. Ammonia.

Theoretical constitution: H_3N or NH_3, one atom of nitrogen to three of hydrogen; by weight, 14 parts nitrogen to 3 of hydrogen. Molecular weight, 17; density, 8.5; specific gravity, 0.59 (air = 1).

Origin and method of preparation: it is a product of the putrefaction of animal matters. Artificially it may be prepared by heating sal-ammoniac and quicklime.

Properties: colorless gas, pungent odor, strongly alkaline, extraordinarily soluble in water, 1149 volumes of the gas in 1 of water. Very volatile.

269. Nitrogen Monoxide or Laughing Gas.

Synonyms: hyponitrous oxide, nitrous oxide, nitrogen protoxide.

Discovered by Priestly in 1776; first came into notice as anæsthetic in 1863; first used in dentistry by Wells of Hartford, in 1845.

Theoretical constitution: N_2O, hyponitrous oxide or nitrogen monoxide; univalent nitrogen with bivalent oxygen—two atoms of nitrogen with one of oxygen; composition by volume, 2 parts of nitrogen to 1 of oxygen; by weight, 28 parts of nitrogen to 16 of oxygen. Molecular weight, 44. Density, 22. Sp. gr., 1.527. Weight of a litre, 1.98 gramme.

Preparation: made by *cautiously* heating ammonium nitrate, which is decomposed, yielding laughing gas and water:

$$\underset{\text{Ammonium nitrate.}}{NH_4NO_3} = \underset{\text{Nitrogen protoxide.}}{N_2O} + \underset{\text{Water.}}{2H_2O}$$

Properties: colorless, odorless, sweetish-tasting gas of neutral reaction, soluble in water 100 volumes of which dissolve 78 volumes of the gas, more soluble in alcohol. Supports combustion, the heat of burning bodies decomposing it and setting oxygen free. Condenses to a colorless liquid under pressure of 50 atmospheres and temperature of 45°F., specific gravity of the liquid, 0.908. Boiling point,—126°F., freezing point,—150°F.

When inhaled it causes exhilaration, anæsthesia, and finally asphyxia. It dissolves in the blood without entering into combination with it, and its action seems to be due partly to its excluding air and partly to its direct effect on the nervous system. The anæsthesia produced by it is of short duration and without an excitement stage. The sensation is usually one of agreeable intoxication; disagreeable after-effects are generally wanting. Lyman holds that the anæsthesia is a narcosis, but Wallian thinks with Ziegler that it is not merely an asphyxiating agent.

Use in dentistry: as a temporary anæsthetic. Out of 121, 709 administrations of the gas recorded from 1863 to 1881, there was not one which resulted fatally, nor produced serious ill-effects.

For anæsthetic purposes the nitrogen monoxide is liquefied and sold in wrought-iron cylinders provided with a stop-cock, on turning which the liquid is vaporized, and may be collected in rubber gas bags or small gasometers. When the gas is to be administered it may be inhaled from the gas bag or gasometer through a rubber tube and mouth-piece provided for the purpose. The advantages of the cylinder are that the gas may be kept for any length of time without loss of strength or volume.

270. **Hydrogen Nitrate or Nitric Acid.**—

Synonyms: hydric nitrate, Glauber's spirits of nitre, spirits of nitre, fuming spirits of nitre, aqua fortis, azotic acid. Official name, Acidum Nitricum.

Known to the Arabs in the 9th century.

Theoretical constitution: HNO_3, an ox-acid whose molecule is composed of 1 atom of hydrogen, 1 of nitrogen, and 3 of oxygen. By volume it consists of 1 part of hydrogen, 1 of nitrogen, and 3 of oxygen. By weight, 1 part of hydrogen, 14 of nitrogen, 48 of oxygen. Molecular weight, 63.

Preparation: made by decomposing potassium nitrate (nitre) with sulphuric acid:

$$\underset{\text{Potassium nitrate.}}{KNO_3} + \underset{\text{Sulphuric acid.}}{H_2SO_4} = \underset{\text{Potassium acid sulphate.}}{KHSO_4} + \underset{\text{Nitric acid.}}{HNO_3}$$

Properties: the pure acid is a colorless, fuming, corrosive, rather heavy, strongly acid liquid of sp. gr. 1.52. The official acid has a specific gravity of 1.42, and contains 69.40 per cent. of absolute acid to 30.60 per cent. of water. Exposed to air and light it is decomposed and becomes yellow. Nitric acid dissolves mercury, copper, silver, and bismuth, especially when warmed; *dilute* nitric acid dissolves iron, lead, and silver. Antimony and tin are attacked by the acid and oxidized, but not dissolved. Nitric acid has no action on gold, platinum, or iridium. It attacks and destroys vegetable and animal tissues, producing a yellow discoloration, especially on animal matters and products. Its stain on clothing can not readily be removed but ammonia prevents destruction of the cloth. Its salts are *nitrates*.

Acidum Nitricum Dilutum is one part of the official acid to six of distilled water. Its sp. gr. is 1.059, and it contains ten per cent. of HNO_3.

Use in dentistry: mixed with four parts of hydrochloric acid, it is used to dissolve gold. [The official mixture is four parts nitric acid by weight, to 15 of hydrochloric acid, and is called Acidum Nitrohydrochloricum].

Nitric acid is also used to dissolve zinc oxide in the preparation of the oxyphosphate cement. It is used in dental medicine as a caustic. It attacks the teeth, and hence, when used in any form in the mouth, care should be taken that it does not touch other tissues than the ones to which it is applied.

Toxicology: nitric acid is a violent poison turning the mucous membranes a bright yellow and then corroding them. The *antidotes* are alkalies or magnesia suspended in water, sodium bicarbonate in water, soap and water; bland liquids should be given and the patient's strength sustained. Burns should be treated like those from hydrochloric acid. (See section 181).

TETRADS.

271. The following is a list of important tetrads:

TABLE 23. TETRADS.

Aluminium.[*]	Tetrads positive to hydrogen.
Cerium.[*]	
Tin.	
Palladium.	
Platinum.	
Iridium.	
Silicon.	Tetrads negative to hydrogen.
Titanium.	
Carbon.	

272. **Aluminium.**—

Symbol: Al. *Latin name*: Aluminium or Aluminum. *Equivalence*: IV and $(Al_2)^{VI}$. *Specific gravity*: 2.50 to 2.67. *Atomic weight*: 27. *Revised atomic weight*: 27.009. *Electrical state*: +. *Fusing point*: 1292°F. *Length of bar*: etc.: 1.0022 (5th rank). *Wt. of cubic ft. in lbs.*: 166.8. *Tensile strength*; 12. *Tenacity*: like silver. *Malleability*: like silver and gold. *Ductility*: 7; (7th rank). *Conducting power* (*heat*): 4; (4th rank). *Conducting power* (*electricity*): better than that of iron. *Resistance to air*, etc.: tarnishes very slowly; not affected by sulphuretted hydrogen. *Solubility*: soluble in hydrochloric acid, and in aqueous solutions of alkaline hydrates; resists cold acids, mineral and vegetable (except hydrochloric). *Direct combinations*: with many metals and non-metals. Does not oxidize; is not attacked by sulphur compounds. *Color and appearance*: bluish white, brilliant. *Structure*: octahedral crystals. *Consistence*: hard as zinc. Very sonorous. *Compounds*:

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[*] Both aluminium and cerium appear to be trivalent, but are really quadrivalent like the ferric compounds.

two atoms with equivalence of six like ferric salts. *Alloys*: aluminium bronze, solder, etc. Does not amalgamate. *Use in dentistry*: for making "plates."

Occurrence: the great mass of the earth is composed of aluminium, in combination with silicic acid, in silicated rocks, such as granite, feldspar, basalt, slate, mica, etc., and in the various modifications of clay. Every variety of clay contains it in quantity varying from 12 to 20 per cent.* The minerals known as corundum, ruby, sapphire, and emery are *aluminium oxide* in crystallized state.

Preparation: the usual process for obtaining aluminium has been to decompose the chloride by metallic sodium:

$$Al_2Cl_6 + 6Na = 6NaCl + 2Al$$

It will be noticed that aluminium acts as a pseudo-triad, $(Al_2)^{vi}$, in the chloride of aluminium.

The process is that of Deville. At the works of Morin in Paris, ten parts sodio-aluminium chloride, five parts of fluorspar or cryolite, and two parts of sodium, are mixed together and thrown upon the hearth of a reverberatory furnace, previously heated to full redness. A violent action takes place, great heat is evolved, and the liquefied mass of slag and metal collects at the back of the furnace. The latter is drawn off and cast into ingots.

Metallic sodium is very troublesome to handle, and its cost has been so high that the price of aluminium has been, in consequence of the difficulty and expense of the process, higher per troy ounce than that of silver. Recent improvements in process have been made in this country; one is to reduce the aluminous materials with sodium vapor, and to use the double fluoride of aluminium and sodium, or double chloride of aluminium and sodium, made at reduced cost; another is to prepare the

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* The sapphire and ruby contain also a little oxide of iron; emery contains oxide of iron and also silica.

metal electrolytically;* another to reduce the aluminous earths with zinc ore. The price will probably be greatly reduced before long. Metallic magnesium has been reduced to one-fifth of its previous price, and, as this substance also is used in manufacture of aluminium, it will, probably, affect the price of the latter.†

273. Value in dentistry and in the arts:‡ aluminium is remarkable for its resistance to the air, and for its great lightness. It is said to be stronger than steel. It is four times lighter than silver, and seven or eight times lighter than platinum. Gas fumes and sulphur do not tarnish it. It is whiter than nickel, and makes a fine substitute for silver. Alloyed with silver and copper, it gives a non-tarnishing and non-corrosive quality to these metals, and greatly increases their tensile strength. Aluminium bronze is composed of 10 pounds of aluminium to 90 pounds of copper, and has a tensile strength of three tons per square inch greater than Bessemer steel. A solder has been invented which, it is claimed, will enable aluminium to be welded. [An alloy of aluminium and tin has been used, 10 parts tin to 100 of aluminium, for internal parts of instruments, as electrical instruments. The apex of the Washington Monument is of aluminium; its surface appears much whiter than silver, and is so highly polished as to resemble a plate glass mirror].

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* The Cowles method consists in passing a powerful electric current through a mixture of mineral copper and carbon. A high temperature is obtained by which the mineral is reduced by the carbon.

† The Netto process involves the use of ingots of sodium.

‡ When aluminium is to be melted to make a casting, for instance, this must not be done in clay crucibles, since it reduces the silica contained therein to silicium, whereby it becomes gray and brittle. It must be melted in lime crucibles; or if clay crucibles are used, they must be lined with carbon or well-ignited cryolite. Graphite crucibles, however, are the best.

In prosthetic dentistry the use of aluminium has been urged, on the ground (1) that it is the only metal which can be used *pure* and unalloyed in the manufacture of plates, (2) that it is the lightest of the metals available for such a purpose. It is claimed by some that aluminium is unalterable in the mouth, and does not irritate the gums, hence is superior to caoutchouc. It is thought, therefore, that it will replace gold and platinum in prosthetic dentistry.* According to Palmer there is little or no galvanic action in the oral cavity when aluminium is used; a carpet tack may be held in the mouth, in contact with the aluminium, without unpleasant sensation.

274. **Alloys of Aluminium.**—

Aluminium solder is 6 parts aluminium, 4 copper, 90 zinc. Others have been devised as follows:

	No. 1.	No. 2.	No. 3.
Zinc	80	85	88
Copper	8	6	5
Aluminium	12	9	7

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* Some have claimed that it is gradually attacked by articles used in diet, such as vinegar and solutions of common salt, and by alkaline solutions. Chandler's objection to its use is the difference in expansion between it and the vulcanite used in fastening the teeth. The heat of the mouth, hot drinks, etc., etc., cause a separation. Carbonate of lime is deposited from the saliva in the opening, until finally the space is perceptible to the tongue.

Aluminium may be soldered by coating it with copper as in electrotyping, then soldering as usual.*

275. Compounds of Aluminium.—

Alums:

Theoretical constitution: alums are what are known as "double salts." They are formed by the combination of aluminium sulphate with other sulphates. The formula for aluminium sulphate is $(Al_2)_2(SO_4)_6$ or $Al_2(SO_4)_3$, aluminium being a pseudo-triad. The formula for potassium sulphate is K_2SO_4, for ammonium sulphate $(NH_4)_2SO_4$. The formula for potash alum or potassium *and* aluminium sulphate is $K_2Al_2(SO_4)_4$, that is $K_2(SO_4) + Al_2(SO_4)_3$. Ammonia alum is $(NH_4)_2Al_2(SO_4)_4 24H_2O$. *Ferric* alum contains no aluminium at all, but is the double sulphate of ammonium and ferric iron, thus $(NH_4)_2Fe_2(SO_4)_4.24H_2O$. The official alum is potash-alum, $K_2Al_2(SO_4)_4.24H_2O$.

Official name: Aluminii et Potassii Sulphas.

Preparation and properties: alum is manufactured, on a large scale, by decomposing various silicates of aluminium with sulphuric acid, aluminium sulphate being formed. To this is added solution of potassium sulphate, if potash alum be desired, or ammonium sulphate, if ammonia alum is sought. On evaporation the alum crystallizes.

Potash alum occurs in form of regular octahedral crystals, white, efflorescent, soluble in 10 parts of cold water and

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* A good solder for aluminium is said to be made by melting together 5 parts of zinc, 2 parts of tin, and 1 part of lead, and rolling this out into thin sheets. The aluminium surface to be soldered must be scraped clear of all oxide, and coated with paraffin. A piece of the solder is then placed upon each portion and heated This causes the paraffin to melt; on further heating the solder melts and unites with the aluminium. The two surfaces thus coated are then soldered together in the usual manner.

0.3 parts boiling, insoluble in alcohol; its solution has an *acid reaction* and an astringent, sweetish taste. By heating for several days at a temperature of 176°F., the water of crystallization is expelled and it becomes dried alum, **Alumen exsiccatum.** Alum is used in dentistry as an astringent, styptic, and, in connection with Labarraque's solution, as a bleaching agent.

Aluminium chloride: this substance, Al_2Cl_6, comes in colorless, deliquescent crystals, very soluble in water, of a sharp saline taste, antiseptic, disinfectant. It is made by passing chlorine gas over a mixture of charcoal and alumina at bright red heat:

$$\underset{\text{Alumina}}{Al_2O_3} + \underset{\text{carbon}}{3C} + \underset{\text{chlorine}}{6Cl} = \underset{\substack{\text{carbon}\\ \text{monoxide}}}{3CO} + \underset{\substack{\text{aluminium}\\ \text{chloride}}}{Al_2Cl_6}$$

It has been used to bleach discolored teeth.

The substance called *Choralum* contains the chloride of aluminium.

Aluminium permanganate: this substance is said to be a constituent of some disinfecting solutions.

Aluminium silicates: there are many silicates of aluminium. Clay is a hydrated silicate, usually mixed with excess of silica. Purer kinds of clay are derived from feldspar of the formula, $Al_2O_3K_2O, 6SiO_2$. On exposure to air the silicate of aluminium alone remains, the alkaline silicates washing away. Earthenware, bricks, and pottery are made from clay, porcelain and the better kinds of stoneware from the purest clay, and glazed with feldspar. Firebricks, crucibles, and the like are prepared from pure varieties of clay, free from lime, magnesia, or iron, but containing a large proportion of silica. Common clays have the formula, $Al_2O_3.2SiO_2$; some kinds of fire clay, $Al_2O_3.6SiO_2$. Silicate of aluminium is an ingredient of hydraulic cement.

Alumina is an oxide, Al_2O_3. Corundum and emery are nearly pure alumina.

276. **Artificial teeth:** teeth are composed of two portions, the *body* or *base* and the *enamel.* The constituents of the body are chiefly *silex, feldspar,* and *kaolin.* The enamel is composed principally of *feldspar.* Coloring matters are also used, and consist of various metals, in a state of minute division, or of metallic oxides.

277. **Feldspar** is a double silicate of aluminium and potassium, its composition being represented by the formula, $K_2Si_3O_7$, $Al_2Si_3O_9$. It also contains lime and oxide of iron. It is prepared for dental uses in the same way as silex. It is readily fusible.

278. **Kaolin** is essentially a silicate of aluminium. It usually contains oxide of iron and some other substances, as magnesia, potash, etc., etc. It is the result of the decomposition of feldspar. Relatively large proportions of kaolin give teeth an opaque and lifeless appearance; modern mineral teeth contain less kaolin and more feldspar. It is prepared for dental uses by washing, letting settle, decanting, letting settle, decanting again, and drying in the sun.

279. **Crown enamels** are composed of feldspar, as a basis, with various coloring matters, such as titanium, spongy platinum, oxide of gold.

280. **The dry method of preparation of**

gum-enamel as practised by Wildman and described by Essig, is divided into three stages: first, the preparation of the oxide; second, fritting, or, by aid of heat, uniting the metallic oxide with a silicious base; and, third, diluting the frit so as to form the desired shade. In this method the purple of Cassius (metallic oxide) is prepared in the dry way by fusing silver, gold, and tin with borax, removing borax glass formed, dissolving the silver with nitric acid, washing well and drying. The frit is formed by mixing the purple of Cassius thus made with a flux composed of quartz, borax glass, and sal tartar. Lastly, the frit is diluted with the proper amount of feldspar.

281. Cerium.—

Symbol: Ce. *Latin name*: Cerium. *Equivalence*: II and IV. *Specific gravity*: 6.62. *Atomic weight* (approx.): 140.4. *Atomic weight* (revised): 140.424. *Electrical state*: +.

The most important compound is the *oxalate*. (Section 435).

282. Tin.—

Symbol: Sn. *Latin name*: Stannum. *Equivalence*: II and IV. *Specific gravity*: 7.29 to 7.30. *Atomic weight*: 117.7. *Revised weight*: 117.698. *Electrical state*: +. *Fusing point*: 442°F. (According to some, 458.6°F.) *Length of bar at 212°*: 1.0023; (4th rank). *Weight of cubic feet in lbs.*: 455.1. *Tensile strength*: 2 to 3.5. *Tenacity*: 1.33 compared with lead; (9th rank). *Malleability*: 4; (4th rank). *Ductility*: 9; (9th rank). *Conducting power* (*heat*): 7; (7th rank). *Conducting power* (*electricity*): 83, (silver = 1000); (9th rank). *Resistance to air*, etc.: 3; (3d rank). *Solu-*

bility: soluble in dilute acids and alkalies. Resists corrosion of air, water, etc., better than iron or copper. Nitric acid converts it into metastannic acid. Dissolved in hydrochloric acid, stannous chloride is formed. In aqua regia, stannic chloride. *Direct combinations*: with oxygen when strongly heated, sulphur, chlorine. It does not combine chemically with mercury. *Color and appearance*: white, brilliant. *Structure*: crystalline in two systems, isometric and quadratic. *Consistence*: soft. *Compounds*: stannic (equivalence IV) and stannous (equivalence II). *Alloys*: pewter, brittania, queen's metal, solder, bell-metal, gun-metal, bronze, speculum metal, fusible metals, sterro-metal, type metal.

Occurrence: tin occurs chiefly in form of *tinstone*, stannic oxide, SnO_2. The ore is found in Cornwall, Australia, Bohemia, Saxony, Malacca, Banca, Siberia, Sweden, North and South America. Tin obtained from Malacca and Banca is known as *straits tin*, and is of great purity. The tin deposits of New South Wales cover an area of over 5,000,000 acres; tin ore is also very abundant in Queensland. In the United States tin ore has been found in West Virginia and adjoining parts of Ohio, in North Carolina, and in the far West, as in Utah, Dakota.

Preparation: the metal is easily obtained from the ore by heating the latter, after purification, with coal:

$$\underset{\text{Stannic oxide}}{2SnO_2} + \underset{\text{Carbon}}{2C_2} = \underset{\text{Tin}}{Sn_2} + \underset{\text{Carbon mon-oxide}}{4CO}$$

283. *Pure tin*, in crystalline form, may be

thrown down by introducing a plate of tin into a strong solution of stannous chloride, on which water is floated. Another method by which tin, entirely pure, may be obtained is by evaporating a solution of stannous chloride to small bulk, and oxidizing by addition of nitric acid. Stannic oxide is obtained, which, after washing and drying, is exposed to a red heat in a crucible with charcoal.

284. Tin in dentistry: tin amalgamates readily with mercury, and in most cases there is condensation. Pure tin in form of foil is used as a filling, and also in connection with non-cohesive gold.

285. Alloys of tin.—

Pewter is an alloy of variable composition, usually tin, lead, copper, and antimony or zinc. Plated pewter is 7 antimony, 2 bismuth, 2 copper, 89 tin. A pewter often used is tin, 92, lead, 8.

Rees's alloy is tin 20, gold 1, silver 2.

Common Solder is an alloy of tin and lead. [Fine solder is 33.3 lead to 66.6 tin. Common solder is equal parts tin and lead; coarse solder is 66.6 lead to 33.3 tin].

286. Compounds of tin.—

Stannous Chloride:

This substance, known to the dyer as "tin salt," is made by dissolving metallic tin in hydrochloric acid. It may also be prepared by distilling tin filings with mercurous chloride. Its formula is $SnCl_2,2H_2O$; molecular weight, 224.5. It is used locally. It is poisonous; the antidotes are baking soda, magnesia, milk, and white of egg. Tin' dissolved in nitrohydrochloric acid yields stannic chloride, $SnCl_4$. The two chlorides of tin in connection with auric chloride yield purple of Cassius. (See section 258.)

287. **Palladium.**—

Symbol: Pd. *Latin name*: Palladium. *Equivalence*: II and IV. *Specific gravity*: 11.80. *Atomic weight*: 106. *Revised atomic weight*: 105.737. *Electrical state*: +. *Fusing point*: lower than platinum, but requires oxy-hydrogen blow-pipe. *Length of bar*, etc.: 1.0010; (12th rank). *Wt. of cubic ft. in lbs.*: 736.6. *Tenacity*: 11½ (Lead = 1): (7th rank). *Malleability*: inferior to platinum. *Ductility*: 6; (6th rank). *Conducting power* (*electricity*): 184 (silver = 1000); (5th rank). *Resistance to air*, etc.: 1; (first rank). More oxidizable than platinum at red heat. *Solubility*: soluble in nitric acid; attacked by iodine; aqua regia best solvent. *Direct combinations*: cyanogen, iodine, hydrogen, sulphur, chlorine, phosphorus, arsenic. *Color and appearance*: like platinum, or a platinum-gold alloy. *Structure*: native, grains of fibrous appearance. *Consistence*: hard as platinum. *Compounds*: palladium (II) and palladic (IV). *Alloys*: salmon-bronze.

Use in dentistry; in amalgam alloys. (See section 223).

288. **Platinum.**—

Symbol: Pt. *Latin name*: Platinum. *Equivalence*: II, and IV. *Specific gravity*: 21.50. One of the heaviest substances in nature. *Atomic weight*: 197. *Revised atomic weight*: 196.700; (according to some, 194.8). *Electrical state*: +. *Fusing point*: above 3500° in oxyhydrogen flame, or coal-gas and oxygen flame. *Length of bar*, etc.: 1.0009; (13th rank, least expansible of the 13 metals). *Wt. cubic ft. in lbs.*: 1.344. *Tenacity*: 15, compared with lead; (4th rank). *Malleability*: 5; (5th rank). *Ductility*: 3; (3d rank). *Conducting power* (*heat*): 8; (8th rank). *Conducting power* (*electricity*): 180 (silver = 1,000): (6th rank). *Resistance to air*, etc.: 1; (1st rank). *Solubility*: dissolves slowly in aqua regia. Acted on by fused alkaline hydrates at red heat. *Direct combinations*: sulphur, phosphorus, arsenic, silicon, chlorine. Absorbs and condenses gases when in finely divided state. *Color and appearance*: white with tinge of blue, brilliant but less than silver. *Structure*: (native) rounded grains; sometimes octahedral crystals. *Consistence*: hard as copper. *Compounds*: platinous (II), and platinic (IV). *Alloys*: with most metals. Gold, silver, lead form easily fusible alloys with it.

Use in dentistry: in amalgam alloys, for plates of continuous gum teeth, for pins for fastening porcelain teeth to the rubber or celluloid plate. Metallic platinum does not amalgamate with mercury, but spongy platinum unites with the latter when triturated with it in a warm mortar or in contact with acetic acid. (See, however, Rollins's process, following below). In finely divided state it is used as a coloring matter for artificial teeth.

Preparation of platinum for coloring the enamel of artificial teeth.—

The ordinary platinum sponge is too coarse to produce the best results without much grinding. Rollins proceeds as follows: Dissolve twenty grammes of platinum in aqua regia and evaporate to a thick syrup, then add one hundred grammes of caustic potash and boil. To this mixture add fifty grammes of grape sugar and boil ten minutes. Wash thoroughly by decantation and dry the residue, which is platinum in an exceedingly fine state. To prepare what is to be called "Platinum Color" use feldspar eight grammes, this platinum five hundred milligrammes.

Mix and grind five minutes on slab. Use this mixture to add to uncolored spar for the enamel.

289. **Platinum metals:** these are platinum, rhodium, palladium, ruthenium, and iridium.

Occurrence: the chief supply of platinum, which, like gold, is found free, is derived from the Ural Mountains. The Russian platinum diggings are near Bogoslowsk, Miask, Newjansk, and Nischnei Tagilsk. It is also found in Brazil, Peru, Columbia, California, and Borneo. The Russian platinum is always associated with other metals: analysis showed in one specimen, 75.1 platinum, 1.1 palladium, 3.5 rhodium, 2.6 iridium, 0.6 osmiridium, 2.3 osmium, 0.4 gold, 1.0 copper, and 8.1 iron.*

Preparation: the platinum is dissolved in fused galena, a little glass is introduced to melt over the surface, and a quantity of litharge, equal in weight to the galena, is gradually added. Sulphurous acid gas, from the lead sulphide and lead oxide, is formed, leaving metallic lead in combination with the platinum, free from osmium and iridium. The lead-platinum combination is then treated in a *cupellation* furnace, that is, a furnace containing a *cup*, made of bone ash; the lead removed as

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* The annual product is two or three tons, of which the United States furnish about 200 ounces. It is worth about $15 an ounce, and the price tends to rise in consequence of the demand for it for use in electric lighting.

an oxide, leaving the platinum in spongy state on the cupel. The spongy platinum is refined in a lime furnace, by the heat of an oxy-hydrogen, or coal gas and oxygen flame.

290. **Compounds of platinum:** platinic chloride, $PtCl_4$, is formed when metallic platinum is dissolved in aqua regia. It is a reddish, deliquescent substance readily soluble in water and in alcohol.

291. Iridium.—

Symbol: Ir. *Latin name:* Iridium. *Equivalence:* II, IV, VI. *Specific gravity:* 21.1. *Atomic weight:* 192.7. *Revised atomic weight:* 192.651. *Electrical state:* +. *Fusing point:* fusible in oxyhydrogen blow-pipe; more refractory than platinum. *Resistance to air:* unalterable in air. *Solubility:* not soluble in aqua regia unless alloyed with platinum. *Direct combinations:* sulphur, chlorine, iodine, oxygen. *Color and appearance:* white, like polished steel. *Consistence:* very hard, brittle. *Compounds:* iridic, iridious, hypoiridious. *Alloys:* with platinum. *Value in dentistry:* for alloy with platinum in manufacture of plates and wire.

292. Silicon.—

Symbol: Si. *Latin name*: Silicium. *Equivalence*: II and IV. *Specific gravity*: 2.49. *Atomic weight* (*approx.*): 28.2. *Atomic weight* (*revised*): 28.1950. *Electrical state*: — *Solubility*: in melted zinc, etc. *Fusing point*: above melted iron. *Preparation*: made by action of sodium on potassium fluo-silicate.

Properties: occurs in three forms somewhat resembling carbon. Is an amorphous, nut-brown powder. In combination, as silica, SiO_2, found in sand, rocks, etc.

293. **Compounds of silicon:** the most important is *silica*, SiO_2. Silica occurs in nature as quartz crystal and in sand. Is found in animal tissues. Compounds are

silicates. Insoluble in water or acids, infusible except by oxyhydrogen flame, sp. gr. 2.66. Percentage composition, silicon, 48.04, oxygen, 51.96. Used in manufacture of porcelain teeth.

Use in dentistry: dentists use silica under the name of *silex* in the preparation of artificial teeth. For dental uses it is prepared by heating to white heat, plunging into cold water, and grinding to a fine powder.

294. **Titanium:** titanium itself is not used in dentistry, and the only compound of interest is the dioxide, titanic oxide, TiO_2, which occurs native in several different forms, viz., as the minerals rutile and anatase, and as brookite.

Rutile is the most abundant, and is used, ground up, as a coloring matter for artificial teeth. If ground moderately coarse it imparts a yellow of redder cast than when ground fine. It is used for the yellow color of the body of porcelain teeth.

295. Carbon.—

Symbol: C. *Equivalence:* II and IV. *Atomic weight* (*approx.*)*:* 12. *Atomic weight* (*revised*)*:* 11.9736. *Electrical state:* — . *Fusing point:* infusible. *Properties:* affinity for oxygen, hydrogen, sulphur. Infusible, non-volatile, unalterable solid. Absorbs gases, disinfectant.

296. **Dental uses.**—In the form of charcoal, coke, and anthracite coal, carbon is used in the dental laboratory. In the form of animal charcoal and of wood charcoal it is used in dental medicine.

Charcoal is prepared on a large scale by burning wood in heaps with limited supply of air. *Carbo ligni* is the official preparation.

Coke is the substance left in retorts after coal has been distilled in the production of illuminating gas.

Anthracite coal is the result of the slow decay of vegetable matter. It often contains 96 to 98 per cent. of carbon.

Carbo animalis purificatus consists of carbon and several salts of calcium, notably the phosphate and the carbonate.

Charcoal, and especially *animal* charcoal, has the power of absorbing gases, of destroying noxious odors, and of filtering coloring matters from solutions of organic substances. One volume of wood charcoal at 212°F will absorb 90 volumes of ammonia gas, 55 volumes of sulphuretted hydrogen, and 9 volumes of oxygen. It is administered internally to counteract the effect of poisons, as, for example, strychnine, but should be removed by the stomach pump.

297. **Illuminating gas** is made by subjecting bituminous coal to the action of dry heat in retorts. The coal is heated to bright redness, and the products given off from it are passed through a series of upright tubes, in form of an inverted U, called *condensers*, where the tar, steam, and ammonia are condensed. The gas is then passed through a series of large boxes called *purifiers*, in which it is purified by coming into contact with various substances as fresh slaked lime or a mixture of sawdust and iron oxide, and then it goes to a large tub-shaped vessel called the *gasometer* to be stored until needed.

It is a mixture essentially of hydrogen and marsh-gas mixed with variable proportions of olefiant gas, acetylene, the oxides of carbon, etc., etc. [Much of the illuminating gas now used is the so-called "water-gas," which contains usually a considerable amount of carbon monoxide, and is made by decomposing steam and then carburetting the gases formed].

298. Compounds of carbon.—

Carbon forms two compounds with oxygen, namely, *carbon monoxide* and *dioxide*. Carbon monoxide, CO, is formed when carbon is burned in deficient supply of air. Molecular weight, 28; density, 14; sp. gr., 0.9678. Is a gas. Colorless, insipid, very poisonous, insoluble, combustible.

Called also "carbonic oxide gas."

Carbon dioxide, CO_2, is a product of combustions and of fermentation. Made by pouring an acid on a carbonate, as sulphuric acid on marble or limestone. Molecular weight, 44; density, 22; sp. gr., 1.529. Colorless, odorless gas, present in air, water, breath, heavier than air. Narcotic. Slightly acid taste. Very soluble in water. Compounds are *carbonates*.

Carbonic Acid gas, known to chemists as carbonic dioxide, or carbon dioxide, is a constituent of the breath, is found in small quantities in the atmosphere, and is a product of fermentation. It is not a true acid, as defined in this book, but an *anhydride*, carbonic anhydride, CO_2. The hydrated acid is not found, but its salts exist, as, for example, the various *carbonates*. like sodium carbonate, Na_2CO_3.

299. Carbon Disulphide.—

Synonyms: carbon bisulphide, carbon bisulphuret or bisulphuret of carbon. Official name, Carbonei Bisulphidum.

Theoretical constitution: CS_2, one atom of carbon and two of sulphur. Molecular weight, 76.

Preparation: made by passing fumes of sulphur over red hot charcoal.

Properties: mobile, colorless liquid of disgusting odor except when pure. Very volatile. Dissolves iodine, sulphur, phosphorus, oils, fats, caoutchouc, etc. Sometimes used as local anæsthetic.

Use in dentistry: to dissolve caoutchouc.

PENTADS AND HEXADS.

300. None of the pentads are used in dentistry except those classified as triads, when varying in equivalence. The following list shows *hexads* of importance:

TABLE 24. IMPORTANT HEXADS.

Manganese.	Hexads positive to hydrogen.
Iron.	
Nickel.	
Cobalt.	
Chromium.	Hexad negative to hydrogen.

301. **Manganese.**—
Symbol: Mn. *Latin name:* Manganesium. *Equivalence:* II, IV, VI; also a pseudo-triad. *Specific gravity:* 8.01 to 8.03. *Atomic weight* (*approx.*)*:* 53.9. *Atomic weight* (*revised*)*:* 53.9060. *Electrical state:* +. *Properties:* grayish white metal of but little lustre, hard, brittle, and nearly as refractory as platinum.

302. **Compounds of manganese.**—
The only important compound for dental uses is the *dioxide*, MnO_2, which, in minute quantity, imparts a purple color to the frit, probably due to formation of an oxysilicate. A *silicate* is also used in enamels; it is a yellow amorphous powder turning brown on exposure to air and soluble in dilute acids.

Manganese dioxide occurs in nature as the mineral *pyrolusite.* It is a heavy, black, crystalline mineral insoluble in water. When heated to redness it liberates oxygen.

303. **Iron.**

Symbol: Fe. *Latin name:* Ferrum. *Equivalence:* II, IV,* VI. *Specific gravity:* 7.79 to 7.84. *Atomic weight:* 56. *Revised atomic weight:* 55.9130. *Electrical state:* +. *Fusing point:* 3500°F (wrought iron). Ordinary, 2900°F. *Length of bar:* 1.0012 (10th rank). *Weight of cubic foot in lbs.:* 489.4. *Tensile strength:* 29.0 (maximum). *Tenacity:* 27½, steel, 42, (1st rank). *Malleability:* 8; (8th rank). *Ductility:* 4; (4th rank). *Conducting power (heat):* 6; (6th rank). *Conducting power (electricity):* 168; (silver = 1000); (7th rank). *Resistance to air:* rusts in moist air. *Solubility:* soluble in hydrochloric and sulphuric acids; in dilute nitric. *Direct combinations:* chlorine, bromine, iodine, sulphur, and members of the phosphorus group except nitrogen. *Color and appearance:* depend on variety. Pure iron is white. *Structure:* white cast iron, crystalline; gray iron, granular; wrought iron, fibrous; crystals probably cubical. *Consistence:* pure iron is soft and tough. *Compounds:* ferric $(Fe_2)^{VI}$, ferrous (Fe^{II}), and ferroso-ferric, $Fe^{II}(Fe_2)^{VI}$. *Alloys:* Aich's metal, arguzoid. German silver plate, sterro-metal.

Use in dentistry: as steel, and in many ways.

Occurrence: the iron ores are very numerous and widely distributed; those used in the manufacture of iron are hæmatite (Fe_2O_3), magnetite (Fe_3O_4), limonite (a hydrate), and siderite ($FeCO_3$).

Preparation: the general process is to reduce with carbon, metallic iron and the oxides of carbon being formed. Sometimes the ore is first roasted to get rid of sulphur, carbonic

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* Iron as a pseudo-triad in ferric compounds is really quadrivalent.

acid, water, etc. The ore, containing iron oxide, is then reduced, *i. e.*, deprived of its oxygen, in a blast furnace, which is filled at the top with alternate layers of coal, broken ore, and fluxes, such as limestone or silicates. Iron obtained by this method is known as **cast-iron,** and contains more or less carbon and slag, when drawn off into moulds to form **pig-iron.** **Wrought-iron** is made by subjecting pig-iron to the **puddling process,** during which the molten metal is thoroughly stirred in reverberating furnaces, where there is a free supply of air, so that the carbon of the pig-iron is burned and other impurities oxidized.

304. *Steel* is now made by the Bessemer process, by blowing air under great pressure into molten cast-iron, consuming the carbon; iron rich in carbon and manganese, termed *spiegel-eisen*, is then added to give the proper amount of carbon.

Malleable iron is steel which has undergone further treatment by heat and atmospheric air.

305. Dental uses of iron: chiefly in tools; iron is by far the strongest and yet one of the lightest of the metals; steel is the strongest and one of the hardest and most elastic of all materials; malleable iron possesses great strength and toughness, but is soft enough to be turned, bored, and punched, and, when heated, is easily wrought and without crack-

ing. Wrought-iron, at bright red heat, can be welded, that is, joined to another piece of metal, without the use of solder. Wrought-iron has the property of acquiring with great rapidity the properties of a magnet and of parting with them rapidly, hence is well adapted for use in the construction of electro-magnetic and magneto-electric apparatus. Cast-iron is easily melted, and can be made into castings, which may be readily filed or turned, or made so hard that no tool can affect them.

When cold, iron is the least malleable of metals in common use, but when heated, its ductility is such that it can be rolled into the thinnest sheets and drawn into the finest wire, which, when $\frac{1}{10}$th inch in diameter, will sustain a weight of 700 pounds. With exception of platinum, iron is the least fusible of the useful metals.

306. **Compounds of Iron:** compounds of **Iron** are chiefly of two kinds, ferr*ic* and ferr*ous:*

Ferric compounds: iron as a pseudo-triad. *Ferric* chloride, Fe_2Cl_6, per-chloride, sesquichloride, chloride of iron, Ferri Chloridum; orange-yellow, deliquescent, soluble. *Liquor ferri chloridi,* U. S. P., contains 37.8 per cent. of the anhydrous. "Tincture of Iron" is one part of the *Liquor* to about two of alcohol (Tinctura Ferri Chloridi, U. S. P.); hemostatic, strong chalybeate, styptic taste, acid reaction, stains teeth and acts on them. *Ferric Hydrate,* $Fe_2(HO)_6$, hydrated oxide, hydrated peroxide, peroxide, sesquioxide, red oxide. Precipitate ferric sulphate or ferric chloride by ammonia or by sodium hydrate. Reddish-brown powder used as antidote to arsenic; must be freshly made. *Hydrated oxide of iron with magnesia*, U. S. P., made by adding magnesia to a solution of ferric sulphate. *Ferric Sulphate*, $Fe_2(SO_4)_3$, in solution forming "solution of tersulphate of iron," U. S. P., color reddish-brown. *Ferric Subsulphate* (doubtful composition) $Fe_4O(SO_4)_5$, called "Monsel's solution," ruby-red; valuable as a hemostatic, may be taken internally. *Dialyzed Iron*, aqueous solution of about 5 per cent. of ferric hydrate with some ferric chloride. Ammonia is used in making it, and the ammonium chloride formed passed through a dialyzer.

Ferrous compounds: iron as a dyad. Ferrous salts are usually green, and alter in the air to *-ic* salts. *Ferrous chloride*, $FeCl_2$, protochloride; *ferrous iodide*, FeI_2, protiodide, green, volatile, deliquescent, soluble. *Ferrous sulphide*, FeS, protosulphide, sulphuret of iron, is used to make H_2S (sulphuretted hydrogen). *Ferrous sulphate*, $FeSO_4$, green vitriol, copperas; dissolve iron in 1½ parts H_2SO_4 diluted with 4 parts water: efflorescent, bluish-green crystals, acrid, styptic taste, soluble in water, insoluble in alcohol, astringent, irritant, disinfectant.

307. Dental uses of compounds of iron: ferric chloride is used externally, to arrest alveolar hæmorrhage, either in form of the deliquesced crystals or in solution. It is also applied to fungous tumors. It is given internally. Monsel's powder and solution are used to arrest hæmorrhages following extraction of teeth, etc., etc.

308. **Nickel.***—

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*Nickel is one of the toughest of all metals, and is now used in manufacture of crucibles which to some extent are taking the place of platinum crucibles, as they cost only about one-tenth as much.

Symbol: Ni. *Latin name:* Niccolum. *Equivalence:* II, IV, (Ni_2) . *Specific gravity:* 8.60 to 8.82. *Atomic weight:* 58. *Revised atomic weight:* 57.928. *Electrical state:* +. *Fusing point*: less than iron. *Weight of cubic foot in lbs*: 541.2. *Tensile strength*: same as iron. *Tenacity*: like iron, very great. *Malleability, Ductility*: very ductile and malleable. *Conducting power* (*heat*): about the same as iron. *Conducting power* (*electricity*): 131; (8th rank). *Resistance to air*: rusts less readily than iron; magnetic. *Solubility*: soluble in dilute mineral acids, especially nitric. *Direct combinations*: with chlorine, cyanogen, oxygen, sulphur, arsenic. *Color and appearance*: silver-white, with a slight yellowish tinge and very lustrous. *Consistence*: hard. *Compounds*: mostly nickelous. *Alloys*: arguzoid, electrum, German silver, tutenag.

309. **Cobalt.**—

Symbol: Co. *Latin name*: Cobaltum. *Equivalence*: II, IV, $(Co_2)^{VI}$. *Specific gravity*: 8.49 to 8.9. *Atomic weight*: 58.9. *Revised atomic weight*: 58.8870. *Electrical state*: +. *Fusing point*: less than that of iron. *Weight of cubic foot in lbs.*: 558.7. *Tensile strength*: like iron. *Tenacity*: like iron. *Malleability*: like iron. *Ductility*: like iron. *Resistance to air*: like nickel. *Solubility*: like nickel. *Direct combinations*: chlorine, oxygen, sulphur. *Color and appearance*: reddish-white; magnetic. *Structure*: has granular fracture. *Consistence*: hard. *Compounds*: cobaltous, cobaltic, and cobaltous-cobaltic like ferroso-ferric.

Compounds of Cobalt.—*

Impure protoxide of cobalt serves as a basis for the preparation of the colors of cobalt, among which are various blues. Oxide of cobalt is sometimes used for the blue color of points of porcelain teeth.

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*The term "cobalt" is sometimes applied to metallic arsenic.

310. **Chromium.**—

Symbol: Cr. *Latin name*: Chromium. *Equivalence*: II, IV, VI, and pseudo-triad. *Specific gravity*: 7.01. *Atomic weight* (*approx.*): 52. *Atomic weight* (*revised*): 52.009. *Electrical state*: −.

311. **Compounds of Chromium. Chromic Anhydride.**—

Synonyms: chromic trioxide, chromic oxide, chromic acid. Official name, Acidum Chromicum.

Theoretical constitution: chromic "acid" so-called is not an acid but an oxide, CrO_3, composed of one atom of chromium to three of oxygen; by weight, 52 parts of chromium to 48 of oxygen. Molecular weight, 100.

Preparation: chromic anhydride separates in crystals from a mixture of potassium dichromate and sulphuric acid:

$$\underset{\substack{\text{Potassium}\\\text{dichromate.}}}{K_2Cr_2O_7} + \underset{\substack{\text{Sulphuric}\\\text{acid.}}}{2H_2SO_4} = \underset{\substack{\text{Chromic}\\\text{anhydride.}}}{2CrO_3} + \underset{\substack{\text{Acid potassium}\\\text{sulphate.}}}{2KHSO_4} + H_2O$$

Properties: fine red, very deliquescent,* needle-shaped crystals, which have strongly corrosive action on organic matter, and decompose certain substances with explosive violence, as alcohol, sugar, or glycerine. It forms dichromates with oxides of the alkali metals, as potassium dichromate with potassium oxide:

$$\underset{\substack{\text{Potassium}\\\text{oxide.}}}{K_2O} + \underset{\substack{\text{Chromic}\\\text{oxide.}}}{2CrO_3} = \underset{\substack{\text{Potassium}\\\text{dichromate.}}}{K_2Cr_2O_7}.$$

The crystals are readily soluble in water, forming an orange yellow solution of strongly acid properties. Alcohol is inflamed by the crystals.

Dental uses, etc.: used in dentistry locally, for removal of tumors, morbid growths, etc., etc. If combined with glycerine, care must be taken not to mix too rapidly, but

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**Absolutely pure* chromic acid, wholly free from sulphuric acid, should not deliquesce when used as a caustic.

drop by drop to avoid explosion. It penetrates tissues deeply.

Toxicology: chromic acid is a poison, and a violently corrosive agent. Poisoning by it should be treated promptly and with vigor as in case of poisoning by sulphuric acid. Cause the patient to drink at once water containing 300 to 400 grains of magnesia, or else half an ounce of soap which has been dissolved in two quarts of hot water and cooled, or water with which wood ashes have been mixed, or a solution of sodium bicarbonate (150 grains in a pint of water). If nothing else is at hand, give milk or the whites of four eggs in a quart of water. Burns from it should be treated as in case of hydrochloric acid, and as promptly as possible.

Chromic oxide of formula Cr_2O_3, better known as the *sesquioxide,* is a green powder insoluble in water and in acids. It is obtained by heating potassium dichromate with sulphur. It is used as a coloring matter for porcelain teeth to modify or tone the bright yellow of the oxide of titanium in the darker shades.

CHAPTER IV.

CARBON COMPOUNDS OR ORGANIC CHEMISTRY.

312. **Theory.**—

1. *Organic Chemistry* is the chemistry of *carbon* compounds.

2. The *elements* found in organic compounds are, besides *carbon*, chiefly *hydrogen*, *oxygen*, and *nitrogen*, sometimes sulphur and phosphorus.

3. *The general properties* of organic compounds are as follows: combustible (except CO_2 and its salts); solids usually when carbon atoms predominate in their molecule; liquids or gaseous when hydrogen predominates; easily volatilized gases or liquids when a small number of atoms in the molecule; liquids of high boiling points or solids when the number of atoms in the molecule is large.

4. *Quantitative* analysis more important than qualitative to establish identity of organic compounds. If the elements of an organic substance are determined, the

analysis is called *ultimate* or *elementary*; if different organic substances when mixed together are separated, the analysis is called *proximate.*

5. The presence of *carbon* in a combustible form will prove a compound to be organic, hence, if a substance burns with generation of carbon dioxide (shown by passing the gas through lime-water) the organic nature of this substance is established. The presence of *hydrogen* may be shown by allowing the gaseous products of combustion to pass through a cool glass tube, when drops of water will be deposited. To show presence of *nitrogen*, heat with a mixture of two parts calcium hydrate to one part sodium hydrate; the nitrogen is converted into ammonia, recognized by its odor and action on paper moistened with copper sulphate solution.

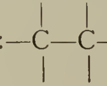
6. A chemical *formula* is called *empirical* when it gives the simplest expression of the composition of a substance; this formula, however, does not necessarily denote the actual number of atoms in the molecule, which may be two or three times the number given in the empirical formula; thus, the empirical formula of acetic acid is CH_2O, but the actual molecular formula contains twice the number of atoms or $C_2H_4O_2$. Besides empirical and molecular formulæ, others called *rational*, *constitutional*, *structural*, or *graphic* are used. The molecular formula of acetic acid is $C_2H_4O_2$, but the formula $HC_2H_3O_2$ shows that acetic acid, like nitric acid, HNO_3, is monobasic, containing one atom of hydrogen, which can be replaced by an atom of a metal; hence $HC_2H_3O_2$ is called a *constitutional* formula.

7. *Radicals* or *residues.* These are expressions for unsaturated groups of atoms known to enter as a whole into different compounds, but having no separate existence. Water, H_2O, is a *saturated* compound, that is the one atom of oxygen—which is a dyad, and may be said therefore

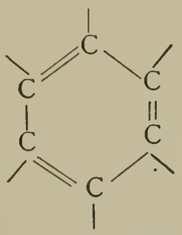
to have *two* points of attraction—combines with two of hydrogen and therefore has both its points of attraction satisfied. If now one atom of H be taken from H_2O, there is left the group of atoms HO, which is called a radical, as it consists of an atom of oxygen, in which but one point of attraction is actually saturated, the second one not being provided for; moreover, this group HO occurs in many compounds—as, for example, in the hydrates, as potassium hydrate, KHO, etc. The *equivalence* of radicals depends upon the number of points of attraction unprovided for: carbon requires four atoms of hydrogen to provide for its points of attraction; therefore CH_3 would be a *monad*, CH_2 a dyad, CH a triad. (See Chapter II).

Radicals are *electro-positive* and *electro-negative.* The most important positive radicals are ammonium NH_4, the ethyl series of radicals (such as methyl CH_3, ethyl CH_4, etc.) and also of other series, phenyl, glyceryl, etc.

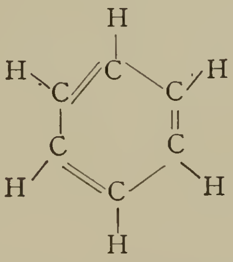
The most important negative radicals are *acid* radicals, as $C_2H_3O_2$, that of all acetates, C_2O_4 that of all oxalates, etc. HO the radical of hydrates and CN of cyanides are negative also.

8. *Chains:* the expression *chain* denotes a *series* of atoms, held together in such a manner that affinities are left unsaturated. The atoms of the series must have a greater equivalence than one, *i. e.*, must be dyad, etc. The existence of such an enormous number of carbon compounds is greatly due to the property of carbon to form these chains. Carbon is a tetrad, hence two atoms would form a chain as follows: $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$; each atom has four

bonds, one of which unites with one of the other, leaving in this particular chain six free affinities. Three atoms of carbon would be $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$; four, $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$, etc., etc. The free affinities may be saturated with various atoms or radicals, hence the almost unlimited number of possible combinations. Atoms are not always united by one affinity. When they are united by *two*, the expression for two atoms of carbon would be $>C=C<$; if by three, $-C\equiv C-$. In the so-called *closed chain* of C_6 we have the atoms united partially by double and partially by single union:



Benzine, C_6H_6, would then be represented as follows:

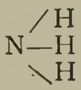
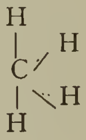


It is easy to see from these two diagrams the origin of the term *skeleton*, which is sometimes used instead of chain.

9. *Homologous series*. Any series of organic compounds, the members of which preceding or following

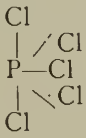
each other differ by CH_2, is called a homologous series.[*]

10. *Types.* Most substances may be classified under the five following types;

I.	II.	III.	IV.
Hydrogen.	Water.	Ammonia.	Methane.
H—H	H—O—H		

V.

Phosphoric chloride.



Almost any compound may be classed in one of these types by replacing the constituents of these types by other elements or radicals of the same equivalence.

11. *Substitution.* Replacement of an atom or group of atoms by other atoms or groups: $C_6H_6 + HNO_3 = C_6H_5NO_2 + H_2O$. Here for one atom of hydrogen in benzine (C_6H_6) has been substituted the group NO_2. (See Chap. II).

12. *Derivatives.* Chloroform, $CHCl_3$, is a *derivative* of marsh gas, CH_4, because it may be obtained from the latter by replacement of three atoms of hydrogen by three of chlorine. The term is applied to bodies derived from others, by some kind of decomposition, generally by substitution. (See Chap. II).

13. *Isomerism.* Two or more substances having the same elements in the same proportions by weight, or having the same percentage composition, and yet being

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[*] When the carbon remains the same but the hydrogen differs by H_2, the series is said to be *isologous*.

different bodies with different properties, are called *isomeric* bodies. When two or more substances have the same molecular formulæ they are said to be *metameric* with one another; thus CN_2H_4O is either urea or ammonium cyanate; hence, urea is said to be metameric with ammonium cyanate. Sometimes structural formulæ will serve to distinguish two substances metameric with each other. When a substance contains some multiple of the number of each of the atoms contained in the molecule of the other, it is said to be *polymeric* with it; thus acetic acid $C_2H_4O_2$, is polymeric with grape-sugar, $C_6H_{12}O_6$. (See Chap. II).

14. *Decomposition.* Organic bodies decompose readily under the influence of heat or chemical agents. Heat will volatilize some organic bodies without decomposition; whilst others are decomposed by heat with generation of volatile products. *Dry or destructive* distillation is the term applied to the process of heating non-volatile organic substances in such a way that the oxygen in the air has no access and to such an extent that decomposition takes place. (See Chap. II).

15. *Combustion and decay.* In common combustion, provided an excess of atmospheric air be present, the carbon of an organic substance is converted into carbon dioxide, the hydrogen into water, sulphur and phosphorus into sulphuric and phosphoric acids, and the nitrogen set free. In decay, which is slow oxidation, the compounds mentioned above are finally produced, but many intermediate products are also generated. Alcohol when burned forms carbon dioxide and water; exposed to the air, it undergoes slow oxidation, forming aldehyde first, then acetic acid.

16. *Fermentation and putrefaction.* An organic substance under favorable temperature and during the presence of moisture and of a substance termed a ferment, undergoes

a peculiar kind of decomposition, during which its molecule is split up into two or more molecules of less complicated composition.

17. *Difference between fermentation and putrefaction.* (See Ferments, section 476).

18. *Action of various agents on organic matter.* Chlorine and bromine usually remove or replace the hydrogen of an organic substance. Sometimes they combine directly with it, and sometimes, in presence of water, act as oxidizing agents by combining with the hydrogen of the water and liberating oxygen. Nitric acid either forms (i) salts with organic matter, (ii) oxidizes it, or (iii) substitutes NO_2 (nitryl) for hydrogen. In the latter case the additional quantity of oxygen added renders the compounds highly combustible or even explosive. Substances having a great affinity for water, as, for example, sulphuric acid, act on many organic substances by removing hydrogen and oxygen, leaving dark or black compounds consisting mainly of carbon. Alkalies may combine directly, form salts, form soaps, oxidize, or evolve ammonia from nitrogenous compounds. Reducing agents, especially nascent hydrogen, either combine directly, remove oxygen, or replace oxygen.

313. The following synopsis will give the student a general idea of the constitution and derivation of the various classes of organic compounds.

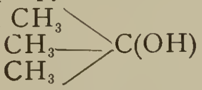
Class 1. Hydrocarbons. Compounds of hydrogen and carbon only.

Paraffin or methane series: saturated, of general formula $C_n H_{2n+2}$, names end in —ane; examples: methane CH_4, ethane C_2H_6, propane, butane, pentane, hexane, heptane, octane, etc., etc., occur in nature as in petroleum, natural gas, ozokerite. First four of series are colorless gases, higher members solids. They cannot combine directly with elements, being saturated. Attacked by Cl, and Br in sunlight with formation of substitution products.

Olefine or ethylene series:—Unsaturated. General formula, C_nH_{2n}, names end in—ene, ethylene C_2H_4, amylene C_5H_{10}. May be prepared by action of dehydrating agents, as H_2SO_4, on alcohols. Burn with luminous, smoky flame. Are gases, liquids, solids in order of series. Combine directly with elements, and are readily oxidized.

Acetylene series:—Unsaturated. General formula, C_nH_{2n-2}. Acetylene, C_2H_2, allylene, C_3H_4. May be prepared by treating monohalogen substitution products of olefines with alcoholic potash. (Acetylene occurs in coal-gas). Are gases or volatile liquids of peculiar odor. Burn with luminous, very smoky flame. Combine directly.

Class II. Monohydric Alcohols. Hydroxy-derivatives of paraffins. General formula $C_nH_{2n+1}.OH$. Names end in —yl, as methyl alcohol $CH_3.OH$, ethyl alcohol $C_2H_5.OH$ etc., the name in —yl, however, being that of a radical (see section 359).* Are primary, secondary, or tertiary: primary contain the group $—CH_2.OH$, secondary $>CH.OH$, and tertiary $—C.OH$. Examples: propyl alcohol $CH_3.CH_2.CH_2.OH$, isopropyl alcohol $CH_3.CH.(OH).CH_3$, tertiary butyl alcohol



$$\begin{matrix} CH_3 \searrow & \\ CH_3 — & C(OH) \\ CH_3 \nearrow & \end{matrix}$$

Neutral, colorless liquids of characteristic odor and burning taste. A few higher members of series are solids. React more readily than paraffins owing to presence of hydroxyl group. Oxidizing agents convert primary alcohols into aldehydes and then into fatty acids, which see below.

Class III. Ethers. Contain an oxygen atom united

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*The student should commit to memory the radicals in table 25, especially the first five.

to two hydrocarbon groups as methyl ether $CH_3.O.CH_3$, corresponding to K.O.K, just as methyl alcohol $CH_3.OH$ corresponds to K.OH. May be prepared by heating alcohols with H_2SO_4. Are all liquids except methyl ether, a gas, and are mobile, volatile, inflammable. Are decomposed by strong acids, yielding ethereal salts (esters). Are acted on by Cl and Br forming substitution products.

Class IV. Aldehydes:—Homologous series of general formula $C_n H_{2n+1}.CHO$. Derived from primary alcohols by removal of two atoms of H from the $—CH_2OH$ group. Examples, formaldehyde $H.CHO$ or CH_2O, acetaldehyde $CH_3.CHO$, or C_2H_4O since $(CH_3.CH_2.OH)+O=(CH_3.CHO)+H_2O$. Up to $C_{11}H_{22}O$ are colorless, mobile, neutral volatile liquids of irritating smell. Combine directly with two monad atoms. Are readily reduced and oxidized.

Acetals are combinations which aldehydes form with alcohols with elimination of water.

Certain substances used as hypnotics may be mentioned here:

Paraldehyde $(C_2H_4O)_3$, is a polymeric form of aldehyde as can be seen from its formula. It may be prepared from aldehyde by treating the latter with a little HCl or with H_2SO_4 or $ZnCl_2$.

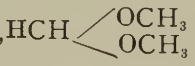
Chloral (*not* chloral *hydrate*) is trichloraldehyde, $CCl_3.COH$, made by action of chlorine on alcohol. Combined with water it forms *chloral hydrate*,

$$CCl_3.COH+H_2O.$$

Chloralamide (chloralformamide) $CCl_3.CHO.HCONH_2$ is a compound of chloral and formamide, $HCO.NH_2$.

Hypnal is a combination of chloral and antipyrin, mono-chloral-antipyrin.

Butyl Chloral, $C_4H_5Cl_3O$, combines with water to form a hydrate.

Methylal,  $HCH\begin{smallmatrix}\diagup OCH_3\\ \diagdown OCH_3\end{smallmatrix}$ is an *acetal* obtained by oxidizing methyl alcohol with H_2SO_4 and MnO_2, fractioning the product, and collecting the fraction boiling between 40° and 50°.

Class V. Ketones. Derived from the secondary alcohols by the removal of two atoms of hydrogen from the $>$CH.OH group. General formula, R.CO.R', in which R and R' may be the same or different radicals.

Among the more important ketones are acetone (dimethyl ketone) $(CH_3)_2$ CO, and propione $(C_2H_5)_2CO$.

The former occurs in the urine, blood, and secretions Both aldehydes and ketones may be regarded as derived from the paraffins, by substituting one atom of O for two of H; they are therefore, isomeric. In the case of aldehydes two atoms of H take the place of one of the CH_3— groups, but in the case of ketones the O atom is substituted for two H atoms of a —CH_2— group.

Class VI. Fatty Acids. Monobasic, saturated, products of the complete oxidation of the alcohol radical CH_3, and characterized by the group CO.OH. The principal members of this group with their formulas are

Formic acid CHO.OH.
Acetic acid $C_2H_3O.OH$
Propionic acid $C_3H_5O.OH$
Butyric acid $C_4H_7O.OH$
Valeric acid $C_5H_9O.OH$
Caproic acid $C_6H_{11}O.OH$

Palmitic acid $C_{16}H_{31}O.OH$
Stearic acid $C_{18}H_{35}O.OH$.

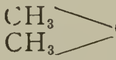
The fatty acids are very stable but undergo double decomposition because of carboxyl group. Lower members are liquids, grow oily on going up the series and from $C_{10}H_{20}O_2$ up are solids.

Certain liquids of peculiar odors may be mentioned here:—

Propionic acid, $C_3H_5O.OH$ or $C_2H_5\ COOH$, occurs in the urine and in perspiration.

Butyric acid, $C_4H_7O.OH$ or $C_3H_7.COOH$, is found in the free state in rancid butter, in perspiration, in the contents of the intestines, and in fæces.

Valeric acid, $C_5H_9O.OH$ or $C_4H_9.COOH$ occurs in crude wood vinegar.

Isovaleric acid  $\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>CH.CH_2COOH$ is found in the fæces and is a product of the decomposition of albuminoids. It may be readily obtained by oxidation of the amyl alcohol of fermentation by aid of sulphuric acid and potassium dichromate.

Valerianates are salts of valeric acid. Those of ammonium, iron, and zinc are used in medicine.

Caproic acid, $C_6H_{11}O.OH$ or $C_5H_{11}.COOH$ is produced in butyric fermentation of sugar and in the oxidation of albuminoids.

Among the higher fatty acids we find

Palmitic acid, $C_{16}H_{31}O.OH$ or $C_{15}H_{31}.COOH$, in palm oil; is a solid occurring in white scales.

Stearic acid, $C_{18}H_{35}O.OH$ or $C_{17}H_{35}.COOH$, a hard, white somewhat glossy solid, odorless, tasteless, and insoluble in water, melting at 69.2°C.

Derivatives of the fatty acids: All the fatty acids, except formic, may be converted into *acid chlorides, bromides,* etc.

Acetyl chloride, for example, may be made by adding phosphorus pentachloride to anhydrous acetic acid.

All the fatty acids, except formic, may be converted into *anhydrides* by treating the acid chloride with an alkali salt. Acetic anhydride, $(CH_3.CO)_2O.$, for example, may be prepared by heating the anhydrous alkali acetates with phosphorus oxychloride, acetyl chloride being first formed which interacts with more salt, forming acetic anhydride.

Fatty acids may be converted into *amides*. Thus *acetamide*, $CH_3.CO.NH_2$, may be produced by heating ethyl acetate with concentrated ammonia under pressure; *formamide* by distilling ammonium formate, etc.

Acetic acid yields three substitution products on treatment with chlorine in sunlight: of these the most important is *trichloracetic acid* $CCl_3.COOH$, though this is best prepared by oxidizing the corresponding aldehyde, chloral, with concentrated nitric acid. It is used in medicine in the quantitative determination of albumen, and as an antiseptic in dentistry.

Fatty acid derivatives include *amido-fatty acids* as amido-acetic acid, $CH_2(NH_2).COOH$, or "glycocoll"; amido-caproic acid, $C_5H_{10}(NH_2).COOH$, or "leucin". Both are decomposition products of albuminoids.

Fats:—Ethereal salts resulting from combination of fatty acids with the tri-acid *glycerol*, $C_3H_5(OH)_3$, after the analogy of tri-acid bismuth hydroxide, thus:

$$C_3H_5(OH)_3+3CH_3.COOH=C_3H_5(O.CO.CH_3)_3+3H_2O$$

Glycerol plus acetic acid equal glyceryl acetate (triacetin) and water, just as $Bi(OH_3)+3HCl=BiCl_3+3H_2O$.

Tripalmitin is a compound of glycerol and palmitic acid; *tristearin* of glycerol and stearic acid; *triolein* of glycerol and oleic acid*. Fats are composed chiefly of these three substances and are solid when the first two predominate, liquid when composed chiefly of triolein.

Soaps are formed when the glycerol compounds above mentioned (glycerides) are decomposed by treatment with alkalies, glycerol being liberated, thus:

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*Oleic acid, $C_{17}H_{33}COOH$, unsaturated, not a fatty acid.

$$C_3H_5\left\{\begin{array}{l}OC_{16}H_{31}O\\ OC_{16}H_{31}O+3NaOH\\ OC_{16}H_{31}O\end{array}\right.$$

$$=C_3H_5\left\{\begin{array}{l}OH\\ OH+3C_{16}H_{31}OONa\\ OH\end{array}\right.$$

Tripalmitin plus sodium hydroxide give glycerol and sodium palmitate or palm-oil soap. Again

$$2C_3H_5\left\{\begin{array}{l}OC_{18}H_{33}O\\ OC_{18}H_{33}O+3PbO+3H_2O=\\ OC_{18}H_{33}O\end{array}\right.$$

$$2C_3H_5\left\{\begin{array}{l}OH\\ OH+3(Pb2C_{18}H_{33}O_2)\\ OH\end{array}\right.$$

Triolein, litharge, and water give glycerol and lead oleate, the latter being what is called *lead plaster.*

Oleo-margarine is a pasty mass of oleic, palmitic, and stearic acids separated from stearin.

Butter when pure contains about 92 per cent. of a mixture of tristearin, tripalmitin, and triolein; also about 7.7 per cent. of *tributyrin* the glyceride of butyric acid. Artificial butter or *margarine* is made from oleomargarine by churning with milk and addition of butter color and salt. *Butterine* contains neutral lard, added to the oleo oil and milk before churning.

Class VII. Esters or Ethereal Salts:—*

Compounds of alcohols with acids.

Halogen ethereal salts:—identical with halogen monosubstitution products of the paraffins. May be prepared by treating paraffins as methane, ethane, etc., with Cl or Br in presence of sun-light; colorless, neutral, pleasant-smelling liquids except methyl chloride, CH_3Cl, which is a gas. The following esters (liquids) are anæsthetics:—*ethyl chloride*, C_2H_5Cl, *ethyl bromide*, C_2H_5Br; [also the deriv.

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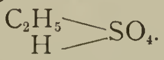
*Called also "compound ethers".

atives *methylene chloride*, CH_2Cl_2, *ethylene chloride* or Dutch liquid, $C_2H_4Cl_2$, and ethylidene chloride C_2H_4Cl].

[*Chloroform*, $CHCl_3$, *iodoform* CHI_3, *Carbon tetrachloride*, CCl_4, are closely related to the above in constitution].

Esters of nitric and nitrous acids:—Ethyl nitrate, $C_2H_5.NO_3$, a colorless liquid; ethyl nitrite, $C_2H_5NO_2$, liquid, in alcoholic solution known as "sweet spirit of nitre." *Amyl nitrite* or iso-amyl-nitrite, $C_5H_{11}O.NO$, is described in section 403. *Ethereal salts* of *sulphuric acid* include *sulphovinic acid,*



$$\begin{matrix} C_2H_5 \\ H \end{matrix} > SO_4.$$

Mercaptans and sulphides:—Compounds of hydric sulphide with alcohols; the mercaptans are *hydro*sulphides. *Sulphonal* and *trional* are related to ethyl mercaptan, $C_2H_5.SH$.

Ethereal salts of organic acids include such compounds as methyl butyrate $C_3H_7.COOCH_3$, or "pear oil." *Ethyl aceto-acetate*, $CH_3.CO.CH_2.COOC_2H_5$ is a similar compound and is of great importance in the synthesis of ketones and fatty acids.

Class VIII. Alkyl* compounds of nitrogen, arsenic, etc.

Amines:—Formed by introduction of an alcohol or basic radical into the ammonia molecule: thus, methylamine $NH_2.CH_3$ in which CH_3 is substituted for H in NH_3, hence a *primary* amine; dimethylamine, $(CH_3)_2NH$, is a secondary amine since two atoms of hydrogen have been replaced; trimethylamine, $(CH_3)N$, is a tertiary amine. *Amides* and *imides* substitute *acid radicals* in place of hydrogen atoms in ammonia: thus, *formamide*, $HCO.NH_2$, and *acetamide*, $C_2H_3O.NH_2$.

Various amine derivatives:—*neurin*, trimethyl-vinyl ammonium hydrate, $N(CH_3)_3C_2H_3.OH$, containing the unsat-

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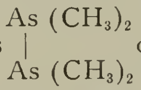
*Alkyl is the term given the alcohol radicals, methyl, ethyl, etc. See table 25, section 359.

urated radical vinyl. *Choline or bilineurin*, trimethyl-oxethyl ammonium hydrate, $N(CH_3)_3(C_2H_4OH).OH$ found in the brain as *lecithin*, in combination with glycerol-phosphoric acid. "*Piperazine*" is diethylene-diamine, $(C_2H_4)_2NH_2$. "*Putrescin*" is tetramethylene-diamine, $C_4H_8(NH_2)_2$. "*Cadaverine*" is pentamethylene-diamine $C_5H_{10}(NH_2)_2$. *Phosphines* are alkyl substitution products of PH_3, thus methyl phosphine, $PH_2.CH_3$. *Arsines*, *stibines*, etc., also occur. *Cacodyl* is  $\begin{array}{c} As(CH_3)_2 \\ | \\ As(CH_3)_2 \end{array}$ or diarsenic tetramethyl.

Class IX. Glycols or Diatomic Alcohols:—dihydroxy derivatives of the paraffins.

Form homologous series. General formula, $C_nH_{2n}(OH)_2$, closely related to monohydric alcohols. Among their oxidation products we find *glyoxal*, *glycocollic acid*, *lactic acid*, and *oxalic*, *succinic*, *malic*, *tartaric*, and *citric* acids. Double tertiary glycols are called "pinacones."

Class X. Trihydric or triatomic alcohols or glycerins:—

Formed by replacement of three atoms of hydrogen in a paraffin by OH groups. Such alcohols act like triacid bases and can combine with one, two, or three molecules of a monobasic acid. *Glycerin* is *propenyl glycerin*, $C_3H_5(OH)_3$, also called *glycerol*. *Nitro-glycerin*, is glycerol trinitrate, $C_3H_5(O.NO_2)$, an ethereal salt.

Unsaturated compounds related to glycerol are *allyl alcohol*, $CH_2{:}CH.CH_2.OH$, etc., *acrolein* or *acraldehyde*, $CH_2{:}CH.CHO$, *acrylic acid*, $CH_2{:}CH.COOH$.

Class XI. Carbohydrates: Composed of carbon, hydrogen, and oxygen in which the ratio of H to O is the same as in water: sugars, starches, celluloses. (Sec. 387).

Class XII. Cyanogen compounds.

Derived from cyanogen $(CN)_2$ like chlorides from Cl_2.

Hydrocyanic acid, HCN, potassium cyanide, KCN, like hydrochloric acid, HCl, and potassium chloride, KCl.*

Nitriles are ethereal salts of HCN, as methyl cyanide or acetonitrile, $CH_3.CN$.

Substances related to cyanogen:—Urea, CH_4N_2O, *uric acid*, $C_5H_4N_4O_3$, *glycine* (amido-acetic acid) $CH_2(NH_2).COOH$.

Substances related to uric acid:—Xanthine, $C_5H_4N_4O_2$, *guanine*, $C_5H_5N_5O$, *hypoxanthine*, $C_5H_4N_4O$. *Guanidine* is an amidine of carbonic acid, CH_5N_3; *creatine*, $C_4H_9N_3O_2$, and *creatinine*, $C_4H_7N_3O$, are related to guanidine.

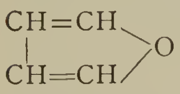
Class XIII. Furfurane, Thiophene, Pyrrol. [These substances are transition compounds between open-chain hydrocarbons, which have been discussed in the preceding pages and the aromatic or *closed-chain hydrocarbons*. In the latter, six atoms of carbon seem to join together in the closed-chain structure and this molecule holds together through many reactions].

Pyrrol, C_4H_4NH, is obtained from coal-tar.

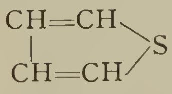
Tetraiodopyrrol, C_4I_4NH, is known as "iodol."

Antipyrin, $C_{11}H_{12}N_2O$, seems to be a derivative of the yet unknown pyrazol which is related to pyrrol.

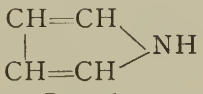
Furfurane, C_4H_4O, and thiophene, C_4H_4S, are two other compounds showing a closed chain structure with less than six carbon atoms. Thus:



Furfurane.



Thiophene.



Pyrrol.

All three are liquids showing analogous color reactions.

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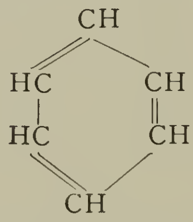
*Ferrocyanides and ferricyanides; see Table 4; sulphocyanates see Table 6.

Class XIV. Aromatics of one nucleus.

Benzene series of hydrocarbons:—the type is C_6H_6, benzene (not benz*i*ne). Its graphic formula is



in which there is alternate single and double linking. Homologues are formed by replacement of one or more of the six hydrogen atoms by methyl and ethyl groups: —thus, toluene $C_6H_5.CH_3$, the xylenes $C_6H_4(CH_3)_2$ etc. They are coal tar products.

The unsaturated hydrocarbons of this series are formed by replacement of a hydrogen atom of ethylene by a benzene radical, as phenyl, C_6H_5, seen in *styrene* (phenyl-ethylene, $C_6H_5.CH{=}CH_2$,) and *phenyl-acetylene* $C_6H_5.C{\equiv}CH$.

Halogen derivatives:—chloro-benzene C_6H_5Cl, bromo-benzene C_6H_5Br, etc., benzyl chloride, benzal chloride, and benzo-trichloride are related to these.

Sulphonic derivatives contain the monad group HSO_3, thus phenol-sulphonic acid $C_6H_4(OH)HSO_3$.

Nitro derivatives contain the monad group NO_2, attaching itself to the nucleus and not to the side-group,

Nitro-benzene, $C_6H_5.NO_2$, or "mirbane oil" is an important compound.

Amido derivatives may be regarded either as benzene in which NH_2 is substituted or ammonia into which C_6H_5 enters. Thus *aniline*, $C_6H_5NH_2$, may be regarded as either amido-benzene or phenylamine. It is a colorless, oily liquid, acting as a weak base. *Sulphanilic acid* is para-amido-benzene-sulphonic acid, $C_6H_4(HSO_3).NH_2$, a substituted aniline with replacement in the nucleus.

Methyl-aniline $C_6H_5.NH(CH_3)$ is a substituted aniline with basic group in side-chain.

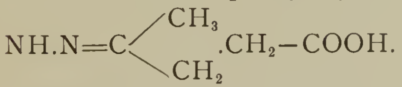
Anilids are substituted anilines with acid groups in side-chain: *acetanilid*, $C_6H_5.NH(C_2H_3O)$, or "antifebrin" is an example.

Para-bromacetanilid, $C_6H_4BrNH(C_2H_3O)$, is known as "Asepsin" or "antisepsin." *Methyl-acetanilid*, $C_6H_5.N(CH_3)\ (C_2H_3O)$, is known as "exalgin."

Among *secondary monamines* is *diphenylamine*, $(C_6H_5)_2.NH$, used as a reagent for nitrites in water analysis.

Diazo and azo compounds:—Both contain the dyad group $-N=N-$, linking in the former a hydrocarbon radical with an acid, as diazo-benzene nitrate, $C_6H_5.N{=}N.NO_3$, in the latter two hydrocarbon radicals, as azo-benzene $C_6H_5-N{=}N-C_6H_5$.

Aromatic hydrazines:—Are derivatives of hydrazine, NH_2-NH_2, formed by replacement of hydrogen atoms by alcohol radicals, thus, *phenyl hydrazine*, $C_6H_5.NH-NH_2$, which form with sugars *hydrazones* and *osazones*. "*Hydracetin*" is acetyl-phenyl-hydrazid, $C_6H_5.NH-NH(C_2H_3O)$. "Antithermin" is phenyl-hydrazine-levulinic acid, $C_6H_5.$



$$NH.N{=}C\begin{matrix}\diagup CH_3\\ \\ \diagdown CH_2\end{matrix}.CH_2-COOH.$$

"Agathine" is a preparation of salicylic aldehyde and methyl-phenyl-hydrazine.

Phenols:—Hydroxyl derivatives of the benzene series in which the OH group replaces a hydrogen atom of the nucleus, thus phenol, $C_6H_5.OH$. They are not oxidizable without decomposition. *Phenol* (carbolic acid) is a monatomic phenol. Among its derivatives are trichlorphenol, $C_6H_2Cl_3.OH$; tribromphenol, $C_6H_2Br_3.OH$; nitrophenols, as *picric acid* (trinitro-phenol) $C_6H_2(NO_2)_3.OH$; amido-phenols; phenetidins, as acetparaphenetidin or "*phenacetin,*" $C_6H_4\left\{\begin{matrix}OC_2H_5\\ NHC_2H_3O\end{matrix}\right.$; glycocoll-phenetidin or "*phenocoll;*" phenol-sulphonic acid, ortho ("*aseptol*" or sozolic acid) $HSO_3.C_6H_4.OH_5$ called also *sulphocarbolic acid*, and its salts sulphocarbolates.

Among the homologues of phenol are the *cresols*, $C_6H_4(CH_3).OH$. Derivatives of the latter are *thymol* or para-propyl-meta-cresol, $C_6H_3.\overset{1}{C}H_3.\overset{3}{O}H.\overset{4}{C}_3H_7$; *aristol* or dithymoldi-iodide, $C_{20}H_{24}O_2I_2$; *carvacrol*, or para-propyl-ortho-cresol, $C_6H_3.\overset{1}{C}H_3.\overset{2}{O}H.\overset{4}{C}_3H_7$.

Diatomic phenols include *pyrocatechin*, $C_6H_4(OH)_2$, *guaiacol* $C_6H_4\left\{\begin{matrix}OH\\ OCH_3\end{matrix}\right.$, *resorcin*, $C_6H_4(OH)_2$, and *hydroquinone*, $C_6H_4(OH)_2$.; *orcin* or dioxy-toluene $C_6H_3(CH_3)(OH)_2$ from which is derived orcëin, $C_7H_7NO_3$, to which *litmus* is related; *creosol*, $C_6H_3(CH_3)\left\{\begin{matrix}OH\\ OCH_5\end{matrix}\right.$ found with guaiacol in beech-wood tar; *eugenol*, $C_6H_3(OH)_2(CH_2.CH{=}CH_2)$ a methyl ether of an unsaturated phenol.

Triatomic phenols include the three isomers, *pyrogallol*, *phloroglucine*, and *oxyhydro-quinone*, $C_6H_3(OH)_3$.

Pentatomic phenols: among these are *inosite*, $C_6H_{12}O_6$, found in the organs of the body and sometimes in urine.

Quinones:—A class of benzene derivatives in which two hydrogen atoms seem to be replaced by two oxygen ones. *Quinone*, $C_6H_4O_2$, is perhaps a ketone of a dihydro-benzene. *Chloranil* is tetrachlor-quinone, $C_6Cl_4O_2$.

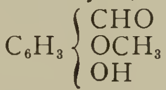
Aromatic alcohols:—Are hydroxyl derivatives of the benzene series, in which the OH group replaces hydrogen of the side group, instead of that of the nucleus. They are primary alcohols containing the group $-CH_2.OH$ hence can be oxidized to aldehydes and acids. *Benzyl alcohol*, $C_6H_5.CH_2OH$, when oxidized yields first *benzaldehyde*, $C_6H_5.COH$, and then *benzoic acid* $C_6H_5.COOH$.

Benzaldehyde is "oil of bitter almonds;" condensed with sodium acetate it forms cinnamic acid.

Aromatic ketones:—Are analogous to the methane ketones: *aceto-phenone* or "hypnone" is $C_6H_5.CO{-}CH_3$; *gallaceto--phenone* is $C_6H_2(OH)_3.COCH_3$.

Phenol alcohols:—Are called oxy alcohols; contain at least two OH groups, one of which (the phenolic OH) is directly attached to the nucleus, and the other (the alcoholic OH) is contained in the side group, which will then be CH_2OH. Their empirical formulas differ by one additional oxygen atom from their corresponding aromatic alcohols.

Phenol aldehydes:—Called oxy aldehydes; contain, besides the aldehyde group COH, the phenolic OH. *Salicyl aldehyde*, $C_6H_4(OH)COH$, is an example. *Vanillin* is methyl-protocatechuic aldehyde,



$$C_6H_3\left\{\begin{array}{l}CHO\\OCH_3\\OH\end{array}\right.$$

Aromatic acids and phenol acids:—Contain one or more carboxylic groups, COOH, linked either directly or indirectly with the phenyl group or the benzene nucleus.

Benzoic acid, $C_6H_5.COOH$, is an aromatic, monobasic, saturated acid; *cinnamic acid*, $C_6H_5.CH{=}CH.COOH$, an unsaturated, polybasic one.

Salicylic acid, (oxybenzoic) $C_6H_4(OH)COOH$ is a phenol acid; *Salol* is phenyl salicylate, *salophen* is acetyl-para-amido-phenol salicylate, $C_6H_4(OH)-COO.(C_6H_4NH.COCH_3)$.

Tyrosine is an amido acid sometimes found in urine; its formula is $C_6H_4(OH).CH_2.CH(NH_2).COOH$. *Gallic acid* is $C_6H_2(OH\}_3.COOH$; *Tannic acid*, $C_{14}H_{10}O_9$. "Dermatol" is basic bismuth gallate, $C_6H_2(OH_3)COOBi(OH)_2$.

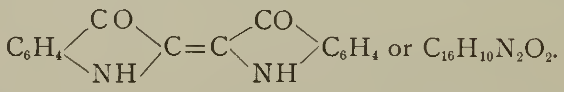
Class XV. Aromatics of more than one nucleus.

These are (a) compounds in which the several benzene nuclei are joined together without condensation, and (b) those in which two or more benzene nuclei have been condensed together to form a new and distinctive nucleus or grouping.

Compounds with uncondensed nuclei:—

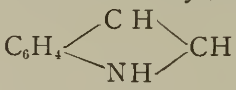
Triphenyl methane, $CH-(C_6H_5)_3$, is important.

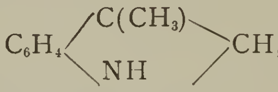
Malachite greens are diamide derivatives of triphenylmethane; *rosanilines* are triamide derivatives, etc. The *phthalein* group are derivatives of triphenyl-methane-carboxylic acid, as *phenol phthalein. Indigo* is made synthetically from *o*–nitro-phenyl-propiolic acid, $C_6H_4(NO_2)-C \equiv C.COOH$, when heated with reducing agents. The graphic formula for indigo is



$$C_6H_4<\begin{matrix}CO\\NH\end{matrix}>C=C<\begin{matrix}CO\\NH\end{matrix}>C_6H_4 \text{ or } C_{16}H_{10}N_2O_2.$$

Indigo carmine is the sodium salt of indigo-disulphonic acid, $C_{16}H_8(SO_3H)_2N_2O_2$, made by treating indigo with fuming sulphuric acid.

Isatin, $C_8H_5NO_2$, is an oxidation product of indigo. By reduction of isatin is obtained *indoxyl,* C_8H_7NO, found in normal urine. *Indol*  $C_6H_4<\begin{matrix}CH\\NH\end{matrix}>CH$ underlies the whole indigo group and is a product of pancreatic fermentation.



$$C_6H_4<\begin{matrix}C(CH_3)\\NH\end{matrix}>CH$$

Skatol, $C_6H_4<\begin{matrix}C(CH_3)\\NH\end{matrix}>CH$, is found in the fæces, having the characteristic odor.

Compounds with two condensed benzene nuclei:—

Two series of hydrocarbons of general formulas C_nH_{2n-12} and C_nH_{2n-18}, derivatives of benzene.

Naphthalene series:—naphthalene, $C_{10}H_8$, is a coal tar product, occurring in white, lustrous scales. It is used as an antiseptic, disinfectant, and preservative against moths; on a large scale for the manufacture of phthalic acid, etc.

"*Thermin*" is a substitution derivative of naphthaline, tetrahydro–beta–naphthylamine.

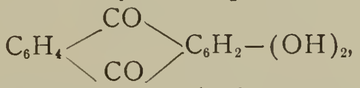
The *naphthols*, $C_{10}H_7.OH$, are the simple hydroxyl derivatives of the naphthalene series. The Naphtol of the U. S. P. is beta-naphthol. *Betol* is beta-naphthyl-salicylate, a derivative of beta-naphthol. Its formula is $C_6H_4(OH)COOC_{10}H_7$.

Asaprol is beta-naphthol-alpha-monosulphonate of calcium.

Alpha and *Beta-Naphthoic acids* are derived from homologues of naphthalene, as alpha and beta methyl-naphthalenes.

Compounds with three condensed nuclei:—anthracene is an example, $C_{14}H_{10}$, in which formula we have two benzene residues, C_6H_4, united by the group C_2H_2 as the middle nucleus.

Alizarine is ortho-dioxy-anthraquinone,



$$C_6H_4 \begin{matrix} \diagup CO \diagdown \\ \diagdown CO \diagup \end{matrix} C_6H_2-(OH)_2,$$

formed by replacement of the hydrogen in the anthraquinone formula by an OH group. "Turkey red" is made from alizarine.

Chrysophanic acid, $C_{14}H_5(CH_3)(OH)_2O_2$, is a hydroxyl derivative of an anthracene homologüe methyl-anthracene. *Chrysarobin*, $C_{20}H_{26}O_7$, found in Goa powder, is related to chrysophanic acid as anthrarobin is related to alizarine.

Compounds containing nitrogen in the benzene nucleus:—Pyridine, C_5H_5N, results from replacement of one triad group, CH, in the benzene molecule. It is a coal-tar product. "Collidines" are tri-methyl pyridines.

Piperidine is an hydrogen addition product of pyridine, $C_5N_5N.H_6$, or hexahydropyridine. *Coniine* the poisonous principle of hemlock is dextro-rotatory-alpha-normal propyl-piperidine, $C_5H_{10}N(C_3H_7)$.

Nicotine, $C_{10}H_{14}N_2$, is hexahydro-dipyridyl $C_{10}H_8(H_6)N_2$. Tropine, cocaine, and ecgonine are hydrogenated pyridine derivatives.

Quinoline, C_9H_7N, results from the replacement of one triad group, CH, in the naphthalene molecule by the element nitrogen. It is a pale-yellowish liquid, (See section 453).

"Kairine" is a quinoline derivative. "Thalline" is the sulphate of a base *tetrahydro-paraquinanisol*, $C_9H_{10}(OCH_3)N$.

"Diaphtherine" is a compound of one molecule of aseptol with two of ortho-oxy-quinoline.

"Analgene" is another quinoline derivative. "Orexine" is the chlorhydrate of phenyldihydro-quinazoline, $C_{14}H_{12}N_2.HCl+2HO$.

Class XVI. Alkaloids: see section 448.

Class XVII. Ptomaines, leucomaines, toxalbumins.

Ptomaines are putrefactive or cadaveric alkaloids. They resemble vegetable alkaloids. Non-poisonous, non-oxygenated liquid ptomaines are *methylamine*, *dimethylamine*, *trimethylamine*, etc.; also *mydine*, $C_8H_{11}NO$, *betaine*, $C_5H_{13}NO_3$, *pyocyanine*, $C_{14}H_{14}NO_2$. Poisonous, non-oxygenated ptomaines are *putrescine* $C_4H_{12}N_2$, *cadaverine* $C_5H_{14}N_2$, *hydrocollidine* $C_{11}H_{13}N$, *collidine* $C_6H_{11}N$, *parvoline* $C_9H_{13}N$, *tyrotoxicon* $C_6H_5N_2$ or $C_6H_5.N=N$. Oxyenated ptomaines which are poisonous are *neurine* $C_5H_{13}NO$, *choline* $C_5H_{15}NO_2$, *muscarine* $C_5H_{15}NO_3$, *gadinine* $C_7H_{16}NO_2$, *mytilotoxine* $C_6H_{15}NO_2$, *tetanine* $C_{13}H_{30}N_2O_4$, *spasmotoxine*, *typhotoxine* $C_7H_{17}NO_2$. Poisonous ptomaines are sometimes called *toxines*.

Leucomaines are basic substances found in living tissues either as the products of fermentative changes or of retrograde metamorphosis. Vaughan gives the following table:—

TABLE OF LEUCOMAINES.

Formula.	Name.	Discoverer.	Source.	Physiological action.
$C_5H_5N_5$	Adenine.	Kossel.	Nuclein-containing organs.	Non-poisonous; muscle stimulant.
$C_5H_4N_4O$	Hypoxanthine.	Scherer.	Nuclein-containing organs.	Non-poisonous; muscle stimulant.
$C_5H_5N_5O$	Guanine.	Unger.	Nuclein-containing organs, guano.	Non-poisonous; muscle stimulant.
$C_5H_4N_4O_2$	Xanthine.	Marcet.	Nuclein-containing organs, calculi.	Non-poisonous; muscle stimulant.
$C_6H_6N_4O_2$	Heteroxanthine.	Salomon.	Urine.	
$C_7H_8N_4O_2$	Paraxanthine.	Thudichum Salomon.	"	Poisonous.
$C_7H_8N_4O_3$	Carnine.	Weidel.	Liebig's meat extract.	Non-poisonous; muscle stimulant.
$C_4H_5N_5O$	Pseudoxanthine(?)	Gautier.	Muscle.	
$C_5H_{14}N_2$	Gerontine.	Grandis.	Liver of dogs.	Poisonous.
$C_2H_5N(?)$	Spermine.	Schreiner.	Sperma, in tissues of leucocythæmics.	Non-poisonous.
$C_5H_8N_4O$	Cruso-creatinine.	Gautier.	Muscle.	
$C_5H_{10}N_4O$	Xantho-creatinine	"	"	Poisonous.
$C_9H_{19}N_7O_4$	Amphi-creatine.	"	"	
$C_{11}H_{24}N_{10}O_5$	Unnamed.	"	"	
$C_{12}H_{25}N_{11}O_5$	"	"	"	
$C_7H_{12}N_4O_2$	"	Pouchet.	Urine.	
$C_3H_5NO_2$	"	"	"	
$C_{34}H_{60}N_2O_5$	Salamandarine.	Zalesky.	Salamander.	Poisonous.

Toxalbumins:—A group of bacterial proteids formed by action of micro-organisms on albuminous matter. They resemble the normal proteids, Class XVIII. Among them are the proteid poison of diphtheria obtained as a white, amorphous powder from cultures of the Lœffler diphtheria bacillus, an intensely poisonous substance; others are the proteids from cultures of the tetanus bacillus, cholera bacillus, typhoid bacillus, etc.

Antitoxins are bodies of unknown chemical composition, thought to be nucleins, which have the power to protect the individual against attacks of the disease during progress of which they were formed. They are made from the blood-serum of animals which have recovered from infectious diseases, as tetanus or diphtheria. The name "antitoxin" is given to the diphtheria antitoxin.

Class XVIII. Proteids. See section 470 and also the part on Physiological Chemistry, Chapter XV.

Class XIX. Ferments. See section 476 and also the part on Physiological Chemistry, Chapter XV.

The student is now ready to study at greater length the preparation and properties of important organic compounds as follows:

314. Hydrocarbons.

Group 1. Paraffins: the general formula for this series is C_nH_{2n+2}, which means that, however many carbon atoms a paraffin contains, it will contain *twice* as many hydrogen atoms and two more. Thus marsh gas, a member of this series, contains one atom of carbon; one multiplied by two and two added to the product equals *four*, therefore the number of hydrogen atoms is *four*, and the formula is CH_4.

American petroleum contains many members of this series. They are isolated from petroleum by *fractional distillation.* This process may be conducted in the following manner: the liquid to be distilled is placed in a retort, through the tubulure of which a thermometer passes to indicate the temperature at which the substance boils. The first portion, which distills over, will consist chiefly of that liquid which has the lowest boiling point, and, if the receiver be changed at stated intervals corresponding to a certain rise in the temperature, a series of liquids will be obtained, containing substances the boiling-points of which lie within the limits of temperature between which such liquids are collected.

315. **Petroleum or Mineral Oil:—**

This substance, known as *rock oil* or *liquid bitumen*, is a natural product, consisting of a number of hydrocarbons,* together with small quantities of sulphuretted, oxygenized, and nitrogenized bodies. It contains about 85 per cent. of carbon, and 15 of hydrogen.

316. Among the products obtained from petroleum are *rhigolene*, *gasoline*, *naphtha*, *benzine*, *kerosene*.†

317. **Rhigolene:** one of the lighter products of petroleum, sp. gr. from 0.590 to 0.625. Highly volatile, inflammable, boils at 70°F, colorless, odorless, when pure. It

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* These are homologous derivatives of CH_4 up to about $C_{16}H_{34}$.

† In distilling the crude oil, naphtha, benzine, rhigolene, etc., being the lightest come over first; then at greater heat, *kerosene*; the residue is composed of the heaviest compounds which require high heat for their distillation: namely, lubricating oil, vaseline, paraffine, etc.

is used for producing local anæsthesia. Most specimens of it have a disagreeable odor of petroleum. It should be kept in a cool place, in a tightly stoppered flask, and should not be brought near a light nor used at all at night.

318. **Gasoline:** this substance is the lightest and most volatile portion of petroleum "naphtha," and is employed for napthalizing gas and air. Its specific gravity is from 0.650 to 0.665. It boils at 119°F.

319. **Naphtha** has a density of from 0.695 to 0.705, and is often an adulterant of kerosene.

Mineral Naphtha or **"benzine":** this substance should not be confused with *benzene*. "Benzine" is a petroleum product, while benzene is a coal-tar product. The synonyms of "benzine" are petroleum spirit, petroleum naphtha, shale naphtha, benzoline.

It is a thin, colorless liquid of 0.69 to 0.74 sp. gr., inflammable, volatile. It dissolves gutta percha, napthalin, paraffin wax, and many similar substances. It is used as an illuminating agent in sponge lamps.

320. **Mineral burning oil or kerosene:** American petroleum yields from 50 to 70 per cent. of its weight of kerosene, which is also called refined petroleum, photogene, and paraffin oil.

It is a solvent of sulphur, iodine, phosphorus, camphor, wax, fats, many resins. It softens india-rubber to a glairy varnish. Its sp. gr. is from 0.78 to 0.82. Good lamp oil should neither be too viscous nor too volatile, and should have a tolerably high boiling point. Cold oil of good quality will not take fire, when a light is applied to it, nor should its vapor inflame. New York State law declares that oils used for illuminating purposes shall not give a vapor that will "flash" below 100°F., nor shall themselves ignite below 300 F.

321. **Vaselene or vaseline.**—

Synonyms: cosmolene, saxolene, petroleum jelly.

Theoretical constitution: *vaselene is a mixture of hydrocarbons*, consisting chiefly of those whose formulæ are from $C_{16}H_{34}$ to $C_{20}H_{42}$, together with some of the olefine series.

Preparations: vaselene consists of those portions of petroleum which, at ordinary temperatures, are soft or pasty. The last distillate or the undistilled portion is treated with superheated steam, and filtered through animal charcoal.

Properties and uses: colorless or pale yellow, odorless, translucent, slightly fluorescent, neutral, semi-solid. Its sp. gr., when melted, is 0.840 to 0.866, and it melts from 95°F. to 104°. It is insoluble in water, nearly in alcohol, freely soluble in ether, chloroform, benzene, carbon disulphide, and turpentine. It is miscible in all proportions with fixed and volatile oils. It forms an intimate mixture with glycerine. It dissolves sulphur, iodine, bromine, carbolic acid, atropine, strychnine, phosphorus, benzoic acid, and iodoform, the last best when warmed. *It can not be saponified, nor does it become rancid;* hence is a valuable agent in ointments. It is but little affected by chemical reagents. *It is a valuable substitute for lard in the preparation of ointments containing sulphur, the iodides, compounds of lead, zinc, and mercury.*

Use in dentistry: vaseline is used as an application to inflamed surfaces, as a dressing in periostitis, and as an emollient after devitalization or removal of dental pulps.

322. **Mineral lubricating oil:** the various products known by this title are obtained from the less volatile fluid portions of petroleum. It consists chiefly of higher members of the olefine series. Its color ranges from pale yellow, through all shades of red, brown, green and blue, to black. Good qualities have very little taste, and no marked smell, even when heated.

323. Group 3. Hydrocarbons of the *fourth* series. General formula, C_nH_{2n-4}.

[Hydrocarbons of the *third* series, C_nH_{2n-2}, are of no importance to the dentist]. Those of the *fourth* series include turpentine and a large number of oils, essential or volatile so-called. These different essential oils are mostly isomers or polymers, having for a formula $C_{10}H_{16}$, or some multiple of it.

324. **Oil of turpentine:** $C_{10}H_{16}$, called also **spirit of turpentine** and essence of turpentine, obtained by distilling turpentine or oleo-resinous juice, exuding from various kinds of pine.

It is a colorless, mobile liquid, having peculiar, aromatic and disagreeable odor; acrid, caustic taste; does not mix with water; soluble in alcohol; dissolves iodine, sulphur, phosphorus, fixed oils, resins, etc.; exposed to the air absorbs oxygen, becomes thicker, finally resinous. *After prolonged contact with air becomes ozonized.* Sp. gr., 0.864. Boiling point, 312°F. It is miscible in all proportions with ether, or at least very soluble in it, and in carbon disulphide, chloroform, benzine. petroleum spirit, fixed and essential oils. *It dissolves fats, waxes, resins, and caoutchouc.*

325. *Sanitas oil* is made by oxidizing oil of turpentine, floating on water, by a stream of heated air.

326. **Terpenes, terpin, terebene, etc.:** there has been great confusion in regard to the names of these substances.

Terpene is the general name for hydrocarbons having $C_{10}H_{16}$ or some multiple for their composition. Thus, for example, pure oil of turpentine, $C_{10}H_{16}$, is called a terpene. [*Camphene* has been used as a general term for terpenes, *but it is also used for a particular kind of terpene*].

Terpene is not the same as terpin or terpine; terpin is a *particular* member of the group to which the *general* name terpene is given. Terebene is a terpene. Terpenes are either natural or artificial: the natural terpenes occur in oil of turpentine; the artificial are camphene, terebene, menthene, cajuputene, etc., etc. The derivative from *French oil of turpentine only* is called terpene hydrate. Derivatives from any oil of turpentine are terpene hydrochloride, terpin hydrate, terpin, terpinol, etc., etc.

327. **Terebene:** this substance, $C_{10}H_{16}$, isomeric with oil of turpentine, is an artificial terpene produced by the action of sulphuric acid on oil of turpentine. *It is a molecular modification of essence of turpentine.* It is a clear, color-

less liquid and an agreeable remedy, having an odor like that of freshly sawn pine wood. It does not mix with water. It imparts a very distinct odor of violets to the urine.

Dr. Wm. Murrell, of London, has employed terebene for the last five years and has made experiments to ascertain its properties. In the proportion of one to five hundred it checks fermentation, and in one to one thousand prevents it.

It absorbs oxygen readily, and is a disinfectant, and antiseptic. It dissolves in the various essential oils, and is a solvent for gutta percha, iodine, and resins. It is soluble in 10 parts of alcohol. Its sp. gr. is 0.860, and it boils at 313°F. Most commercial terebenes are contaminated with resin, turpentine, and dioxide of hydrogen. It is, however, almost impossible to prevent the formation of hydrogen dioxide in terebene, which, so far as topical action is concerned, does no harm, but is of advantage. Iodol and terebene are now used together in proportions as follows: iodol, 10 grains, terebene, 1 fluid ounce.

Terebene is used in dentistry as an *antiseptic*, *disinfectant*, and stimulant.

328. **Terpin:** and **terpin hydrate:** the "terpin" used in medicine should preferably be called terpin hydrate, as it is not properly terpin. Nor is it by any means terp*ene* hydrate. The substance now used as an expectorant is $C_{10}H_{16}\ (H_2O)_2,\ H_2O$. It occurs in large, transparent crystals.

329. **Essential or volatile oils:**[*] theoretical constitution: most of the volatile oils of plants are *terpenes*, that is, hydrocarbons of formula $C_{10}H_{16}$; others are polymers of terpenes of

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[*] Called *essential* oils because usually the fragrant essence of plants especially of the flowers.

formula $C_{15}H_{24}$. The hydrocarbons of plants are liable to change in contact with air or moisture, so that they are not found in the pure state, even when freshly obtained. Some essential oils consist mostly of certain ethers, some of aromatic aldehydes.

Preparation: the volatile oils of plants may be obtained either by *pressure,* as in case of oils of laurel, lemon, or bergamot; by *distillation* with water, or by passing a current of *steam* over the matter to be extracted; by *fermentation and distillation*, as with oils of mustard and bitter almonds; by *solution in a fixed oil.*

General properties: essential oils of plants are *liquid* at ordinary temperatures, but deposit solid matters in severe cold. Usually lighter than water, colorless or yellow, rapidly darkening and ultimately becoming resinoid, of marked and highly characteristic odor, readily combustible, *nearly insoluble in water*, *freely soluble in alcohol*, miscible in all proportions with carbon disulphide, fixed oils, turpentine, and petroleum spirit; as a rule not saponified nor acted on by alkalies, but destroyed by strong nitric or sulphuric acid. They may be separated from their alcoholic solutions† by addition of water or solution of

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†An alcoholic solution of a number of these oils is called a *cologne.*

sodium sulphate. They are very often adulterated with alcohol, chloroform, oil of turpentine, and fixed oils. Cheaper essential oils are often mixed with the more expensive. Essential oils are gradually affected by exposure to air, some oxygen being absorbed, while at the same time a peculiar resin is formed. This oxidizing action is attended by development of ozone. If a spray of one of these oils be discharged into a room where there is plenty of sunlight, enough ozone is generated to purify the air.

It is likely that the oxidation and change of these oils is due to the presence of small traces of water. Mr. John Williams has obtained anhydrous essential oils, by means of apparatus in which the oils were distilled without presence of water.

330. **Anise oils:** the Saxon oil is the best, though the Russian is much liked. The official, Oleum Anisi, is colorless or yellowish, with the peculiar odor and taste of the seed. Its sp. gr. is 0.976 to 0.990, increasing by age. At 50°–59°F. it solidifies, but is fluid at 62°.6. It is soluble in an equal weight of alcohol.

331. **Bergamot:**Oleum Bergamii. It is of sweet, very agreeable odor, and of bitter, aromatic, pungent taste. In color the oil is pale green-yellow. The reaction is slightly acid. It is soluble in alcohol.

332. **Cajuput:** this oil is transparent, with lively, penetrating, camphor-like odor, of green color, and warm, pungent taste. The green color is due to copper, sometimes to chlorophyll. It is met with of a greenish color, even when no copper is present. A specimen of Paris oil contained, according to Guibourt, 0.022 per cent. of copper.

Cajuput oil is used in dentistry as a local application in odontalgia, and in neuralgia. Oleum Cajuputi is the official name.

333. **Caraway:** this oil, Oleum Cari, is somewhat viscid, pale yellow, becoming brownish with age, with odor of the fruit, and of aromatic, acrid taste. It consists of two liquid oils, *carvene* and *carvol*, is of neutral reaction, and soluble in alcohol.

334. **Carvacrol:** obtained by treating caraway oil with iodine, and washing the product with caustic potash. Pure carvacrol is a viscid, colorless oil, nearly insoluble in water, of an odor like creasote, and of strong, acrid, persistent taste. It is lighter than water. It is antiseptic, disinfectant, and escharotic. It is used in dentistry locally in odontalgia, where there is sensitive dentine, alveolar abscess, as an *antiseptic*, and in gargles. It dissolves Hill's Stopping and gutta percha.

335. **Cinnamon:** obtained by distillation from cinnamon, of a light yellow color when freshly prepared, becoming deeper by age and finally red. It has a pungent, hot taste. It is used in dentistry locally, for relief of odontalgia.

336. **Cloves:** the oil of cloves contains a *cedrene* or hydrocarbon having the formula $C_{15}H_{24}$, and called *caryophyllin*. It contains other substances, as tannin, resin, and an oxygenized oil called *eugenol*, or *eugenic acid*. Oil of cloves is clear and colorless when freshly prepared, but yellow and finally reddish-brown on exposure. It has a hot, aromatic taste, and the odor of cloves. Good Zanzibar cloves yield about 18 per cent. of oil. Oil of cloves is used to disguise the odor of

carbolic acid, creasote, etc. It is used in dentistry to relieve odontalgia.

337. **Eucalyptus:** the oil of eucalyptus is colorless or very pale, yellowish, of characteristic aromatic odor, and pungent, spicy, cooling taste, neutral in reaction and soluble in alcohol. The official name is Oleum Eucalypti.

338. **Eugenol:** $C_{10}H_{12}O_2$, an oxidized oil, prepared by decomposing potassium eugenate with sulphuric acid. It is properly an acid, and will be considered under the head of acids.

339. **Lavender:** this oil is obtained from the flowers of *Lavandula vera*, and is of a pale-yellow color.

340. **Oil of Gaultheria** is a stimulant, volatile oil from the leaves of *Gaultheria procumbens*, first colorless, gradually becoming reddish, and one of the heaviest of the volatile oils. About 90 per cent. of the oil is composed of the so-called methyl salicylate, $(CH_3(C_7H_5O_3)$. The formula of salicylic acid is $C_7H_6O_3$; that of methyl salicylate, $C_7 \left\{ \begin{matrix} H_5 \\ CH_3 \end{matrix} \right\} O_3$.

341. **Mint:** oil of peppermint, Oleum Menthæ Piperitæ, is of greenish-yellow color, becoming reddish by age. It has a strong aromatic odor, and a warm, camphorous, pungent taste, succeeded by a sensation of coolness, when air is drawn into the mouth.

342. **Neroli:** the oil obtained from orange flowers is termed oil of neroli, and is a volatile oil of delightful odor.

343. **Pyrethrum:** the oil dissolved in ether is used in odontalgia. Pyrethrum or pellitory is a powerful local irritant.

344. **Rose:** this substance, known also as *attar* or *ottar* of rose, is nearly colorless, concrete below 80°F., liquid between 84° and 86°F. It has a powerful and diffusive

odor, is slightly soluble in alcohol, and of a slightly acid reaction. The official name is Oleum Rosæ. Probably *all* the oil of rose of the Turkish market is adulterated. It should, when slowly cooled to 50°F., deposit a crystalline substance, called a *stearopten*, free from oxygen.

345. **India-rubber:** caoutchouc or India-rubber is the dried, milky juice obtained from several trees growing in the tropics. When freshly obtained the juice is acid in reaction. It contains several hydrocarbons which are soluble in ether, benzole, carbon disulphide, chloroform, and turpentine, but insoluble in water and in alcohol. It is hard and tough in the cold, softens on heating, becomes elastic, melts, and, on cooling, is soft and viscid. It combines directly with sulphur, hardening, and forming **Vulcanized India-rubber;** carbon disulphide is used to facilitate the union. Mixed with half its weight of sulphur, **Vulcanite** or **Ebonite** is formed.*

Dental rubber: India-rubber is prepared for vulcanizing by incorporating with it either sulphur alone, or some of its compounds; a coloring matter is also added, in many cases mercuric sulphide (vermilion) but white clay, oxide of zinc, and calcium carbonate are also used. Para rubber is the kind used, the vermilion being added when a "red rubber" is desired, and the oxide of zinc or some form of

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* Both India-rubber and gutta-percha resist the action of most chemical substances, and hence are dissolved with difficulty.

aluminium silicate, as white clay, when a "white rubber." "Black rubbers" are the result of vulcanizing the rubber directly with sulphur, no pigment being added. It is claimed that the various pigments, when in large percentage, produce soft, inflexible rubbers. Difference in shade of red is supposed to be due to difference in percentage and kind of vermilion used.

346. **Gutta-percha** resembles caoutchouc in chemical characters, and is the *hardened milky juice* of an Indian tree. It is *harder than rubber and less elastic*, but becomes quite soft in hot water, and can then be moulded. When purified it is brown-red, of a density of 0.979, electrified by friction, and is a very slow conductor of electricity. It has, at ordinary temperatures, *considerable tenacity*, is as strong as leather but less flexible. At 115°F., it is pasty and still very tenacious. At 103° and 104°F., it may be spread out into sheets, or drawn out into threads or tubes. Its suppleness and ductility diminish as the temperature is lowered, and it has not at any temperature the elastic extensibility of caoutchouc. Softened by heat, it may be worked by pressure into any shape. It is *soluble in carbon disulphide*, benzene, chloroform, in hot oil of turpentine. *It is insoluble in water,* in which it is best preserved, *resists alkalies, hy-*

drochloric acid, and hydrofluoric acid. Gutta-percha alters, and this fact must not be forgotten. If in thin sheets or threads, at a temperature of from 77° to 86°F., it gradually becomes useless and gives off a pungent odor. The change is due to oxidation.

Use in dentistry: gutta-percha is used as a plastic filling material. It is an ingredient of Hill's Stopping. Together with oxide of zinc, it is used as a filling material. According to Flagg it is easy to raise the gutta-percha to any reasonable degree of temperature at which it becomes plastic, by simply increasing the relative quantity of inorganic admixture, but this very increase is destructive to the value of the gutta-percha.

As found it is often adulterated, but owing to advanced knowledge pure gutta-percha can be more readily obtained than formerly. We have to distinguish between two forms of adulteration, those used for the purpose of fraud in weight,—that is, foreign substances such as small stones, sand, and pieces of bark; and, second, those that combine with it to injure its strength,—pitch, tar, etc. But, strange to say, none of these latter interfere with its hardness when cold. This last adulteration the dentist has to guard against, and therefore to test its strength it should be slightly warmed. The two best grades are known to the trade as "G. P. A." and "G. P. F." The G. P. A. is of a light-brown color, and the G. P. F., when sheeted, is a beautiful marbled white. (Meriam).

For dark-colored stopping Meriam uses G. P. A., and for light, G. P. F., and for medium, the two mixed.

For convenience they had best be bought sheeted, keeping in mind that the different forms in which it is offered do not indicate different varieties. The gutta percha should always be fresh, and feel soft and unctuous in handling.

The splint gutta percha, often called pure, which is occasionally recommended, is adulterated with tar or resin, and it can readily be seen that such adulteration must injure its fibre.

Pure gutta percha can be obtained by dissolving in chloroform, drawing off with a siphon, and then distilling off the chloroform, or dissolving in disulphide of carbon and filtering through animal charcoal. These methods need not be used to-day, as G. P. F. sheeted will be found white enough for all purposes. (Meriam).

Meriam uses oils for softening the surface.

347. **Artificial gutta perchas** are now made. According to Zingler copal resin, sulphur, petroleum, casein, tannin, and ammonia are the substances used in manufacture.

348. **Camphor.**—

Theoretical constitution: $C_{10}H_{16}O$. It is sometimes classified among the aldehydes, but for convenience will be considered among the hydrocarbons on account of its oils. Camphor is a concrete substance derived from camphor-laurel tree; soft, tough cakes, easily powdered on addition of a little alcohol; translucent, strong fragrant odor, aromatic bitter cooling taste, volatile, inflammable; lighter than water; slightly soluble in water, but soluble in alcohol, ether, chloroform; dissolved in alcohol forms *spirit of camphor*, from which it may be precipitated by water; dissolved in water, containing a little alcohol and a little magnesium carbonate, forms *camphor-water:* boiled with bromine, forms *mono-bromated camphor*, $C_{10}H_{15}BrO$. Gum-camphor has a rotatory movement on water which is stopped by the least trace of fat. Camphor is a local irritant, stimulant, and poison. It is a constituent of celluloid.

Spirit of camphor is locally employed in dentistry to allay pain. With ether it is used as a local anæsthetic.

Taken internally, it is poisonous, although recovery from its effects are usual. The treatment consists in use of emetics and castor oil.

349. The official *Oleum Camphoræ* is made by heating camphor. It is a light reddish-brown fluid, of the taste and odor of camphor.

350. **Resins, Balsams, Gum-resins, etc.:** *resins* are *oxidized terpenes*, produced by the oxidation of the essential oils of plants. They are brittle, solid, transparent bodies, of no well marked odor or taste, soluble in alcohol, insoluble in water, combustible, yield a lather with alkalies.

Resins are employed in the manufacture of varnishes: copal resin is prepared by simple exudation.

351. **Guaiacum** resin is prepared by destructive distillation, and in other ways, from a tree growing in South America and the West Indies. It comes in large, irregular, semi-transparent, brittle pieces, externally of an olive or deep green color, internally red. It has a slight balsamic odor, and leaves a hot acrid sensation in the mouth and throat. It is wholly soluble in alcohol, partly soluble in water.

352. **Gum-resins** are resins *mixed with gum, sugar, etc., in plants,* and are insoluble in water, soluble in glycerine, turpentine, and strong alcohol. They are a mixture of several bodies, hence have not a definite chemical formula.

353. **Myrrh** is an exudation from an Arabian or African tree, and is a *gum-resin.* It is

of reddish-yellow or reddish-brown color, of fragrant, strong, peculiar odor, and bitter, aromatic taste. It is translucent, pulverizable, and brittle. It should dissolve in fifteen times its weight of water, when rubbed up with an equal weight of sal-ammoniac. It has a resinous fracture, and makes a light yellowish powder. Inferior kinds are darker, less translucent, and less odorous. The resin of myrrh is called *myrrhic acid.* Myrrh forms an emulsion with water, and is soluble in alcohol and in ether. An old tincture of it has been shown to have an acid reaction.* It is used in dentistry as a local application. The powder is also used in dentifrices.

354. **Gums** are non-volatile, colloid, almost tasteless bodies, occurring in the juices of plants. (See Carbohydrates).

355. **Sandarach:** sandarach is a substance composed of three resins, which are of different solubility in alcohol, ether, and turpentine. Sandarach comes in tears, which are small, and of a pale yellow or brown color, and more or less transparent: they are dry and brittle. Sandarach is inflammable, and melts on being heated. It is soluble in alcohol, ether, and warm oil of turpentine. It is used in dentistry, dissolved in alcohol, as a *varnish.*

The name sandarach is sometimes given to the disulphide of arsenic, which, however, has nothing to do with the resin sandarach, and should not be confused with it.

356. **Lac:** lac consists of resin, soluble coloring matter, lacin, wax, and salts. The resin is about 90 per cent. of

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*Brackett.

lac. **Shell Lac** is one of the commercial varieties of lac, and is an exudate from several kinds of trees growing in the East Indies; it is caused by punctures of insects. It is prepared from the crude lac by melting, straining, and pouring on a flat, smooth surface. Shellac comes in thin, shining, hard, brittle fragments, odorless, insoluble in water, but freely soluble in alcohol, more so in warm alcohol. It is used in dentistry as a *varnish.*

357. **Naphthalene:** naphthalene or naphthalin, $C_{10}H_8$, or $(C_{10}H_7)H$, is a *coal tar product*, distilling from this substance between 356° F. and 428°. It crystallizes in large, white, rhombic plates, of silvery lustre, and characteristic odor, and of a biting, somewhat aromatic taste. It melts at 174.5° F., and boils at 420° to 428°. It volatilizes very sensibly, even at ordinary temperatures. It is *inflamamble*, burning with a luminous and very smoky flame. Its specific gravity is 1.15. When melted, it dissolves sulphur, phosphorus, iodine, and indigo. It is insoluble in water, but soluble in hot alcohol, benzene, and ether, also in wood-spirit, chloroform, carbon disulphide, petroleum spirit, fixed and volatile oils. It is insoluble in alkaline or dilute acid solutions, slightly soluble in concentrated acetic acid. It is an *antiseptic* substance, and, when used as dressing, should be thoroughly purified by recrystallization from alcohol or by distillation with steam. It is not corrosive, and when *entirely* pure is odorless; it is, however, almost impossible to obtain it free from the characteristic odor, but the latter may be entirely overcome by adding a few drops of oil of bergamot to 4 oz. of the naphthalin. In powdering naphthalin, addition of a little alcohol greatly facilitates the operation. As an antiseptic, the best results have been obtained from use of it in powdered form. Combinations of this substance with iodoform and with boric acid should make valuable antiseptics. The naphthalin made in this country can be

reduced to a moderately fine powder; the pure, imported naphthalin cannot be reduced to powder except when very cold. Attention should be paid to the fact that it is *inflammable*.

358. **Naphthols:** $C_{10}H_7O$. There are a number of these compounds. What is commercially known as "hydronaphthol," is properly, *beta-hydro-naphthol*, has powerful antiseptic properties (1-7200 limit) and is *non-poisonous*.

[That which is called in commerce "beta-naphthol," is properly, according to Wolff, *betanahydro-naphthol*, and according to Bouchardat, Kaposi, Miner, Piffard, and others, is poisonous. To distinguish them dissolve in alcohol. Hydronaphthol (non-poisonous) dissolves in 10 parts alcohol, with a deep-brown coloration, while beta-naphthol dissolves without coloration].

Naphthol used medicinally crystallizes in thin, shining plates, readily soluble in alcohol, ether, chloroform, and fatty oils.

359. **Ethyl series of radicals, alcohols, and carbohydrates.**

Before considering the alcohols, it is well for the student to become familiar with the ethyl series of radicals.

TABLE 25. ETHYL SERIES OF RADICALS.

Compound Radicals.	Hydrides of, or Marsh Gases.
Methyl, CH_3	Methane, CH_3H or CH_4 (marsh gas).
Ethyl, C_2H_5	Ethane, C_2H_5H or C_2H_6
Propyl, C_3H	Propane, etc.
Butyl, C_4H_9	Butane, etc.
Amyl, C_5H_{11}	etc., etc.
etc., etc.	etc., etc.

TABLE 25—*Continued.*

Oxides or Ethers.	Hydrates, or Alcohols.
$(CH_3)_2O$, or C_2H_6O, methyl ether.	CH_3HO, or CH_4O, wood spirit, methyl alcohol.
$(C_2H_5)_2O$, or $C_4H_{10}O$, ethyl ether.	C_2H_5HO, or C_2H_6O, ordinary alcohol.
etc	etc.
etc.	etc.
etc.	$C_5H_{11}HO$, or $C_5H_{12}O$, amyl alcohol, fusel oil.
etc.	

360. Theoretical formation: the starting point in forming these compounds is with the *hydrates* or alcohols, and not with the compound radicals themselves. For example, when an alcohol, as C_2H_6O, is oxidized with *oxygen limited in amount*, there results what is called an *aldehyde* or dehydrated alcohol, as C_2H_4O, two atoms of hydrogen being withdrawn and *no oxygen* added.

If, however, the alcohol is oxidized with *plentiful oxygen*, an atom of oxyen is added in place of the two atoms of hydrogen withdrawn, and an *acid* is formed; thus, from C_2H_6O comes $C_2H_4O_2$, or acetic acid.

361. Tabular view of aldehydes and acids of ethyl series of radicals:

Radicals.	Alcohols.	Aldehydes.	Acids.
Methyl. CH_3	CH_4O	CH_2O	CH_2O_2 (forming acid).
Ethyl, C_2H_5	C_2H_6O	C_2H_4O	$C_2H_4O_2$ (acetic acid).
etc.			
etc.			

Compounds of the hydrocarbon radicals with chlorine, bromine, etc., are called *haloid ethers*, while salts proper of the hydrocarbon radicals are called *compound ethers*. Ethers are, in general then, compounds of the hydrocarbon radicals other than the marsh gases, alcohols, aldehydes, and acids. (See section 407).

362. **Alcohols:*** alcohols may be regarded

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*It will be noticed that the chemist's conception of alcohols includes many substances, such as glycerine, which resemble little our ordinary alcohol.

as substances derived from hydrocarbons by replacing one or more hydrogen atoms by the radical hydroxyl, HO. Thus ethyl hydride, $(C_2H_5)H$, becomes ethyl alcohol, $(C_2H_5)HO$, by exchanging one atom of H for the radical HO. Alcohols are called monatomic, diatomic, or triatomic, according as HO replaces one, two, or three atoms of H in a hydrocarbon. *Ordinary alcohol is a monatomic alcohol*, diatomic alcohols are also called *glycols*, and of triatomic alcohols glycerine is a notable example.

The alcohols are *hydrates*, resembling the inorganic hydrates, as, for example, potassium hydrate, KHO; common alcohol is ethyl hydrate, C_2H_5 HO.

363. **Alcohol.**—

Synonyms: ethyl alcohol, common alcohol, ethyl hydrate, ethylic alcohol, Spirit of Wine.

Theoretical constitution: C_2H_5HO, hydrate of the radical ethyl, two atoms of carbon, six of hydrogen, and one of oxygen; formula sometimes written C_2H_6O. Molecular weight, 46. 24 parts by weight of carbon, 6 of hydrogen, and 16 of oxygen.

Preparation: alcohol is obtained by the fermentation of saccharine liquids, brought about by the growth of a microscopic plant called yeast.

Grape sugar or glucose yields alcohol when fermented:

$$\underset{\text{Glucose}}{C_6H_{12}O_6} = \underset{\substack{\text{carbon}\\ \text{dioxide.}}}{2CO_2} + \underset{\text{alcohol}}{2C_2H_5HO}$$

The fermented liquid is distilled, and a dilute alcohol obtained; repeated distillations will finally give an alcohol containing about 14 per cent. of water. To obtain alcohol, free from from water, the former must be mixed with half its weight of lime, and the alcohol distilled off from the mixture.

Properties: absolute alcohol containing no water is a transparent, mobile, volatile, colorless liquid of an agreeable, pungent odor, characteristic of itself, and a burning taste, boiling at 173° F., of a sp. gr. 0.794, and has never been solidified. It is neutral in reaction, inflammable, *burning with a non-luminous flame, dissolves resins, essential oils,* alkaline hydroxides, alkaloids, calcium chloride, mercuric chloride, and many other substances, but especially those rich in hydrogen. Mixed with water, a *contraction* of volume occurs, with production of heat. *Its attraction for water is very great; it absorbs moisture from the air and abstracts it from membranes, tissues, etc.* Shaken with pure, colorless sulphuric acid, it should not become colored. (Presence of fusel oil). It is poisonous.

364. *Absolute alcohol:* commercial usage accepts as

absolute, alcohol of not less than 99.5 to 99.7 per cent. of sp. gr. (at 60° F.) 0.7938, boiling at 172.4° F.

Alcohol, U. S. P., is 91 per cent. by weight of real alcohol, or 94 per cent. by volume, the rest being water.

Alcohol dilutum is 45.5 per cent. by weight, or 53 per cent. by volume.

Spirit of wine (*rectified spirit*) is 84 per cent. by weight.

Proof-spirit is 49 per cent.

Spirits are substances distilled from fermented liquors; brandy, whisky, rum, and gin are examples. They contain from 35 to 45 per cent. of alcohol by volume, although some specimens run as high as 50 per cent. (brandy, rum) and some as high as 60 per cent., (whisky).

Wines contain from 6 to 25 per cent., sherry and port being the strongest.

Beers average 4 to 5 per cent., though some are very weak, containing only 1 per cent.

Use in dentistry: alcohol is used in dentistry for various purposes, as styptic, antiseptic, obtunding agent, for drying cavities, in lotions, gargles, etc., etc., and as a solvent and preservative.

Toxicology: the stomach pump should be used in cases of poisoning by alcohol, and, if the bladder is distended, use of the catheter is indicated. Cold affusion to the head, fresh air, ammonia, and strong coffee are valuable, especially if the stupor be intense.

365. **Tinctures** are alcoholic solutions of the medicinal agents in plants, prepared by maceration, digestion, or percolation.

366. **Fluid Extracts:** these preparations are concentrated, and represent considerable drug-power in small bulk. Each Cubic centimetre represents a gram of the crude drug.

367. **Wood Spirit:** methyl alcohol, or wood spirit, is methyl hydrate, CH_3HO, called pyroligneous ether,

pyroxylic spirit; wood naphtha is largely composed of it. It is made by distillation from wood. It is a liquid of spirituous odor, and is inflammable.*

368, **Fusel Oil** is amylic alcohol, $C_5H_{11}HO$, hydrate of the radical amyl, called also *potato spirit*. Fusel oil proper is a mixture of several alcohols, of which amylic alcohol is one. It is made from residues left in the still, after common alcohol is distilled off. It has a peculiar, irritating odor, and is very poisonous. Is produced in the fermentation of grain, hence often an impurity in whisky.

369. **Glycerine.**—

Theoretical constitution: this substance is a triatomic alcohol derived from propane $(C_3H_7)H$, by substitution of 3HO for *three* atoms of H. The formula for propane may be written C_3H_8; take away three atoms of H and we have C_3H_5; add 3HO and there results C_3H_53HO, or $C_3H_8O_3$. Glycerine is, then, the hydrate of a radical, C_3H_5, called *glyceryl, tritenyl*, or *propenyl*. Hence the modern term for glycerine, namely, *tritenyl hydrate*.

Properties and uses: glycerine is obtained from fats by treatment with alkalies, **soap** being formed and glycerine liberated. The process is called **saponification.** Pure glycerine is a colorless, or light straw yellow, thick, syrupy liquid, unctuous, inodorous, of sharp, sweet taste; soluble in water, alcohol, and oils, but not in ether or chloroform. *It is valuable*

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*Methylated spirit is composed of 9 parts ordinary alcohol to 1 part wood alcohol.

as a solvent for many medicinal substances, official solutions of which in glycerine are called glycerites. Glycerine is permanent and does not evaporate or dry at any temperature. Official **Glycerinum** has a sp. gr. of 1.25. It dissolves about fifty familiar substances used in medicine, among which are boric acid, borax, carbolic acid, creasote, potassium iodide, arsenic, alum, zinc salts, morphine salts, tannate of quinine.

Use in dentistry: its value in dentistry is as a solvent, and when combined with other substances, as an emollient and solvent. Teeth lotions contain glycerine, as for example the following: tincture of quillaia, eau-de-cologne, water, borax, glycerine, with coloring. Glycerine is found to be of service in the process of vulcanizing India rubber, giving the latter the property of resisting oils and fats. Glycerine may be used to detect carbolic acid adulteration in creasote. (See Creasote).

370. **Glycerites:** these are solutions of various substances in glycerine. Those most commonly used in dentistry are the glycerites of *carbolic acid*, *gallic acid*, *tannic acid*,* *sodium borate*, *starch*, *thymol*, and *pepsin*.

The glycerite of borax (sodium borate) becomes acid and unfit for use after a time.

371. **Boroglyceride:** boroglyceride, $C_3H_5\ BO_3$, is *glyceryl borate*, or tritenyl borate, made by heating boracic acid, $H\ BO_3$, with glycerine, C_3H_53HO, or $C_3H_8O_3$:

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*The glycerite of tannin is used as an application to spongy gums.

$$\underset{\text{Glycerine.}}{C_3H_8O_3} + \underset{\text{boracic acid.}}{H_3BO_3} + \text{heat} = \underset{\text{boroglyceride.}}{C_3H_5BO_3} + \underset{\text{water.}}{3H_2O}.$$

6 parts of boric acid in fine powder and 9 of glycerine are heated together in a porcelain dish at 302° F., stirring well until aqueous vapors cease to be given off, and a homogeneous, transparent mass is formed, which becomes hard and tough on cooling. Care is taken not to heat the mixture too strongly, as that would render the product dark colored. Boroglyceride is a colorless, tough, solid substance, soluble in water, and in alcohol, odorless, tasteless, not poisonous. *It is used in dentistry as an antiseptic*, and, in combination with sodium sulphite, for bleaching teeth.

372. **Sodium glyceroborate:** this substance is made by heating equal parts of sodium borate with glycerine. Soluble, deliquescent, odorless, antiseptic.

373. **Calcium glyceroborate:** made by heating equal parts of calcium borate with glycerine. Soluble, deliquescent, odorless, antiseptic.

374. **Creasote:** creasote, **Creasotum,** is a mixture of substances, but consists chiefly of *creasol*, $C_8H_{10}O_7$, and *guaiacol*, $C_7H_8O_2$. *It is a product of the distillation of wood-tar,* occurring in the lowest layer of the distilled liquid. It is colorless, or faintly yellow, when fresh and pure, of sp. gr. 1.046, U. S. P., but usually varying from 1.040 to 1.090. It boils at 392°-410° F. *It is of disagreeable, penetrating, smoky odor, and burning, caustic taste.* It is soluble in 80 parts of cold water, and 24 of hot, and in all proportions in alcohol, ether, acetic acid, and carbon disulphide. Ignited, it burns with a white,

sooty flame. It forms a clear mixture with collodion; precipitates solutions of gum and of albumin. On growing old, it gradually becomes brownish in color. It may be distinguished from carbolic acid by not solidifying when cooled, by not coloring ferric chloride permanently, by its lower boiling point, and by being *insoluble in glycerine.*

A specimen of creasote, if pure, should leave no stain on paper, after being dropped on it and volatilized by heat. Mixed with equal volume of collodion, it should not cause the latter to gelatinize.

Creasote water, Aqua Creasoti, consists of one fluidrachm of creasote to one pint of water. Solidified creasote is made from 10 parts of collodion to 15 of creasote.

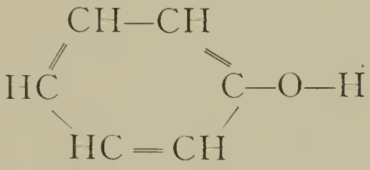
Use in dentistry: creasote is used as an obtunding agent, styptic, antiseptic, to counteract any acid in a tooth cavity, to harden the contents of dental tubuli and render them imperishable.

Toxicology: *creasote is poisonous*, in overdoses causing giddiness, obscurity of vision, depressed heart action, etc., etc.

The treatment consists in administration of white of egg, milk, wheat flour, and stimulants, as aromatic spirit of ammonia. An emetic should be first administered.

375. **Phenyl alcohol or carbolic acid.**—* Synonyms: phenol, phenylic alcohol, phenic acid. Official name, Acidum Carbolicum.

Theoretical constitution; carbolic "acid" is really an alcohol, C_6H_5HO, or hydrate of the radical phenyl†, C_6H_5, graphically



It is by weight composed of 72 parts carbon, 6 of hydrogen, and 16 of oxygen. Molecular weight, 94.

Preparation: crude carbolic acid is obtained by distilling coal-tar between the temperatures of 302°F. and 374°F.

Official carbolic acid is a pure phenol, obtained by distilling crude carbolic acid between 338°F. and 365°, separating from other products, and purifying by repeated crystallization.

Properties: carbolic acid, in the pure state, forms needle-shaped, colorless, interlacing crystals, neutral in reaction, having a characteristic, slightly aromatic odor, and pungent, caustic taste; the taste is sweetish when the acid is

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* Called "acid" because of its ready combination with bases forming carbolates or phenates, so-called.

† This radical phenyl belongs to the aromatic series.

slightly diluted. *It produces a white eschar on animal tissues, having a benumbing* (*caustic*) *effect.* When pure, carbolic acid is permanent in the air, and not affected by light, but the ordinary acid usually changes to pink or red. The color does not in the least impair the medicinal value of the phenol.

Water dissolves 6 per cent. of phenol, according to Squibb. Five parts of phenol dissolve in 1 part of alcohol; 4 in one of ether; 3 in 1 of chloroform; *7 in 2 of glycerine;* 4 in 7 of olive oil. It is also soluble in benzol, carbon disulphide, fixed and volatile oils. Variations in the melting and boiling points of phenol are due to the greater or less proportions of water in it. Phenol is liquid at ordinary temperatures, when it contains 8 to 10 per cent. of water. The best grades in the market contain at least 2 per cent. of water, and often over 4. *One volume of liquefied carbolic acid,* containing 5 per cent. of water, *forms, with 1 volume of glycerine, a clear mixture,* which is not rendered turbid by the addition of 3 volumes of water (absence of creasote and cresylic acid). Carbolic acid should have no odor of creasote nor of volatile sulphur compounds. A clean, sweet, phenol odor is one of the best signs of good quality in carbolic acid. It should also be hard and dry. An anhydrous acid, fused with from 4 to 5 per cent. of water, should, on cooling, become a solid mass of crystals again. The crystals become liquid at a temperature of from 96.8°F. to 197.6°. When reddened and liquefied, carbolic acid resembles creasote, but gives, dissolved in water, a *permanent* violet-blue with ferric chloride, *while creasote gives a blue which changes to green then to brown.* The crystals may be prepared, for antiseptic use, by warming the bottle till they liquefy, then adding a few drops of glycerine. *Carbolic acid is a valuable antiseptic.* It coagulates albumin and is poisonous. Death has followed external application of the acid, in large quantity, to extensive surfaces.

Use in dentistry: as an antiseptic, disinfectant, styptic, escharotic, obtunding agent, local anæsthetic, etc., etc.

Toxicology: carbolic acid is a powerful poison, being corrosive and also producing coma, the acid being rapidly diffused, and the odor of it, after death from poisoning, noticed everywhere throughout the body, even in the brain. The treatment is to give emetics, as, for example, apomorphine hydrochlorate subcutaneously, then raw eggs *ad libitum*, and magnesia suspended in a mixture of olive and castor oils; lime water with sugar is also recommended. The coma must be treated as in cases of opium poisoning, by artificial respiration, galvanism, etc., etc. Chances of recovery from poisonous doses of the acid are not good. The urine should be watched, when carbolic acid is being used, and if it becomes dark-colored, it is a sign that too much of the agent is being used.

376. **Various preparations containing carbolic acid.**

Robinson's remedy is composed of equal parts of caustic potash (potassium hydrate) and carbolic acid, mixed by trituration.

Chloral hydrate and carbolic acid, when mixed in proportion of 1 part of chloral to 1.7 parts of the acid, liquefy, and the liquid is soluble in water in all proportions.

377. **Phenates:** carbolic acid, with solutions of the alkalies, forms soluble compounds called phenates or phenylates, which are capable of dissolving large quantities of phenol.

378. **Phenol sodique or sodium phenate:** this substance, C_6H_5NaO, is also called carbolate of sodium, sodium phenoxide, Sodæ Phenas. It is made by the direct combination of carbolic acid with sodium oxide; caustic soda and a little water are used in the reaction, which is as follows:

$$\underset{\text{Carbolic acid}}{C_6H_5HO} + \underset{\substack{\text{sodium}\\\text{hydrate}}}{NaHO} = \underset{\substack{\text{sodium}\\\text{phenoxide}}}{C_6H_5NaO} + \underset{\text{water}}{H_2O}.$$

Sodium phenate occurs in form of acicular crystals of light pinkish color, liquefied by heat. It is used in dentistry as an astringent, styptic, disinfectant, etc., etc. It is freely soluble in water.

379. **Phenol terchloride:** this substance is of Russian introduction, and is extemporaneously prepared by mixing one part of a four per cent. solution of carbolic acid with five parts of a saturated solution of chlorinated lime; the filtrate is said to be 25 times more powerful than carbolic acid. According to some authorities it may be made by passing a stream of chlorine gas through pure melted carbolic acid, until a violet color is seen.

Dental uses: **Phenol terchloride** is used as an antiseptic and disinfectant. It is combined with iodoform, and used as a capping and filling material, incorporated with decalcified dead bone.

380. **Phenol-camphor*** is best obtained by heating

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* Synonyms: Carbol-camphor, Camphor-carbol, Campho-Phenique.

pure crystallized carbolic acid (phenol) until it fuses, and then gradually adding gum camphor; a clear liquid is obtained which is characteristic on account of its permanence. In preparing this substance, use equal parts of camphor and carbolic acid: it remains liquid for an indefinite time, and does not solidify on being subjected to the low temperature of a frigorific mixture of snow and sodium chloride. Phenol-camphor [$C_8H_{11}O$(?)] is a limpid, colorless, volatile, refractive liquid, possessing the fragrant odor of camphor, entirely extinguishing the one of carbolic acid, and has a sweetish, camphoraceous, but biting taste, not as caustic as that of carbolic acid, somewhat benumbing the tongue. It is *soluble in alcohol*, ether, chloroform, and ethereal oils, but *insoluble in glycerine and in water*, being heavier than the latter. When ignited it burns with a smoky flame. There is reason to believe that it is a chemical compound. Dr. Schaefer has used phenol-camphor as a *local anæsthetic* in tooth-ache, introducing it on cotton into the cavity of a carious tooth. This substance can be likewise used as an *antiseptic*. It mixes well with paraffin, cosmoline, and a number of oils. In impregnating cotton gauze (antiseptic gauze) phenol-camphor may be used as a substitute for carbolic acid. Phenol-camphor is less irritating, less caustic than carbolic acid, and has also the advantage of possessing a pleasant odor. It is used in dentifrices.

381. **Resorcin:** this substance has for its formula $C_6H_6O_2$, or better $C_6H_4\left\{\begin{matrix}HO\\HO\end{matrix}\right.$, from which it will be seen that it differs from carbolic acid, in that the radical HO has been substituted for one atom of hydrogen, carbolic acid being C_6H_5HO, and resorcin, C_6H_4 2HO.

It is made from gum-resins, such as galbanum, extract of sapin wood, or Brazil wood, by fusing them with caustic potash. It occurs in the form of colorless crystals, of somewhat sweetish, slightly pungent taste, very soluble in water, less so in alcohol, ether, glycerine, and vaseline, insoluble in chloroform, and carbon disulphide. It is not so irritating as carbolic acid. It is said to be a disinfectant and local anæsthetic.

It is used in dentistry as an antiseptic.[*] Strong solutions are caustic, but dilute ones merely astringent.

382. **Menthol:** this substance is really *menthyl alcohol*, $C_{10}H_{20}O$, and is found in peppermint oil. It is a white, crystalline solid of but slight peppermint-oil odor when pure, soluble in alcohol, and in the essential oils. It has been called peppermint camphor, Japanese camphor, peppermint stearescence, and stearoptene of peppermint, but, in constitution, is a monatomic alcohol. *It is an antiseptic and local anæsthetic.* It is used in dentistry as an obtunding agent, local anæsthetic, and antiseptic. Care must be taken in applying it, as small doses, taken internally, have been known to produce vomiting.

383. **Eucalyptol:** $C_{12}H_{20}O$, liquid, colorless, of aromatic odor. It is derived from the leaves of *Eucalyptus globulus*, and is sometimes called eucalyptus oil. It is but slightly soluble in water, but is soluble in alcohol. It is an efficient *antiseptic*, and is used in dentistry on this account, and as an astringent, styptic, and *local anæsthetic. It has solvent action on gutta percha.* The purest eucalyptol is as clear as water, of specific gravity 0.910 to 0.920 at 60°F., and boils between 338°F. and 343°. There is in the market an eucalyptus oil which differs from the genuine eucalyptol; 90 per cent. alcohol makes a clear solution of eucalyptol, while the eucalyptus oil is but slightly soluble in it.

Alantol: $C_{20}H_{32}O$. A liquid stearopten found besides helenin in the root of elecampane.

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[*] Said to be a stronger antiseptic than carbolic acid, and not so poisonous.

384. **Myrtol:** myrtol is obtained from the distillation of the leaves of the myrtle; it is a liquid possessing the characteristic perfume of the plant. It is of less density than water, evaporates at the ordinary temperature, stains paper, but the stains disappear entirely. It has a warm, slightly acrid taste, soon followed by a sensation of freshness. It is said to be an excellent *disinfectant* and an energetic *antiseptic*.

385. **Safrol:** this substance is obtained by fractional distillation from crude oil of camphor. It has a strong sassafras odor and taste, and is used for disguising the taste of other substances.

386. **Thymol:** formula $C_{10}H_{14}O$. There are many thymols. The one found in essence of wild thyme is used in dentistry, and may be procured by treating the essence with potassium hydrate; insoluble in water, antiseptic. Freely soluble in alcohol. Used in dentistry, combined with glycerine, as an antiseptic.

387. **Carbohydrates:** these are substances containing six atoms of carbon, or a multiple of six, and twice as many atoms of hydrogen as of oxygen. They closely resemble the alcohols, and may be divided into three classes: *saccharoses*, *glucoses*, and *amyloses*.*

Of the saccharoses, cane sugar and milk sugar are important.

388. **Cane Sugar:** saccharose, cane sugar, beet sugar, $C_{12}H_{22}O_{11}$, does not occur in the body; white, inodorous, *very sweet.* Cold water dissolves three times its weight; insoluble in alcohol. Converted by ferments first into mixture of glucose and lævulose, called *invert* sugar.

**Saccharin* is not a carbohydrate, but the sulphinide of benzoic acid. (See Benzoic Acid).

Blackens with H_2SO_4. (Glucose unites with the acid and does not blacken). Cane sugar occurs in the juices of many plants, fruits, flowers, and in honey. It is found also in the juice of the sugar cane, in sorghum, beet-root, and sugar-maple. *The most soluble sugar* as well as the sweetest and most crystallizable.*

389. **Milk-sugar:** lactose, sugar of milk, Saccharum Lactis, $C_{12}H_{22}O_{11}H_2O$, one of the constituents of milk of mammals; rarely found in vegetables. To prepare it, coagulate skimmed milk with a little acetic acid, heat, filter, concentrate filtrate by evaporation, let crystallize, dissolve in boiling water and re-crystallize. Odorless, white, *hard*, occurs in four-sided, rhombic prisms; *taste faintly sweet*, gritty between the teeth; soluble in seven parts cold water, one of boiling; insoluble in even 60 per cent. alcohol; not charred by H_2SO_4; not directly fermented by yeast, but easily when cheese is added; does not form a syrup with water. *Used in tooth powders and in triturating medicines.*

390. **Glucose:** $C_6H_{12}O_6$, is raisin sugar and grape sugar; it is also called dextrose and starch sugar. It is found in vegetables, fruits, and honey. Is white, inodorous, and soluble in its own weight of water. *Only one third as sweet as cane sugar.* Ferments directly with yeast, and when in contact with decaying animal matter. Made on a large scale from corn starch, by boiling with dilute sulphuric acid, neutralizing with lime, draining off clear syrup, evaporating, and allowing to crystallize. Fermented, it decomposes into alcohol and carbonic acid. *Valuable reducing agent.*

391. The **amyloses** are starch, dextrine, gum, etc. **Starch** is found in grains of cereals and in potatoes; is food of plants becoming sugar as they ripen. Insoluble

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*Dissolved in water forms Syrupus Simplex, or simple syrup.

in cold water, alcohol, or ether; in boiling water it becomes gelatinous, but does not dissolve; heated dry it becomes dextrine, which is converted into glucose by action of diastase (a ferment found in cross-spired barley).

Dextrine: is an amorphous, yellowish-white, soluble substance; does not give blue coloration with iodine; basis of mucilage. Reduces alkaline copper solutions.

The formula for dextrine is probably $C_6H_{10}O_5$. That of starch some multiple of $C_6H_{10}O_5$.

392. **Honey:** honey is practically a strong solution of dextro-glucose and lævo-glucose in water. Analyses show that the lævulose and dextrose are nearly equal in amount. Fictitious honey is sometimes manufactured from glucose and flavoring materials; the presence of glucose, as an adulteration, is indicated by increased proportion of ash, and by the presence of a notable amount of calcium sulphate. *Honeys* are preparations of medicinal substances in honey, the clarified article being used. *Honey of sodium borate* contains a drachm of borax to the ounce of clarified honey.

393. **Gums:** these bodies are probably carbohydrates. They are a peculiar class of bodies, occurring in the juices of plants. They are entirely non-volatile, of little or no taste, uncrystallizable, and colloidal. They are either soluble in water, or swell up in contact with it. They are not capable of being fermented by yeast and are insoluble in alcohol.

394. **Gum Arabic** is the dried exudation from the bark of various species of *Acaciæ*. Picked Turkey gum is the finest, and occurs in colorless lumps, full of minute cracks. It consists chiefly of calcium arabate, the calcium salt of arabic or gummic acid. It is inodorous, of feeble, slightly sweetish taste, and with water forms a viscid mixture, called a *mucilage*. The mucilage is used in dentistry as an emollient.

395. **Gum Tragacanth:** this is a white, or yellowish substance which is only very slightly soluble in water, and swells up in it. It contains usually about 60 per cent. of a substance which yields *pectic acid*, also 8 or 10 per cent. of soluble gum, probably *arabin*, the rest being starch, cellulose, water, etc., etc.

396. **Cellulose:** *Cellulin*, *lignin*, $C_6H_{10}O_5$, is an isomer of starch, and constitutes the essential part of the solid framework or cellular tissue of plants. Swedish filter-paper, linen rags, and cotton wool are more or less pure cellulose. Soluble only in a solution of cupric oxide in ammonia.

Absorbent cotton: consists essentially of cellulose.

397. **Collodion** is made by dissolving 4 parts of pyroxylin in a mixture of 26 parts alcohol and 70 of ether. Pyroxylin is prepared by steeping cotton in a mixture of nitric and sulphuric acids.

Flexible collodion is collodion to which 5 per cent. of turpentine and 3 per cent. of castor oil have been added.

Cantharidal collodion is made from powdered cantharides and flexible collodion, with sometimes addition of a little Venice turpentine, to prevent contraction on drying.

Iodized collodion is a solution of iodine in collodion, 20 grains to the ounce. *Iodoform collodion* contains 1 part iodoform to 15 of collodion.

Styptic collodion contains 20 per cent. of tannic acid.

Collodion is a colorless liquid, of ethereal odor, and very inflammable; exposed to the air it rapidly evaporates, leaving a thin, transparent, strongly contractile film of dinitro-cellulose, which is insoluble in water or in alcohol. It is precipitated by carbolic acid. Collodion is used in dentistry as a local application in alveolar abscesses, in combination with other agents in odontalgia, on cotton as temporary filling, as a styptic, etc., etc. A colored preparation of collodion is used to coat the surface of plaster models. Collodion, when thickened, may be rendered thinner by dilution with a solution of 1 part alcohol in 3 parts ether.

Cantharidal collodion is used as a counter-irritant in dental periostitis. A German preparation of cantharidal collodion has been proposed by Dieterich to contain—in 1,900 parts of collodion—3 parts of cantharidin and 97 of oil of rape. The German blistering collodion is stronger than the U. S.

398. **Celluloid:** pyroxylin is reduced to a pulp, mixed with camphor, oxide of zinc, and vermilion, subjected to immense pressure, and seasoned.

ETHERS, GLUCOSIDES, FATS, WAXES, ALDEHYDES, KETONES, ETC.

399. **Ethers** are derived, theoretically, by replacing the hydrogen atoms in water by hydrocarbon radicals; they are, therefore, *oxides*. Ethers are either *simple* or *mixed*, according as the hydrocarbon radicals are alike or different; thus common ether is a *simple* ether, $(C_2H_5)_2O$, that is, $C_2H_5—O—C_2H_5$, while methyl-ethylic ether is a *mixed* ether C_3H_8O, that is, $CH_3—O—C_2H_5$.

Haloid ethers are bromides, chlorides, etc., of the hydrocarbon radicals: thus, hydrobromic ether is C_2H_5Br, or ethyl bromide. *Compound ethers* are salts of the hydrocarbon radicals, as, for example: methyl acetate, $CH_3(C_2H_3O_2)$, or $CH_3—O—C_2H_3O$. *Fats* are compound ethers, in which the hydrocarbon radical is *glyceryl*—

in almost all cases; thus, stearin is stearate of glyceryl, $C_3H_5(C_{18}H_{35}O_2)_3$.

400. **Common Ether.**—

Synonyms: ethyl ether, ethyl oxide, vinic ether, sulphuric ether, Æther, Æther Sulphuricus.

Theoretical constitution: $(C_2H_5)_2O$, or ethyl oxide, derived from H_2O by substituting C_2H_5 for each atom of hydrogen; contains 4 atoms of carbon, 10 of hydrogen, and 1 of oxygen in its formula; by weight, 48 parts carbon, 10 of hydrogen, and 16 of oxygen. Molecular weight, 74. Graphic formula, $C_2H_5—O—C_2H_5$.

Preparation: sulphuric acid is used to etherize alcohol, hence the name sulphuric ether. There is not, however, any sulphuric acid in pure ether. 1 part of strong sulphuric acid and 6 or 7 of commercial alcohol are heated to 266° F., in a retort, and then alcohol is run in, slowly, by means of a funnel, while the temperature is kept between 266° F. and 284°, and the mixture distilled. The liquid resulting from the distillation contains on its surface crude ether, which, purified by washing, dried, and redistilled, is ready for the market. The reactions are as follows:

First stage,

$$\underset{\text{Alcohol}}{C_2H_5HO} + \underset{\substack{\text{sulphuric}\\ \text{acid.}}}{H_2SO_4} = \underset{\substack{\text{ethyl sulphuric}\\ \text{acid.}}}{(C_2H_5)HSO_4} + \underset{\text{water.}}{H_2O}.$$

Second stage,

$$\underset{\text{Ethyl sulphuric acid}}{C_2H_5HSO_4} + \underset{\text{alcohol}}{C_2H_5HO} = \underset{\text{ether}}{(C_2H_5)_2O} + \underset{\text{sulphuric acid.}}{H_2SO_4}$$

The second equation shows that the acid is obtained again, hence a small quantity of sulphuric acid can be used to convert considerable alcohol into ether. Ether for anæsthetic purposes is further purified by shaking with water and contact with lime and chloride of lime.

Properties: pure ether is a mobile, very volatile liquid, colorless, limpid, and inflammable, of sweetish, characteristic odor* and burning taste. It should be kept in bottles closed by ground-glass stoppers, as it readily evaporates. It is soluble in 10 volumes of water, and in alcohol in all proportions. When *pure* it dissolves oils, resins, many organic bodies, iodine, bromine, sulphur, phosphorus, and mercuric chloride. Ether should not only be kept from the air, but also from the light. Its vapor is 2½ times as heavy as air, therefore flows, and will inflame with explosion from contiguous flame. The sp. gr. of ether is variously given as 0.720, 0.736, and 0.713; that of stronger ether, Æther Fortior, is 0.728. The latter contains about 94 per cent. of pure ether, and 6 per cent. of alcohol. Ether used for anæsthetic purposes should not effect blue litmus, should leave no

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*Called *ethereal* odor.

residue when evaporated on a watch glass, and should not impart a blue color to ignited copper sulphate. Samples should be tested before being used.

401. Use in dentistry: ether is used as an anæsthetic, both by inhalation and locally; also as an anodyne, and in various conditions, as aphthæ, etc. *It is useful as a solvent.*

Toxicology: the treatment, in cases where dangerous symptoms appear, is to cease administering the ether at once, and, if the breathing begins to fail, to pull out the tongue, to apply electricity, the poles being placed over the phrenic nerves (on a line with the 4th cervical vertebra) and to try artificial respiration. In administering ether, the *breathing* should be watched.

402. **Ethyl bromide.**—

Synonyms; bromide of ethyl, hydrobromic ether, Ethyl Bromidum,

Theoretical constitution: C_2H_5Br, bromide of the radical ethyl, one molecule of ethyl and one atom of bromine, or two atoms of carbon, five of hydrogen, and one of bromine in its molecule. It is one of the so-called **haloid** ethers (see Ethers).

Preparation, properties, etc.: ethyl bromide is obtained by distilling potassium bromide with alcohol, water, and sulphuric acid. The resulting product is redistilled with calcium chloride,

Ethyl bromide is a very volatile, colorless liquid, of ethereal odor, strong, sweetish, pungent taste. It is heavier than water, and but slightly soluble in it; soluble in ether and in alcohol. It often contains bromoform as an impurity, and, if it acquires a disagreeable odor, becomes brown on standing, or is inflammable or explosive, it is not fit for use.

Use in dentistry: *ethyl bromide is an anæsthetic*, producing complete anæsthesia in a few minutes, followed by recovery of consciousness in from one to two minutes after it is withdrawn.

Toxicology: several deaths from its use as an anæsthetic were reported some time ago, and its use was discontinued. But of late, according to Asch of Berlin, the discovery has been made that the toxic effects were due to sulphur and arsenic impurities consequent on the old method of preparation. It is said that C. P. ethyl bromide, made by the modern method described above, has been used repeatedly without deleterious results.

403. **Compound ethers.—Ethyl nitrite,** $C_2H_5NO_2$, diluted with alcohol forms "sweet spirits of nitre."

Amyl nitrite: this substance is the nitrite of the radical *amyl;* its formula is $C_5H_{11}NO_2$.* Molecular weight, 117. It is made by heating equal volumes of purified amyl alcohol (fusel oil) and nitric acid, until the mixture boils. *It is a yellowish, ethereal liquid, having the odor of over-ripe pears, and an aromatic taste.* Its specific gravity is from 0.877 to 0.900. It is volatile and inflammable, soluble in alcohol; solution rapidly deteriorates. Several samples of amyl nitrite examined by Allen contained only 80 per cent. of real amyl nitrite. It is used in dentistry as an antidote for chloroform, being administered by inhalation, and for relief of neuralgia, epileptic attacks during extraction of teeth, etc., etc.

Toxicology: in administering amyl nitrite by inhalation,

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*It may be obtained put up in glass bulbs holding a drop or two. The latter are to be crushed before inhalation.

care should be observed. The handkerchief should be withdrawn when the face becomes flushed and the heart excited.

404. **Glucosides:** these bodies are regarded as ethers of glucose.* Those used in dentistry are tannin and gallic acid.

Tannin, tannic acid, gallotannic acid, is $C_{14}H_{10}O_9$. The tannic acid used in dentistry is obtained from powdered galls. It forms light-yellow, amorphous scales, of faint characteristic odor, and strongly astringent taste, easily soluble in water and in dilute acids. Tannin unites with albumin, gelatin, etc., forming insoluble compounds. In the blood, it absorbs oxygen and becomes gallic acid. It is an active astringent and styptic, and is a valuable agent in dentistry as a local application in many disorders, as mercurial stomatitis, hemorrhage after extraction, etc. It is sometimes used dissolved in glycerine, *Glyceritum Acidi Tannici,* and also in the preparation known as **styptic colloid,** which is a saturated solution of tannin and gun cotton.

405. **Gallic acid,** $HC_7H_5O_5$, or $C_6H_2(HO)_3CO_2H$, is obtained by exposing moistened galls to the air for six weeks. A peculiar kind of fermentation takes place, and

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* Because when treated by ferments or dilute acids they are decomposed and yield glucose among other products. They occur in plants, andare often accompanied by an albuminoid substance which may act as a ferment and turn them into glucose.

the tannic acid of the galls is converted into gallic acid. Gallic acid is a white solid, occurring in long, silky needles. It has an astringent, slightly acid taste, and is acid in reaction. It is not readily soluble in cold water; it is soluble in three parts of boiling water, in alcohol, and in ether. It is used in dentistry in form of a gargle, as astringent, antiseptic, and styptic.

406. **Fats and fixed oils:** these substances, as has been stated before, are compound ethers of glyceryl. Some are liquid and others solid. *Stearin* is the constituent of the more solid fats, *palmitin* of mutton, lard, and human fat; *olein* is the fluid constituent of fats and oils; fats treated with hot alkalies or with superheated steam, are saponified, as the term is, stearates, palmitates, and oleates of the alkalies being formed (**soap**) and glycerine.

407. *Cacao butter* is a concrete oil from the kernels of the fruit of *Theobroma Cacao.*

408. *Waxes* belong to the spermaceti group of oils. They do not yield glycerine when saponified.

409. *Bees-wax* is the material of which the honeycomb of bees is composed. It occurs as a compact, tough, solid substance of a yellow or brown color, almost tasteless, but of characteristic, aromatic odor. It is not greasy to the touch. On exposure to air in thin slices, it becomes decolorized. It may be bleached by nitric acid. It is insoluble in water, but soluble in the fixed oils, oil of turpentine, benzol, ether, and carbon disulphide. It is difficultly soluble in alcohol. Its specific gravity is from 0.959 to 0.969.

410. The yellow wax is **Cera Flava;** bleached, it is called **Cera Alba,** or white wax. The best method of bleaching is exposure to moisture and the rays of the sun. A new process is, first, to melt together 8 parts of

yellow wax and 1 to 1½ parts of rectified oil of turpentine, and then expose to air, etc. Grain wax may be bleached by dioxide of hydrogen. Other chemicals can not be used as they change its constitution.

411. **Croton Oil:** this oil belongs to the Castor Oil group of oils, distinguished for their very high specific gravity and viscosity. They are readily soluble in alcohol, and are strongly purgative. Both castor oil and croton oil are miscible with glacial acetic acid in all proportions. In drying character, they resemble the oils of the Cotton Seed Oil group.

It produces pustules, when applied to the skin, and is valuable as a counter-irritant.

Toxicology: in overdoses it has frequently proved fatal.

412. Chloroform.—

Synonyms: trichlormethane, dichlor-methyl chloride, formyl terchloride.

Theoretical constitution: $CHCl_3$, or methane, CH_4, in which three atoms of hydrogen have been replaced by three of chlorine. Chloroform has, in its molecule, one atom of carbon, one of hydrogen, and three of chlorine; by weight, 12 parts carbon, 1 of hydrogen, and 106.2 of chlorine. Molecular weight, 119.2.

Preparation: *commercial chloroform is usually made by the action of bleaching powder on alcohol;* in 24 parts of water 6 parts of bleaching powder are dissolved, the mixture strained into a retort, heated to 102°F., and one part of strong alcohol added. The mixture is then distilled. Bleaching powder is chiefly calcium hypochlorite, which with alcohol yields on distillation chloroform, calcium formate, calcium chloride, and water, through various intermediate stages.

Chloroform for anæsthetic purposes, *purified chloroform*, U. S. P., is prepared from the commercial by mixing with sulphuric acid, agitating, drawing off the chloroform, treating with sodium carbonate, and distilling over calcium oxide.

In a new process for making chloroform, alcohol is said to be dispensed with, and the chloroform made by distillation of wood and subsequent treatment of the distillate. Chloroform is also made from chloral hydrate, and by electrolysis, from chlorides of the alkalies in presence of alcohol, aldehyde, or acetone.

Properties: chloroform is a mobile, *colorless, volatile liquid* of bland, peculiar, *sweetish, ethereal odor*, and hot, aromatic, saccharine taste. Specific gravity of the purified is 1.5022, and boils at 142°F. The official chloroform of the U. S. Pharmacopœa contains a little alcohol, and its sp. gr. is 1.488. It is heavier than water and not soluble in it, but is freely soluble in alcohol and ether. *It dissolves a large number of substances,* among them camphor, fixed and volatile oils, many resins, fats, caoutchouc, sulphur, phosphorus, iodine, bromine, and many alkaloids.

Purified chloroform should not affect litmus paper, nor color green a mixture of chromic and sulphuric acids. Sulphuric acid should not color it brown, nor should potassium hydrate. Allowed to evaporate on the hand, no foreign odor should be noticed.

It is said not to be inflammable, but is combustible burning with a dull, smoky flame on application of a naked flame to it.

Spirit of chloroform contains an ounce of chloroform in two ounces of dilute alcohol.

Uses in dentistry: as *an anæsthetic*, both general and local, though, for the latter purpose, usually combined with other agents; as an anodyne, and antispasmodic. It is also an *antiseptic* and *styptic*. Applied to the skin, it acts as an irritant and vesicant, if evaporation is retarded.

Toxicology: deaths following administration of chloroform have been quite frequent. Paralysis of the heart, and, in some cases, exclusion of air from the lungs are the causes of death. In administering it, some air should be admitted along with it. It should never be administered to persons suffering from diseases of the heart or kidneys. At the slightest symptom of heart failure during administration of chloroform, the patient should be placed in a recumbent position, cold affusions applied, and artificial respiration, together with induced electricity, be resorted to. Inhalations of from three to five drops of amyl nitrite have been recommended.

413. **Iodoform:** this substance, CHI_3, is similar in theoretical constitution to chloroform, except that it contains iodine instead of chlorine. It may be made by acting on alcohol, aldehyde, and many other substances with iodine and potassium carbonate or hydrate. *It is usually prepared by heating together an aqueous solution of potassium carbonate, iodine, and alcohol,* until the brown color of the iodine has disappeared. It occurs in *small, lemon-yellow, lustrous crystals of an odor*[*] *not so bad at first, but soon becoming unsupportable.* It melts at 248°F., and volatilizes gradually at ordinary temperatures. *It is nearly insoluble in water* and in acids, but soluble in alcohol, ether, chloroform, disulphide of carbon, fixed and volatile oils. It is not, however, so easy to dissolve it, as many of the books would lead us to infer. It is neutral in reaction. Iodoform is not an escharotic, and is an *antiseptic, disinfectant,* and *anæsthetic.* It is now made by electrolysis from iodide of potassium dissolved in alcohol, through which a stream of carbonic acid is constantly passed. Iodoform is decomposed by sunlight (turning

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[*] The odor is called "*saffron-like*," and is not perceptible in the preparation known as *bituminized iodoform.*

violet). It loses 0.016 per cent. an hour, exposed in a thin layer to the air.

Use in dentistry: *it is used as an antiseptic*, and anodyne; dissolved in oil of turpentine, it is said to be a germicide. It acts chemically, by allowing escape of free iodine, and also mechanically, favoring cicatrization. In dentistry, iodoform is combined with numerous agents, among them eucalyptol, arsenic, creasote, carbolic acid, camphor, etc., etc.

The odor of iodoform may be disguised by mixing 1 part of cumarin with 25 of iodoform.* The odor may be removed from the hands, by washing them in an aqueous solution of tannic acid. A French antiseptic dressing containing iodoform is composed of equal parts of powdered iodoform, cinchona, benzoin, and magnesium carbonate, the latter being saturated with eucalyptol. Acetate of potassium should be given in cases of poisoning.

414. **Iodol:** tetra-iodo-pyrrhol, C_4I_4NH, made from pyrrole, a product of the destructive distillation of proteids. Light-yellowish-gray, micro-crystalline powder, *odorless*, almost tasteless, almost *insoluble in water*, soluble in three parts alcohol† (by weight), in 2 parts ether, and in 7 parts warm oil. *Contains nearly 89 per cent. iodine*, and

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* Oil of sassafras is also said to be useful in disguising the odor.

† Alcohol must not be boiled when used as a solvent for fear of decomposing the iodol.

used as a *substitute for iodoform.* Used in dentistry as an *antiseptic.* Iodol *wax* has been used as a temporary stopping. Said not to be so toxic as iodoform.

415. **Aldehydes:** aldehydes lie midway between alcohols and organic acids; they have two less atoms of hydrogen than the corresponding alcohol.

Paraldehyde $(C_2H_3HO)_3$ or $C_6H_{12}O_3$, is used as a substitute for morphine, and is a liquid.

416. **Chloral hydrate.**—

Chloral is prepared by passing dry chlorine into absolute alcohol, until saturated, then adding sulphuric acid and distilling. The chloral thus obtained is a colorless liquid; if, now, this liquid be treated with a small quantity of water, it becomes a solid, C_2Cl_3 HO.H_2O, which is the well-known **chloral hydrate.** The latter is a colorless, transparent, crystalline solid, of aromatic, pungent odor and taste, soluble in water, very soluble in alcohol, ether, glycerine, fixed and volatile oils, neutral in reaction, melting at 136.4°F., and boiling at 203°. It has a bitter, caustic taste; it liquefies when mixed with carbolic acid or camphor. It volatilizes slowly at ordinary temperatures. It is decomposed by weak alkalies into chloroform, and a formate of the alkali metal; this change was thought to take place in the blood when chloral was taken internally, but recent investigations fail to support the theory.

In preparing chloral, 5 per cent. of ferric chloride is added by some to the alcohol, before the chlorine gas is introduced.

Use in dentistry: chloral hydrate is used in dentistry locally, for relief of odontalgia, etc. It is an antiseptic, and local anæsthetic, especially when combined with other agents. Chloral hydrate is familiarly termed "chloral."

Toxicology: the treatment, in cases of poisoning, consists of use of the stomach pump, and maintenance of respiration.

417. **Croton-chloral hydrate** is, chemically speaking, *butyl-chloral hydrate.* Its. formula is $C_4H_5Cl_3O.H_2O$. It is made by passing dry chlorine through aldehyde cooled to 14°F. Butyl-chloral is obtained, and, on addition of water, butyl-chloral-hydrate. It occurs in the form of crystalline, micaceous scales, of pungent odor, sparingly soluble in water, readily in alcohol, and in hot water, nearly insoluble in chloroform.

418. **Ketones:** these substances are consequent on the first action of oxidizing agents on secondary alcohols, just as primary alcohols yield aldehyde when oxidized. Secondary alcohols contain the group of atoms CHHO, instead of CH_2HO, which is found in ordinary alcohol.

419. Organic acids and salts.—

Organic acids may be deemed to be built upon the water type, half the hydrogen, in one or more molecules of water, being replaced by a compound organic radical, always containing oxygen: for example, water is H_2O or H—O—H; replace half the hydrogen, that is, one atom, by C_2H_3O, a compound organic radical containing oxygen, and we have $H—O—C_2H_3O$ or $HC_2H_3O_2$, acetic acid. It will be noticed that *this formula is the same as that of ethyl aldehyde, plus one atom of oxygen.* Alcohol, aldehyde, and acetic acid resemble one another in a certain way. Thus, the formula for ethyl alcohol is C_2H_6O, that of aldehyde, C_2H_4O—or alcohol minus two atoms of hydrogen—and that of acetic acid, $C_2H_4O_2$, or aldehyde plus one atom of oxygen.

420. **Acetic acid:** its formula is $C_2H_4O_2$, or $C_2H_3O—O—H$. It is a monobasic acid, like nitric, hence its formula is conveniently written, $HC_2H_3O_2$, and the radical $C_2H_3O_2$ occurs in all acetates, the H (one atom) being replaced by some positive element, as K, Na, Pb, etc. Acetic acid is the result of the fermentation of saccharine fluids, *after* alcoholic fermentation is over. It is prepared, however, from the residuary liquid obtained in the distillation of wood.

Acidum Aceticum, U. S. P., $HC_2H_3O_2 = 60$, is a watery solution, composed of 36 per cent of hydrogen acetate, and 64 of water. It is a clear, colorless liquid, of a distinctly vinegar-like odor, a purely acid taste, and a strongly acid reaction. Sp. gr. 1.048 at 59°F. Miscible in all proportions with water and alcohol, and wholly volatilized by heat. *Acidum Aceticum Dilutum* has 6 per cent. of absolute acetic acid, and a sp. gr. of 1.0083. *Acidum Aceticum Glaciale*, glacial acetic acid, is nearly or quite absolute acetic acid: at or below 59°F., it is a crystalline solid; at higher temperatures, a colorless liquid. It is very corrosive.

Acetic acid dissolves resins, camphor, fibrin, and coagulated albumin; it precipitates mucin. It blisters the skin and is a corrosive poison: antidotes are alkalies, alkaline carbonates, soap, etc. Glacial acetic acid is used by dentists, externally, as a caustic.

421. **Acetates:** important acetates are those of ammonium, aluminium, and lead.

Spirit of Mindererus: ammonium acetate, $NH_4(C_2H_3$

O_2). To make it, saturate dilute acetic acid with ammonium carbonate and filter. Colorless, pungent, odorless liquid; should be freshly made.

Used in dentistry as a lotion, and internally as a refrigerant. Its formula is usually written $NH_4C_2H_3O_2$. It is completely volatilized by heat.

422. **Aluminium acetate:** a solution of it, known as Liquor Aluminii Acetatis, occurs in pharmacy and is used by dentists as an antiseptic, disinfectant, and deodorizer. It contains from 7½ to 8 per cent of basic aluminium acetate. ($Al_2(HO)_2(C_2H_3O_2)_4$, 324).

423. **Lead acetate** is known officially as Plumbi Acetas, $Pb(C_2H_3O_2)_2, 3H_2O = 378.5$. For pharmaceutical purposes it is made from oxide of lead, acetic acid, and water; $PbO + 2HC_2H_3O_2 + 2H_2O = Pb(C_2H_3O_2)_2 3H_2O$ Colorless, glistening, transparent crystals, efflorescent, soluble, of sweetish, astringent taste. Aqueous solutions become turbid from presence of carbon dioxide of the air, causing formation of carbonate of lead which is insoluble.

424. **Sub-acetate of lead:** the acetate and hydrate, basic acetate, $Pb(C_2H_3O_2)_2$, $Pb(HO)_2$. Colorless liquid, more poisonous than the acetate. Precipitated by solutions of gum. Used in Goulard's extract, *Liquor Plumbi Subacetatis*, a 25 per cent. solution of the sub-acetate.

425. **Lead water,** which is two fluidrachms of Liquor Plumbi Subacetatis in a pint of distilled water, is used in dental practice as a local application. It is known as Liquor Plumbi Subacetatis Dilutus.

Compounds of lead are poisonous, but chronic poisoning is more common than acute; in the latter case, emetics should be administered or the stomach pump used, large draughts of milk containing white of egg given, and sulphate of magnesium dissolved in **dilute** sulphuric acid.

426. **Trichloracetic acid** should really be considered

under the head of chloral hydrate, for it is formed when the latter is oxidized by nitric acid. It is called also trichloroacetic acid. Its formula is $HC_4Cl_3O_2$; it is a colorless, crystalline solid, soluble in water and in alcohol. It is a caustic and coagulates albumin. It is used in dentistry as a germicide and an antiseptic. According to Dr. Filippowitch it is a powerful antiseptic even in 0.2 per cent. solutions, while in 1 per cent. or 2 per cent. solutions it destroys all forms of organic life; in 5 per cent. it does not arrest the growth of yeast, but does that of bacteria and micrococci.

427. **Benzoic acid:** formula, $HC_7H_5O_2$. This acid may be obtained from benzoin, naphthalin, toluol, or from the urine of herbivorous animals. It is a solid substance occurring in lustrous blades, or needles, but slightly soluble in cold water, soluble in boiling water, more soluble in alcohol and ether. Borax added to it increases its solubility in water, as does sodium phosphate also. The acid is monobasic, like nitric acid. Most benzoates are soluble. Benzoic acid is an *antiseptic*, and is used in dentistry as such; also, as a local hæmostatic, in combination with powdered alum. It is one of the ingredients of Harris's Gum Wash.

Ammonium benzoate, $NH_4C_7H_5O_2 = 139$, is the benzoate most used. It occurs in the form of prismatic crystals, colorless, and transparent, or white and granular, soluble in 5 parts of water. It becomes yellow on long exposure to air. Benzoates, like benzoic acid, are antifermentative in action. Ammonium benzoate is administered in cases of phosphatic calculus, which, in time, it dissolves. *Lithium benzoate* has for its formula $LiC_7H_5O_2 = 128$.*

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* A derivative of benzoic acid is the new sweet substance *Saccharin*; a white, crystalline powder, soluble in 250 parts water, easily soluble in alcohol and ether. *Said* to be 280 times as sweet as cane-sugar. Solubility increased by addition of alkaline solutions.

428. Eugenic acid.—

Synonyms: eugenol, caryophyllic acid, oxidized essence of cloves.

Theoretical constitution: $C_{10}H_{12}O_2$.

Occurrence: found along with a hydrocarbon in oil of cloves.

Preparation: crude oil of cloves treated with potash is distilled, and the residue is subjected to the action of a mineral acid. The substance may also be obtained from cinnamon leaves.

Properties: colorless oil of sp. gr., 1.07, of spicy, burning taste, soluble in water and in alcohol. Reddens litmus, and coagulates albumin. On contact with air, becomes darker and resinous.

Use in dentistry: as a germicide, obtunding agent, etc., etc.

429. **Hydrocyanic acid:** Acidum Hydrocyanicum, HCN or HCy, cyanhydric acid. Exists ready formed in juice of the bitter cassava; may be obtained from bitter almonds, kernels of plums and peaches, apple seeds, cherry laurel, etc.; clear, colorless, volatile liquid, of peculiar, pungent odor. The official acid contains about 2 per cent. of the anhydrous acid. Its compounds are cyanides, or *cyanurets*, as formerly termed.

430. Mercuric cyanide, HgCy or HgCN, has already been considered.

431. **Oleic acid:** formula $C_{18}H_{34}O_2$, or $HC_{18}H_{33}O_2$, or $C_{17}H_{38}COOH$, is of the fatty acid series, like acetic acid. It is found, in combination with glyceryl, in most animal fats and non-drying vegetable oils. Its salts are called *oleates*, and are definite chemical compounds.

Metallic oleates seem to exert an antiseptic action, not only on the fats with which they may be combined, but also on discharges from suppurating surfaces, etc., etc. The pure oleic acid is free from unpleasant odor or rancidity. Oleates of the alkaloids are prepared by dissolving the alkaloid in oleic acid. Important oleates are those of aluminium, arsenic, bismuth, cadmium, copper, iron, lead, mercury, silver, tin, zinc, and iron.

432. **Mercuric oleate** is of stable composition, as now prepared, and has all the therapeutic effects of mercury. It does not become rancid nor stain the linen. Its formula is $Hg(C_{18}H_{33}O_2)_2 = 762$. It is made from yellow mercuric oxide. The official U. S. P. oleate is a liquid.

Percentage of Metal in the Metallic Oleates.

100 parts of oleate of	correspond to	Oxide	%
Aluminium		Al_2O_3	5.86
Arsenic		As_2O_3	21.55
Bismuth		Bi_2O_3	22.22
Copper		CuO	12.67
Iron (ferric)		Fe_2O_3	8.89
Lead		PbO	28.95
Mercury (precip.)		Hg	28.32
Silver		Ag_2O	29.77
Zinc		ZnO	12.90

433. **Oxalic acid:** $H_2(C_2O_4), 2H_2O = 126$.

Occurs in combination in *Oxalis* and in Rhubarb. Made from sawdust by action of caustic alkali. Colorless, transparent crystals, readily soluble, odorless, of intensely acid taste. Dangerous poison.

The treatment, in cases of poisoning, consists in giving lime, chalk, or magnesia in very small quantities of milk, and subsequently emetics if there is no vomiting.

434. The **salts** of oxalic acid are **oxalates,** and contain C_2O_4; the acid is dibasic, hence calcium oxalate would have CaC_2O_4 for its formula; potassium oxalate, $K_2C_2O_4$, etc., etc.

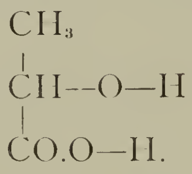
435. **Cerium oxalate** is $Ce_2(C_2O_4)_3.9H_2O = 708$.

436. **Lactic acid:** this acid is of importance

to the dental student in view of the experiments of Miller, Black, Magitot, and others in regard to caries.

Theoretical constitution: $C_3H_6O_3$

graphically



$$\begin{array}{l} CH_3 \\ | \\ CH{-}{-}O{-}H \\ | \\ CO.O{-}H. \end{array}$$

Composed of 3 atoms of carbon, 6 of hydrogen, and 3 of oxygen; by weight 36 parts of carbon, 6 of hydrogen, and 48 of oxygen. Molecular weight, 90. Formula usually written $HC_3H_5O_3$, to denote the monobasic character of the acid.

Occurrence and preparation: lactic acid is the acid of sour cabbage and of sour milk. It is produced in these substances by the action of a special ferment called **lactic ferment.** It is found in several parts of the human body, namely, in the urine, intestinal juices, and in the gastric juice. It exists in many products after fermentation, as in beet juice, various vegetables, nux vomica.

437. It, or isomeric modifications of it, occurs in the fluids which permeate muscular tissues. A variety called **sarco-lactic acid** is found in the muscles and also in the hepatic cells. *Abnormally*, lactic acid is found in the blood, particularly in leukæmia, pyæmia, etc.;

it may be found in purulent discharges, in the saliva in diabetes, and in the urine, especially after phosphorus poisoning, in acute atrophy of the liver, leukæmia, trichinosis, and occasionally in rickets and osteomalacia.

438. On a large scale lactic acid is prepared by the lactic fermentation, so called, of cane sugar and glucose. Flour is treated with dilute sulphuric acid and its starch thus converted into glucose; the free sulphuric acid is neutralized with milk of lime and sour milk is added, which gives rise to a fermentation in the sugars. This fermentation is checked before the so-called butyric fermentation sets in, by heating to the boiling point. Calcium lactate is formed, and the hot solution, after filtration, is evaporated down and allowed to crystallize. From calciumlactate, lactic acid is obtained by saturation with sulphuric acid.

In the human body, lactic acid is possibly a derivative of sugar:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} \quad = \quad \underset{\text{Lactic acid.}}{2(C_3H_6O_3)}$$

It is decomposed in the system into carbonic acid and water, perhaps splitting up first into butyric acid, carbonic acid, and hydrogen.

The lactic acid found in sour milk is produced by the transformation of the sugar of milk into lactic acid, by the influence of decomposing casein:

$$\underset{\text{Milk-sugar.}}{C_{12}H_{22}O_{11}} \quad + \quad \underset{\text{Water.}}{H_2O} \quad = \quad 4HC_3H_5O_3.$$

Properties: the official U. S. P. lactic acid is a colorless, syrupy, odorless, strongly acid liquid containing 75 per cent. of lactic acid. Sp. gr., 1.212. It mixes readily with water, alcohol, and ether; is nearly insoluble in chloroform.

Lactic acid possesses the property of dissolving calcium phosphate. It has been shown, by Magitot and others, to be capable of decomposing the teeth; sections of dentine, placed by Miller in infected culture fluids, were decomposed by the lactic acid formed. Leber and Rottenstein found that solutions of lactic acid, 1 part in 100 of water, decalcified the teeth.

Miller's experiments tend to show that, during caries, lactic acid is formed in the teeth and in sufficient amount to destroy the dentine.

439. Lactic acid is a monobasic acid, $H(C_3H_5O_3)$; its salts are *lactates*, and are all soluble. Phosphates dissolved in lactic acid form *lacto-phosphates*. Calcium lacto-phosphate is made by the action of lactic acid on calcium phosphate.

440. **Salicylic acid:** formula $C_7H_6O_3$, or $HC_7H_5O_3$, or $C_6H_4(OH)CO_2H$. It is also called *oxybenzoic acid*. It forms a large percentage of oil of wintergreen, but is prepared on a large scale by the action of carbon dioxide on sodium phenate (carbolate).

Properties: odorless, white and lustrous masses of fine, small, colorless needles, soluble in boiling water and in alcohol; tasteless at first, but afterwards sweet and astringent, causing acridity of the fauces; soluble in cold water containing three parts of sodium phosphate. Antiseptic and disinfectant. Heated dry in a test tube, sublimes in beautiful needles before melting-point is reached, and at higher temperature is dissipated. It is soluble in alcohol, ether, and glycerine. Its salts are salicylates; it is a monobasic acid, $H(C_7H_5O_3)$, therefore, sodium salicylate, for example, is $NaC_7H_5O_3$. Salicylic acid is used in dentistry as an antiseptic, dissolved in water containing a little sodium phosphate or sodium sulphite, or in glycerine, or in ether. It, like many other acids, attacks the teeth slightly, hence is not suitable for mouth washes. It is acid in reaction.

441. **Salol:** this substance is the phenyl ether of salicylic acid, that is, phenyl salicylate, $C_6H_4OH.COO.C_6H_5$; empirically, $C_6H_5C_7H_5O_3$, one atom of hydrogen in salicylic acid being replaced by the univalent radical C_6H_5. It is a white crystalline powder, of mild aromatic odor, insoluble in water but soluble in alcohol. Used in dentistry as an antiseptic.

Betol is the salicylate of beta-naphthol, $C_6H_4OH.COO.C_{10}H_7$. Said to be freer from detrimental properties than alcohol, White, insoluble in water.

442. **Sozolic Acid** (formerly called **Aseptol***):

Formula, $C_6H_4(HO)SO_2(HO)$, orthoxy-phenyl-sulphurous acid, containing SO_2 in place of carbonyl (CO) of salicylic acid.

It is a reddish syrupy liquid, of sp. gr., 1.40, with a feeble and not disagreeable odor. It dissolves in water in all proportions. With ferric chloride it gives the same violet coloration as salicylic acid. Though a decided acid, it has not the corrosive action of phenol. It is said to arrest absolutely every fermentation, diastatic or fungoid, to a much greater degree than phenol and other well-known antiseptics. The advantages of sozolic acid lie chiefly in its great solubility and freedom from odor—qualities which, together with the absence of corrosive action, should make it suitable for toilet preparations in many cases.

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* Aseptol is a 33½ per cent. solution of the acid.

It is a valuable antiseptic, according to D. F. Hueppe, and doubtless will partially replace carbolic acid as a disinfectant and antiseptic. It would seem destined to be of value in dentistry in treatment of fetor of the breath.

443. **Tartaric acid:** $H_2(C_4H_4O_6)$, Acidum Tartaricum. Occurs in grapes, pineapples, tamarinds, and other fruits, as a tartrate. Prepared from crude tartar. Colorless, transparent crystals, soluble in water. Solutions are strongly acid, and deposit fungous growth.

In dentistry it is used, combined with "chloride of lime," to bleach discolored teeth.

444. **Cream of tartar** or **potassium bitartrate:** potassium acid tartrate, $KH(C_4H_4O_6)$, made from argols or crude tartar, a deposit on the sides of wine casks; odorless, of gritty taste, white, almost insoluble in cold water, soluble in from 15 to 20 parts boiling.

445. **Rochelle salt:** potassium sodium tartrate, $KNa(C^4H^4O_6)\ 4H_2O$. Large, transparent, colorless, slightly efflorescent crystals, of mildly saline and bitter taste, readily soluble.

446. **Tartar emetic:** tartrate of **potassium** and a radical called **stibyl;** potassium antimonyl tartrate, $2(KSbO.C_4H_4O_6).H_2O = 664$, is prepared by boiling 4 parts of antimonous oxide with 5 parts of cream of tartar in 50 of water. It is soluble in 17 parts of water, but insoluble in alcohol. It is poisonous: treatment should consist in use of stomach pump or emetics, administration of tannin in form of tea, infusion of nut galls, oak bark, etc., and of stimulants.

447. **Other organic acids:** valeric or valerianic, $HC_5H_9O_2$; citric: $H_3C_6H_5O_7.H_2O$. A new disinfectant is oxynaphthoic acid, alpha: a white, odorless, micro-crystalline powder, nearly insoluble in water, soluble in alcohol.

ALKALOIDS.

448. **Alkaloids** *are artificial, natural, or cadaveric.* Artificial alkaloids are the various amines, as methylamine, ethylamine, etc. Methylamine is a gas, ethylamine a liquid, propylamine a volatile oil.*

449. **The natural alkaloids**: a class of substances chiefly of vegetable origin, often active principles of plants, supposed to be like *alkalies*, hence name. Those containing no oxygen are volatile; those having oxygen are non-volatile. As a rule, are soluble in alcohol, ether, chloroform; contain nitrogen, turn plane of polarized ray of light to left (with few exceptions), furnish with platinic chloride, double chlorides; have bitter taste, resemble alkalies in uniting with acids to form salts, of which the sulphates, nitrates, chlorides, and acetates are usually soluble, and the oxalates, tartrates, and tannates usually insoluble; in solution are precipitated by many re-agents, including iodine dissolved in iodide of potassium: very poisonous.

The alkaloids used in dentistry are for the most part *natural* alkaloids, as morphine, cocaine, etc., etc.

Cadaveric alkaloids, or *ptomaines*, are those found in putrefying animal or vegetable matter, and, in certain

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* Many therapeutic agents have been discovered among the amines and their derivatives, *e. g.* antifebrin, a derivative of aniline which is itself, *phenylamine.*

pathological conditions, in the human body during life. Pyæmic fluid yields an alkaloid, which has been named *septicine*.

Most of the natural organic bases or alkaloids resemble the –amines or compound ammonias; an **–amine** may be regarded as formed by the replacement of one or more atoms in the ammonia (NH_3) molecules by positive or hydrocarbon radicals, thus:

$$N\begin{cases}H\\H\\H\end{cases}$$

ammonia

$$N\begin{cases}CH\\H\\H\end{cases}$$

methylamine.

Some of the alkaloids are more like ammonium compounds than like amines. The molecular structure of the vegetable alkaloids is, in most cases, but very imperfectly understood.

450. **Aconitine:** $C_{30}H_{47}NO_7$, is the alkaloid of aconite, *Aconitum Napellus*, occurring as a glacial mass or white powder, crystallizing with difficulty in rhombic plates. It is soluble in 150 parts of water, slightly soluble in ammonia water, soluble in benzol, soluble in 2 parts ether, soluble in 2½ parts chloroform. It has a sharp, pungent taste, and is one of the most powerful poisons known. It is fatal, probably, in doses of $\frac{1}{13}$th grain. Samples of aconitine vary in strength, some being wholly inert, others powerfully poisonous. Morson's and Duquesnel's *crystalized* aconitine have about the same solubility, and are of about the same strength. Duquesnel's is in form of large crystals usually, some weighing $\frac{1}{10}$th of a grain.

Oleate of aconitine contains usually 2 per cent. of the alkaloid.

Aconitine, in dental practice, is administered internally, for neuralgia of the fifth pair of nerves. The treatment, in cases of poisoning, should consist in administration of emetics, and of stimulants as ammonia, brandy, strong coffee, and tea. Liniments and friction to the limbs and spine should be used, mustard plasters applied to pit of stomach, and slight galvanic shocks through the heart administered.

Tincture of aconite is a valuable local application in dentistry, especially when combined with various agents, as iodine, chloroform, etc. Poisoning by tincture of aconite is to be treated as above; the chief symptoms are numbness and tingling, great sense of fatigue, muscular weakness, etc., etc.

451. *Napelline*, an alkaloid obtained by Duquesnel from aconite, is less powerful than aconitine, and has hypnotic properties.

452. **Atropine:** $C_{17}H_{23}NO_3$. This alkaloid is from *Atropa Belladonna*. The *sulphate* of atropine is used in dentistry. Its formula is $(C_{17}H_{23}NO_3)_2H_2SO_4$, and it is made by combining atropine with sulphuric acid and evaporating. [The hydrogen of acids is not replaced by alkaloids, when they combine with the acids; in this respect the compounds formed differ from compounds of the alkali metals and acids: thus, while atropine sulphate is $(C_{17}H_{23}NO_3)_2$, H_2SO_4, potassium sulphate is K_2SO_4].

Atropine sulphate is a white, crystalline powder, or forms small, colorless, silky prisms. It is soluble in 3 parts cold water, and 10 parts, 90 per cent alcohol. *The concentrated solution should be neutral to test paper.** It is insoluble in ether, inodorous, of disagreeable, bitter taste, and is an active poison. In dental practice, it is used locally as an obtunding agent, etc., and also internally, for neuralgia, etc. The fatal dose is two grains; the treatment should consist in administration of emetics, and subcutaneous injection of pilocarpine or of morphine.

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* In order to test atropine sulphate, drop a little of the dry powder on litmus paper, both red and blue, previously moistened with water. It should not affect either paper.

Dryness of the throat, diplopia, vertigo, and in serious cases, delirium, are among the symptoms of poisoning by this substance.

453. **Chinoline** or **quinoline:** C_9H_7N.

This substance is an artificial alkaloid,† and is not the active principle of any plant. It was first made from coal tar, then from cinchona, but now is made from nitrobenzole, aniline, and glycerine, to which sulphuric acid has been added, the mixture being heated and cooled alternately. It is a colorless, oily liquid, of sp. gr. 1.094, and boiling at 460° F. In chemical constitution it may be regarded as naphthalin, $C_{10}H_8$, in which *one* CH group is replaced by N.

Chinoline forms crystalline salts with acids. The one used in dentistry is the tartrate, $(C_9H_7N)_2\ H_2C_4H_4O_6$, theoretically, but the real composition of German chinoline tartrate is said to be $3C_9H_7N.4C_4H_6O_6$, requiring 60.8 per cent. of tartaric acid. Chinoline tartrate forms (microscopic) columnar crystals; it is soluble in 75 parts of water at 60.8°F., and in 150 parts of 90% alcohol, and 350 of ether. Its taste is peculiar, somewhat burning, penetrating, and suggesting peppermint. It has a faint odor, slightly suggesting bitter almonds.

It is used in dentistry as an antiseptic, usually in 5 per cent. solution. It is sometimes combined with carbolic acid. Its aromatic odor is less pleasant than that of pyridine, which it resembles.

Chinoline enters into a definite combination with iodoform. One part of iodoform, dissolved in ether, is mixed with three of chinoline also dissolved in ether.

Salts of chinoline should be kept away from the light.

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† *Antipyrine* is a derivative of chinoline; and is an antipyretic and anodyne.

454. **Cannabis Indica** products: the *tincture* of Cannabis Indica, diluted 3 to 5 times, has been used by A. Aaronson and others, as a local anæsthetic in extracting teeth.

455. **Cannabinum Tannicum** or cannabin tannate occurs as an amorphous, yellowish or brownish-gray powder, indifferent toward litmus, having a very faint odor of hemp, and a somewhat bitter, strongly astringent taste. When heated on platinum foil, it swells up and finally leaves minute traces of a white ash. It is almost insoluble in cold water, alcohol or ether, and dissolves but little on warming; but it is easily soluble in water or alcohol acidulated with hydrochloric acid.

456. **Cannabine:*** this is the name of an alkaloid recently prepared from Cannabis Indica. It appears as a viscid, brown substance, transparent in thin layers, of a strongly aromatic odor and a sharp, bitter, and somewhat scratching taste. It is insoluble in water, easily soluble in alcohol, ether, petroleum ether, chloroform, benzol, disulphide of carbon, ethereal and fixed oils. The solutions are golden-yellow when highly diluted, brown when concentrated. When heated on platinum foil it leaves no residue.

457. **Cocaine:** $C_{17}H_{21}NO_4$. This now famous alkaloid is prepared from *Erythroxylon Coca*, a shrub indigenous to certain regions in South America. It is found chiefly in Peru and Chili, and the alkaloid is extracted from the leaves. The process of extracting cocaine from coca leaves is given in full in Squibb's Ephemeris, Vol. II., No. 7; it is too long for insertion here.

Pure cocaine crystallizes in colorless, four or six sided monoclinic prisms, soluble in 704 parts of water at 53.6°F., easily soluble in alcohol, and still more so in ether.

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* The pure alkaloid must be carefully distinguished from the resinoid called "Cannabin."

Cocaine melts near 197°F. Cocaine combines readily with dilute acids, forming easily crystallizable salts, which are more or less sparingly soluble in water, but soluble in alcohol. They are insoluble in ether, of bitter taste, and leave a transient sensation of insensibility upon the tongue.

The hydrochlorate, or muriate, of cocaine is the salt which has been most used. The *crystallized* hydrochlorate has for its formula, $C_{17}H_{21}NO_4,HCl. 2H_2O$, when crystallized from aqueous solutions. Dried and rendered anhydrous, its formula is $C_{17}H_{21}NO_4,HCl.$; crystallized from alcohol (B.P.), its formula is the same as the latter, for it is anhydrous. Hydrochlorate of cocaine occurs in the form of short, transparent, prismatic crystals, permanent in air. It is sparingly soluble in water, but readily soluble in alcohol, ether, and in vaseline.

The hydrochlorate is termed *hydrochloride* by some authors; the hydrogen of the hydrochloric acid is not given off in the combination, as is seen from the formula.

458. Other compounds of cocaine are the *hydrobromate*, $C_{17}H_{21}NO_4,HBr$; the citrate, $(C_{17}H_{21}NO_4)_3H_3C_6H_5O_7$; the oleate, $(C_{17}H_{21}NO_4)HC_{18}H_{33}O_2$, containing 5 per cent. of the alkaloid; the salicylate, $C_{17}H_{21}NO_4$, $HC_7H_5O_3$, the *phenate* or carbolate*, and the phtalate. *Salts of cocaine are used in dentistry* as local anæsthetics and anodynes, especially in alveolar pyorrhœa, extirpation of pulps of teeth, and that of hypersensitive dentine. They have also been used by injection, for extraction of teeth. Combined with menthol, and dissolved in alcohol, chloroform, or ethyl bromide, they are used as a lotion in neuralgia and odontalgia; for the same purpose, dissolved in oil of cloves. Toxic symptoms have followed injection

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* The carbolate is a colorless mass of faint odor, very readily soluble in alcohol.

of 6 drops of a 20 per cent. solution into the gums; relieved by inhalation of amyl nitrite, 3 drops at a time, 3 inhalations.

The *purity of cocaine salts* is of the greatest importance. The permanganate test should be used for possible organic impurities.*

459. **Morphine:** morphine, morphia, $C_{17}H_{19}NO_3.H_2O$, exists as meconate of morphine in opium, which is the concrete, milky juice exuding on incising the unripe capsules of *Papaver Somniferum*, or white poppy. On account of the comparative insolubility of morphine, its *salts* are preferred for use in dentistry. Of these the acetate, hydrochlorate, and sulphate are official. They are all freely soluble in water.

460. *Morphine acetate*, $(C_{17}H_{19}NO_3)HC_2H_3O_2.3H_2O$, occurs in the form of a white or yellowish white, amorphous or crystalline powder of bitter taste. Soluble in both alcohol and water. It is known officially as *Morphinæ Acetas*.

461. *Morphine hydrochlorate*, $(C_{17}H_{19}NO_3)HCl.3H_2O$, also known as the hydrochloride or muriate, occurs in the form of snow-white, feathery, flexible, acicular crystals, of bitter taste and silky lustre, wholly soluble in both alcohol and water. Morphinæ Hydrochloras or Murias is the official term.

462. *Morphine sulphate*,† $(C_{17}H_{19}NO_3)_2H_2SO_4.5H_2O$, oc-

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* To test the hydrochlorate (muriate) of cocaine, take 1½ grains cocaine muriate and dissolve in 80 minims of *distilled* water; add 2 drops of dilute C. P. sulphuric acid, then 1 drop of a 1 to 100 solution of potassium permanganate in distilled water. Instant discoloration, or in less than one minute, shows presence of organic impurities. The purest is said not to discolor in an hour. Comparative tests, that is of several samples at a time, are desirable.

† For hypodermic use, the *phtalate* of morphine is recommended. It comes in transparent, glassy scales, and is said not to be so liable to decomposition as the sulphate.

curs in form of crystals like the hydrochlorate, neutral in reaction, odorless, with bitter taste, soluble in both water and alcohol.

463. **In dentistry the salts of morphine**, especially the acetate and the hydrochlorate, are used in devitalizing mixtures and as obtunding agents, also for temporary relief of odontalgia, usually in combination with carbolic acid, oil of cloves, etc., etc. The acetate is used in nerve paste, rather than the sulphate, which latter is thought more irritating. Morphine is also given internally, in facial neuralgia, etc. The average fatal dose of the salts of morphine is 2 grains. Treatment of poisoning by these agents should consist in the use, by all means, of the stomach pump, washing out the stomach either with an infusion of coffee or green tea, or else with water in which finely powdered charcoal is suspended, using a fresh amount for each injection. If the pump is not used, vomiting should be encouraged, zinc sulphate in 5 grain doses, with fifteen minute intervals, being given, or *apomorphine hydrochlorate* subcutaneously, in doses of from 1-15 to 1-5 of a grain. Subsequently, 15 drops of tincture of belladonna, or 1-35 grain of atropine sulphate (subcutaneously), should be given. In the early stages of poisoning the above mentioned treatment is often all that is necessary. In later stages artificial respiration and use of the battery (Faradic current) are imperative. Enemata of strong coffee may be administered.

464. . **Quinine;** $C_{20}H_{24}N_2O_2 + 3H_2O$. This alkaloid occurs in cinchona bark, together with a number of others of which cinchona, quinidine, and cinchonidine are the most important. Quinine (crystallized), is a white powder, of bitter taste and alkaline reaction. It is nearly insoluble in water. Quinine itself is seldom used. Salts of it are sulphates, hydrochloride, salicylate, tannate, hydrobromide, valerianate, citrate (of iron and quinine), hypo-

phosphite. The sulphate, disulphate, hydrobromide, hydrochloride, and valerianate, are official.

465. **Quinine Sulphates:** there are three of these, of which the diquinic sulphate $(C_{20}H_{24}N_2O_2)_2.H_2SO_4.7H_2O$, is the official sulphate. It occurs as long, brilliant needles, efflorescing to a white powder. It is but sparingly soluble in water: 1 in 780 parts; in alcohol, 1 in 65. It is readily soluble in dilute acids, but nearly insoluble in ether or chloroform.

The official *bisulphate* is obtained by dissolving the sulphate in dilute sulphuric acid. Its formula is $C_{20}H_{24}N_2O_2.H_2SO_4.7H_2O$.

There is another sulphate, obtained by dissolving quinine in excess of dilute sulphuric acid. Its formula is $(C_{20}H_{24}N_2O_2)2H_2SO_4.7H_2O$. It is not official. There is also a hypophosphite.

466. **The salts of quinine are used in dentistry** in the treatment of various facial and neuralgic affections and as ingredients of dentifrices.

467. **The alkaloids of Nux Vomica:—**

Strychnine, Strychninum, strychnia, $C_{21}H_{22}N_2O_2$. Occurs in seed of Strychnos Nux Vomica, or poison-nuttree; also in Strychnos Ignatia, or St. Ignatius bean, found as strychnate or acetate.

Brucine is the other alkaloid, and is more soluble than strychnine.

The bitter taste of strychnine is perceptible in a solution containing but one part in 1,000,000. Strychnine sulphate $(C_{21}H_{22}N_2O_2)_2.H_2SO_4.7H_2O$, is official, and readily soluble in water. Salts of strychnine are very poisonous, ¼ of a grain having caused death. The treatment, in cases of poisoning, should consist in inhalation of chloroform, use of emetics, and, if possible, the injection into the stomach and withdrawal therefrom of powdered charcoal. Chloral hydrate and paraldehyde are sometimes administered as antidotes, and chloroform given internally.

468. **Veratrine:** $C_{37}H_{53}NO_{11}$, is an alkaloid found in *Veratrum sabadilla* and in *Cevadilla*, the seeds of *Asagræa officinalis:* also in *Veratrum album* or white hellebore, and *Veratrum viride*, or American hellebore. It occurs as a white, or grayish-white amorphous powder, of acrid taste; it causes violent sneezing, if inhaled. The *oleate* of veratrine is official, and is made to contain 2 per cent. of the alkaloid, and also ten per cent.

In dental practice, veratrine in form of ointment is used for neuralgia, etc.

469, **Other alkaloids:—**

Antipyrine, dimethyloxyquinizine, useful as an adjunct to cocaine in dental anæsthetization. Synthetic alkaloid. Formula, $C_{11}H_{12}N_2O$. White, crystalline, odorless, bitter tasting powder.

Antifebrin or acetanilide.

$$N\left\{\begin{array}{ll} C_6H_5 & \text{crystalline, odorless, solid;} \\ H & \text{slightly soluble in warm water;} \\ C_2H_3O_2 & \text{very soluble in alcohol.} \end{array}\right.$$

Synthetic alkaloid.

Alstonine, the alkaloid of *Alstonia constricta.* White crystals.

Apomorphine, emetic.

Caffeine: a new compound is the *boro-citrate* of caffeine.

Cytisine, alkaloid of *Cytisus laburnum.*

Ditaine, $C_{22}H_{30}N_2O_4$, alkaloid of Dita-bark from Alstonica scholaris.

Erythrophleine from Erythrophleum bark; said to be a local anæsthetic.

Ethyl-oxy-Caffeine, $C_8H_9(O.C_2H_5)N_4O_2$, used as a local anæsthetic by subcutaneous injection.

Hyoscyamine from the black Hyoscyamus plant; *eserine* from calabar bean; *narceine* from opium.

Is-atropyl Cocaine, $C_{19}H_{23}NO_4$, obtained as secondary product in manufacture of cocaine and thought to be possibly the cause of toxical accessory symptoms consequent on the administration of even slightly impure cocaine.

Jerubebine, alkaloid of *Solanum paniculatum*.

Lamine from flowers of *Lamium album*; hemostatic.

Oxy-propylene-di-iso-amyl-amine: synthetic, alkaloid. Colorless liquid.

Ulexine, alkaloid from *Genista tinctoria*.

NEWER ALKALOIDS, GLUCOSIDES ETC.

Arbutin, glucoside of uva ursi. Diuretic.

Arecoline, alkaloid from areca nut; alkaline liquid.

Aspidospermine, mixture of Quebracho alkaloids.

Bebeerine-alkaloid from nectandra rodiæi—not berberine.

Boldine, alkaloid of Boldo Chiliensis.

Convallarin, *glucoside* from convallaria, insoluble in water, drastic purgative.

Convallamarin, glucoside from convallaria majalis, soluble in water, powerful heart tonic.

Diuretin, is theobromine sodium salicylate.

Muawin, glucoside from the muawi tree. Resembles digitalin.

Narceine (*hydrochlorate*), hypnotic alkaloid from opium.

Papaverine (*hydrochlorate*) alkaloid from opium.

Piperine, alkaloid from piper nigrum.

Tropa-cocaine the alkaloid from javanese coca.

Nicotin, $C_{10}H_{14}N_2$, from tobacco. Liquid. Sp. gr. 1027. Soluble in water.

Coniin, $C_8H_{17}N$, liquid, from *conium maculatum*. Has been prepared artificially.

Sparteine, $C_{15}H_{26}N_2$, liquid.

The three above are known as volatile alkaloids, colorless when pure and first separated, but turning brown on exposure to the air. They have disagreeable, penetrating odor. The following are also alkaloids:

Lobelin, Indian tobacco, liquid.

Sophorin, *Sophora Japonica*, liquid.

Apomorphine, $C_{17}H_{17}NO_2$, made by heating morphine with HCl to about 300 F.

Homatropin from atropine.

Colchicine $C_{17}H_{19}NO_5$ from *colchicum autumnale.*

Theine is of the same formula, source, and properties.

Theobromine $C_{17}H_8N_4O_2$, is from cacao. Crystals, not very soluble in water.

Piperine, $C_{17}H_{19}NO_3$, cayenne pepper, *yellow* crystals, isomeric with morphine.

Pilocarpine, $C_{11}H_{16}N_2O_2$, from jaborandi; increases perspiration.

Pelletierin, $C_8H_{13}NO$, is from the pomegranate root and is a liquid.

Adonidin, glucoside from adonis vernalis; cardiac tonic.

Arecoline, alkaloid from areca nut. Powerful anthelmintic and heart poison.

Baptisin, glucoside from baptisia tinctoria. Purgative, etc.

Caffeine, $C_8H_{10}N_4O_2$, is the alkaloid of coffee; it is soluble in water and of feeble basic properties. New salts, very soluble, are the sodio-benzoate, sodio-cinnamate, sodio-citrate, sodio-salicylate, sodio-borocitrate, phenate, and phthalate.

Coronillin, glucoside from coronilla scorpoides.

Digitalin, *digitalein*, and *digitoxin*, alkaloids of digitalis, the last the most poisonous.

Eurybin, glucoside from eurybia moschata.

Euonymin, resin from eunonymus atropurpureus.

Lactucin, active principle of lactucarium. Hypnotic.

Lantanine, alkaloid from lantana brasiliensis.

Leptandrin, glucoside from leptandra.

Ouabain, glucoside from wood of acocanthera ouabaio.

Papain, digestive ferment from carica papaya.

Scoparine, active principle of cytisus scoparius. Diuretic.

Scopolamine, alkaloid of scopolia atropoides. Mydriatic.

Spasmotin, sphacelotoxin, poisonous principle of ergot.

Strophanthin, glucoside from strophanthus. Heart tonic.

Solanine, alkaloidal glucoside from the solanaceæ.

ALBUMINOUS SUBSTANCES.

470. **Proteids:** a certain amount of knowledge in regard to these substances is essential. *Proteid* is the general term given to *albuminous* compounds, which form the chief part of the solids of the organs, blood, muscle and lymph of animals, and seeds of plants. They are not crystalline, but colloid, do notid ffuse through animal membranes, and readily putrefy when exposed to the air. They are white, flaky or granular, amorphous, and difficult to obtain in the pure state.

Some are soluble, others insoluble in water; they are soluble in mineral acids and caustic alkalies, but almost insoluble in alcohol and ether. They have the peculiar property, however, of becoming insoluble either spontaneously, or after action of heat, or under influence of weak acids. They all yield what seems to be the same substance, *syntonin*, and, under the influence of the gastric juice, they are capable of generating peptones, or bodies easily assimilated and very nutritious. Proteids, when heated, do not volatilize, but, when burnt, they give off products having odor of burnt horn.

No accurate formulæ have been found for proteids, but they are known to contain carbon, hydrogen, *nitrogen*, oxygen, sometimes sulphur, sometimes phosphorus, and iron; in their ash, calcium phosphate is found. Their percentage composition, according to Wurtz, is carbon 52.7 to 54.5, hydrogen 6.9 to 7.3, nitrogen 15.4 to 17, oxygen 20.9 to 23.5, sulphur 0.8 to 2.2.

471. Proteids heated with a solution of mercurous nitrate, containing nitrous acid, assume a fine red color. On exposure to the air, proteids putrefy readily, fine granulations being developed in their interior, which change into vibrios, oxygen at the same time being absorbed, while **carbon dioxide** (carbonic acid gas), nitrogen, **ammonia, sulphuretted hydrogen**, hydrogen, ammonium sulphide, are discharged, and fatty acids, as butyric, **lactic acid,**—amines, leucin, tyrosin, etc., formed.

472. Proteids are classified by Hoppe-Seyler as follows:

1. Native albumins: soluble in water and precipitated by boiling; albumin of serum (blood albumin) and albumin of white of egg. Blood albumin is coagulated by a temperature of from 122°F. to 163°, but not by ether. Egg albumin begins to coagulate at 129°, coagulation increasing at 145° and 165°; it is precipitated by ether. Blood albumin, in solution, may be precipitated by concentrated nitric acid, citric or acetic acid plus potassium ferrocyanide, picric acid, and by many other substances.

2. Globulins: insoluble in water, soluble in 1 per cent. sodium chloride solution, but precipitated (except vitellin) by saturated solution of common salt or by addition of large quantity of water. The globulins are vitellin,

crystallin, fibrinogen, fibrino-plastin, myosin or muscle fibrin. Syntonin may be prepared from myosin by treating the latter with a very little HCl.

Fibrin: a white, elastic, more or less fibrillated solid, insoluble in water and dilute sodium chloride solutions, prepared by rapidly stirring freshly drawn blood with a bundle of twigs, and washing the coagulum with water. Neutral solutions of fibrinogen and fibrinoplastin, mixed, in presence of fibrin ferment form fibrin. Fibrin does not dissolve in 1 per cent. solution of HCl, but swells, becoming soluble on addition of pepsin. Fibrin coagulates spontaneously on exposure to air.

4. Albuminates or derived albumins, sometimes called modified albumins: these are (1) acid albuminate, known also as syntonin, albumose, and parapeptone, and (2) alkali-albuminate found in blood corpuscles, blood serum, etc., and closely resembling casein.

5. Peptones: albuminous bodies are converted by the action of the gastric, pancreatic, and, doubtless, intestinal juices, into more diffusible and soluble bodies called peptones.

6. Amyloid substance or lardacein.

7. Coagulated albumin, as produced by action of heat on solution of serum albumin.

8. Special albumins found in cysts, dropsical fluids, etc. (Metalbumin, paralbumin).

9. Collagens: albuminous bodies which do not yield syntonin when treated with dilute acids. Hot aqueous solutions become jelly-like on cooling. The collagens are ossein, gelatin, chondrin, mucin, and elastin. Ossein is the proteid basis of bones, and contains 49.9 per cent. of carbon, 7.3 of hydrogen, 17.2 of nitrogen, 24.9 of oxygen, and 0.7 of sulphur. Chondrin is the proteid found in cartilages.

473. *Mucin* is found in several parts of the body and is

one of the excretion products of the protoplasm of epithelial cells lining mucous surfaces, and of the secreting mucous cells of the sublingual and submaxillary glands. Its average composition is 49.5% carbon, 6.7% hydr,ogen 9.6% nitrogen, and 34.2% oxygen. Dry mucin yields about 2.44% ash and contains no sulphur. In chemical constitution it is a nitrogenous glucoside and probably an albumin derivative. Mucin, when obtained in the free state, occurs in white or yellow, thready, tenacious masses. It swells in water and mixes with it, but does not dissolve. It is soluble in dilute HCl, in weak alkalies, but insoluble in alcohol, ether, chloroform, dilute acetic acid, very dilute mineral acids. Acetic acid makes it shrink; caustic potash makes it more thready at first, then dissolves it. Its solutions are precipitated by acetic acid, and, according to Oliver, by alcohol, dilute mineral acids, and all vegetable acids.

Elasticin or (elastin) is the proteid composing the fibres of yellow elastic tissue.

474. 10. Proteid derivatives: leucin, $C_6H_{13}NO_2$, or amidocaproic acid, is an important proteid derivative, and is a constant product of the decomposition of albumin and of nitrogenous substances. It is formed in decomposing cheese. Tyrosin, $C_9H_{11}NO_3$, is also a proteid derivative. Both are occasionally found in the saliva. Both unite with both acids and bases.

475. 11. Nitrogenized products of tissue metabolism: uric acid, sarkin, xanthin, guanin, etc., etc. **Uric acid,** $C_5H_4N_4O_3$, is found in calculi, blood, urine, etc., etc. It is very sparingly soluble in water. It forms urates, of which lithium urate is the most soluble. Compounds of lithium are, therefore, administered in cases of uric acid calculi.

476. **Fermentation:** according to Gautier, fermentation takes place whenever an organic

compound undergoes changes of composition under the influence of a nitrogenous, organic substance, called a *ferment,* which acts in small quantities and yields nothing to the fermented substance. In a word, *fermentation is the decomposition of carbo-hydrates into simpler compounds, by the agency of living microbes.*

Putrefaction is the name given to decomposition-fermentations in animal or vegetable organisms *rich in proteids;* in putrefaction, offensive odors are given off. Neither fermentation nor putrefaction is simply oxidation, but the presence of oxygen appears to be necessary to set up the change. The presence of water is also necessary to processes of fermentation.

477. **Ferments:** ferments are in general of two kinds (1) **soluble** or **unorganized** (enzymes, and (2) **organized.**

478. **Soluble** or **unorganized** ferments are proteid substances having the power, under favorable circumstances, of causing certain chemical changes in bodies with which they come into contact, whilst they themselves undergo no change. Several soluble ferments are of vegetable origin, and of these diastase is the most important; those of animal origin are pepsin, ptyalin, trypsin, etc., etc. They are soluble in water, very diffusible, and, although not precipitated by boiling, nevertheless lose their activity. They neither give to the bodies with which they are brought in contact nor take from

them. Their activity is destroyed by borax, but not by hydrogen dioxide. They do not reproduce themselves during the period of their activity.

479. *Diastase* (maltin) is the ferment formed in grains, at time of sprouting, from the gluten. It converts starch into dextrin and maltose. *Ptyalin*, the salivary ferment, has the same action; they act slowly on unchanged starch, but rapidly on cooked starch. The starch is first liquefied, then converted into dextrin, then into maltose. The amount of starch that can be transformed is anywhere from 2,090 to 100,000 times the weight of the ferment.

480. *Pepsin* is secreted in the glands of the stomach. It is obtained from the stomach of the pig by digesting the mucous membrane in hydrochloric acid, and precipitating by sodium chloride. It is a yellowish or grayish-white powder, insoluble in water, but soluble in water to which glycerine has been added. It is of peculiar odor, and bitter, nauseating taste. Heat of 230°F. decomposes it and renders it inert, but its solutions lose activity at much lower temperatures. The temperature most favorable for its activity is 98.6°F., and presence of a dilute acid as hydrochloric, lactic, phosphoric, etc., is required to develop its peculiar action. $\frac{1}{10}$th per cent. NaCl also favors its action, but half of one per cent. hinders it. Carbolic acid or excess of alcohol retards its action. **In dental practice, pepsin** is used in the treatment of putrid pulps, as an antiseptic and deodorizer.

It has been used and recommended by Coleman, of England, to digest dead pulp in inaccessible teeth, dilute hydrochloric acid being employed along with it.

481. **Organized ferments:** soluble ferments, as we have seen, are responsible for all physiological fermentations; on the other hand, pathological fermentations are caused by *organized ferments*, which are forms of low or-

ganisms, vegetable in origin, whose activity is greatest at temperatures ranging from 68°F. to about 104°. Their activity is retarded by temperature below or above these limits, and temperatures near 212°F. entirely destroy their activity, as does also hydrogen dioxide. The latter agent stops also the chemical change which is the direct result of the growth of the organized ferments. These ferments are remarkable in that a very minute quantity will grow and exert its action as long as appropriate nourishment is furnished it. Organized ferments have, then, powers of growth and reproduction, and the ferment power cannot be separated from the ferment organism by filtration or by any solvent. The chief food of organized ferments is ammoniacal salts and alkaline phosphates. The most important of the organized ferments are yeast (alcoholic ferment) acetic acid ferment, lactic and butyric acid ferment, the ferment of "thrush," and the putrefactive ferments.

482. *Yeast spores* are always to be found either in the air, or on fruit. Their chief action is to convert saccharose into grape sugar, and then to change the latter into alcohol and carbonic acid with a trace of succinic acid and glycerine. The equation of the change due to yeast would be:

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} \quad + \quad \underset{\text{Water.}}{2H_2O} \quad = \quad \underset{\text{Alcohol.}}{2C_2H_6O} \quad + \quad \underset{\text{Carbolic acid,}}{2H_2CO_3}$$

Yeast is known as *Torula* (*Saccharomyces*) *cerevisiæ.*

483. The *acetic acid ferment* belongs to the bacteria family and grows in alcoholic solutions containing a little albuminous matter or various salts, as those of ammonium, or alkaline and earthy phosphates. It acts by oxidation changing alcohol to acetic acid, the *mycoderma aceti* acting as an oxygen carrier.

484. The *lactic acid ferment* grows in a neutral or alkaline medium and best without oxygen, at a temperature

of from 95°F. to 104°F. Various kinds of sugar and dextrine, under the action of *bacterium lactis*, are converted into lactic acid in the presence of a decomposing albuminous substance, especially casein, and water. The process is also favored by presence of chalk, or alkaline carbonates, which neutralize the lactic acid as fast as it is formed; were it not for this neutralization; the production of acid would prevent the continuance of the fermentation. The equation is as follows:

$$\underset{\text{Lactose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Glucose.}}{2C_6H_{12}O_6} + \underset{\text{Lactic acid.}}{4C_3H_6O_3}$$

also

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Lactic acid.}}{2C_3H_6O_3}$$

Lactic acid is, according to Miller, formed in the teeth during caries.

485. The *butyric ferment* goes hand in hand with the lactic. Lactic acid is split up by its agency into butyric acid, carbon dioxide, and hydrogen.

$$\underset{\text{Lactic acid.}}{2C_3H_6O_3} = \underset{\text{Butyric acid.}}{C_4H_9O_2} + \underset{\substack{\text{Carbon.}\\ \text{dioxide.}}}{2CO_2} + \underset{\text{Hydrogen.}}{2H}$$

486. The *thrush ferment* is a fungus, which appears on the mucous membrane of the mouths of infants, especially of those brought up by hand. The saliva becomes acid and white spots appear, especially on the tongue, gums, and soft palate.

487. Various forms of bacteria cause *putrefactive fermentation* in proteids, by which the latter are decomposed into fats, tyrosin, leucin, ammonia, sulphuretted hydrogen, carbon dioxide, hydrogen, and nitrogen. *It is from the decomposition of proteids that the sulphuretted hydrogen in the mouth is formed.*

488. **Classification of Bacteria, etc.:** the term *microbe* is used, in general, to designate the minute organized

beings which are found on the borderland between animals and plants; in the majority of cases they may be regarded as true plants. Broadly, microbes may be divided into *parasitic fungi* and *moulds*, *ferments*, and *bacteria*, and to the last the term *microbe* in particular is usually applied.

489. **Fungi** are plants devoid of stems, leaves, and roots; they consist only of cells in juxtaposition, devoid of chlorophyll; they never bear a true flower and are simply reproduced by means of very minute bodies, usually formed of a single cell, called a *spore* and representing the seed. Among the parasitic fungi and moulds may be found the rust of wheat and grasses, the ergot of rye, mould of leather and dried fruit, potato fungus, mildew, the fungi of certain skin diseases as tinea, thrush, etc.

490. **Ferments** are closely allied to a variety of fungus called *microsporon*, but as they live in liquids or on damp substances they are classified by many among the Algæ, a species of water fungi. Ferments, however, differ from Algæ in not containing chlorophyll. Each plant of the ferment variety is usually composed of a single cell, spherical, elliptical, or cylindrical, formed of a thin cell-wall, containing a granular substance called *protoplasm**, which is the essential part of the plant. The cells have an average diameter of ten micro-millimetres; they grow and bud, and each divides into two parts. Among the ferments, we find those of wine, beer-yeast, bread-yeast, etc., etc.

491. **Bacteria** are alike in form and organization to ferments, but, as a rule, are of smaller size. Microbes or bacteria (Schizophyta or Schizomycetes) appear, under

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* The composition of protoplasm is essentially proteids, water, certain mineral matters, fats, starch, and sugar.

the microscope, as small cells of a spherical, oval, or cylindrical shape, sometimes detached, sometimes united in pairs, or in articulated chains and chaplets. The diameter of the largest of these cells is but two micro-millimetres, and that of the smallest is a fourth of that size. A power of from 500 to 1,000 diameters is necessary to make them clearly visible under the microscope.

Morphologically, Dujardin-Beaumetz recognizes six forms: (1) Monad, micrococcus, or moner, immobile point-like microbes, often regarded as spores. (2) Bacteridia and bacillus, immobile, linear microbes. (3) Bacteriens, cylindrical mobile microbes, the end rounded, or the body indented in the centre, so as to form a figure of 8. (4) Vibriones, eel-shaped, undulating, mobile and flexuous microbes. (5) Spirilla and spirochœte, corkscrew-like, spirally moving microbes. (6) Capitated microbes, *Bacterium capitatum*, mobile rods, with one or both extremities long, globular, and more refractive than the rest of the body.

This classification has reference to the cells as seen singly or in very limited numbers; when aggregated so as to form colonies there are distinguished four forms:

1. Torula, in the form of a necklace, composed of micrococci.

2. Leptothrix, made up of bacteria, clustered end to end.

3. Mycoderma, immobile, composed of bacteria in sheets.

4. Zöoglœa, being masses of bacteria, immobile, inclosed in a sort of jelly which holds them together.

492. Varied conditions of existence influence the form taken by these organisms, so that distinctions into genera and species are not as yet made on precise data. The *microbe of acetic fermentation* is a true bacterium (bacter-

ien). The *microbe of lactic fermentation* is also a bacterium. The *microbe of butyric fermentation* is a bacillus.

493. In **putrefaction,** or fermentation of dead organic matter exposed to the air, the substances are first rapidly covered with moulds, they lose coherence, and after a few days give off carbonic acid, nitrogen, hydrogen, and fetid effluvia, due largely to carburetted, sulphuretted, and phosphoretted hydrogen, and to the circulation of decomposing organic particles. The microbes which appear simultaneously with the moulds, penetrate deeply into the tissues, disintegrate them by feeding at their expense, and the putrid condition increases; then the decomposition changes its nature and becomes less intense. The putrefied matter is finally dessicated, and leaves a brown mass—a complex mixture of substances combined with water and of fatty mineral substances, which gradually disappear by slow oxidation. (Gautier). In such putrefaction of animal matter in water are found microbes in the form of globules or short rods (*Micrococcus*, *Bacterium termo*, *Bacillus*, *etc.*), either free, or in a semi-mucilaginous mass to which the term *Zooglœa* has been given. These microbes deprive the liquid of all its oxygen. A thin layer on the surface absorbs oxygen; in the interior, albuminoid matter is changed into more simple substances, and the microbes on the surface change the latter into gases. A substance remains rich in fats, earthy and ammonical salts, and fit to serve as nutriment to plants.

494. **The microbes of the mouth** of a healthy man are numerous, and include (1) Spirochœte, (2) a species of Sarcina, and (3) more especially, a large organism called *Leptothrix buccalis* which is never absent from the rough surface of the tongue nor the interstices of the teeth. The saliva contains a *micrococcus* which may become exceptionally virulent.

The microbe of dental caries: according to

Miller, dental caries is chiefly due to the development of one or more species of bacteria. The microbe most common in decayed teeth is very polymorphic, *micrococcus*, *bacterium*, chains, and filaments are found, all different phases of the same plant, which is responsible both for acid fermentation in the mouth and for the formation of lactic acid.

495. **The microbe of pus,** as found in blood poisoning, is termed Micrococcus septicus: it may either appear free or in the form of chaplets (*vibrio*), or in the interior of the colorless corpuscles of pus, or embryonic cells, which, in form of *zooglœa*, it ruptures. The germs of Micrococcus septicus are introduced into the blood, and multiply there through the exposed surface from a wound or by agency sometimes of the instrument causing the wound. When bacteria multiply in the blood, they must necessarily have an irritating effect on the walls of the capillaries and the cells are transformed in consequence into embryonic or migratory cells which differ but slightly from the colorless blood-corpuscles and are pus-corpuscles. (Trouessart).

496. **Action of pathogenic microbes:** this is complex and is analyzed according to Trouessart as follows: (1) the action of a living parasite nourished by and multiplying at the expense of the fluids and gases of the system; (2) the formation by this parasite of a poisonous substance (ptomaine) the elements of which are derived from the organism, and it, the ptomaine, acts as a poison on this organism.

497. **Pus and suppuration:** acccording to Knapp, suppuration in every case depends on the action of microbes. Pus being defined as an albuminous, non-coagulable fluid

containing multitudes of leucocytes, suppuration is deemed to be the splitting up of living nitrogenous tissue into simpler compounds through influence of certain bacteria.

498. **Protection against microbes:** this is to be accomplished by what is, in general, called *disinfection.* Substances used for the purpose of preventing zymotic diseases, so-called, have been classified as follows:

1. *Diluents:* air and water.

2. *Absorbents:* dry earth and plaster of Paris.

3. *Destructive agents:* lime and sulphate of iron are most important. Under certain circumstances, permanganate of potassium, caustic potash, mineral acids.

4. *Antiseptics:* these check the development of the organism of putrefaction but do not necessarily kill disease germs. Most important: alcohol, sulphate of iron, borax. Commonly used: salt, saltpetre, carbolic acid.

5. *Germicides:* agents which have the power of killing disease germs; most important are chlorine and substances which contain it, as corrosive sublimate. All germicides are antiseptics, but the antiseptics proper are not germicides. Nearly all bacteria are destroyed in a very short time by high temperatures.

499. **Antiseptics are used in dentistry** for

moistening the pellet of cotton introduced into a cavity which is to be sealed: Harlan recommends carbolic acid, aseptol, creasote, terebene, resorcin, iodol, iodoform, beta-naphthol, eugenol, pheno-resorcin, eucalyptol, thymol, myrtol, menthol, boroglyceride, etc., etc., as antiseptics.

Disinfectants, or agents which will destroy foul odors by combining with them chemically, and will cleanse, purify, and destroy infection are used in the treatment of engorged antra, in and around the roots of teeth, in carious or necrosed bone, on buccal, pharyngeal, and laryngeal mucous membranes; in a word, wherever foul odors, infectious material, or decomposing matters are found. Harlan recommends Labarraque's solution, Condy's fluid, aqueous solution of zinc chloride, hydrogen dioxide, solutions of the acetate or chloride of aluminium, mercuric chloride, mercuric iodide, the hypochlorites, iodine, resorcin, trichlor-phenol, boracic acid, benzoic acid, etc.

Smith recommends corrosive sublimate dissolved in hydrogen dioxide. Abbott recommends half a grain of corrosive sublimate in twenty-one fluidounces of water.

Iodoform and eucalyptus, iodoform and oil of cinnamon, solutions of aluminium chloride, carbolic acid (with equal parts caustic potash—Robinson's remedy) salicylic acid, carvacrol, thymol (in glycerine) chinoline tartrate, creasote, eugenol, resorcin, Sanitas oil, Listerine, boro-glyceride, are antiseptics most commonly used by dentists in the treatment of various diseased conditions.*

In alveolar pyorrhoea Harlan recommends hydrogen dioxide and solution of zinc iodide.

500. In washing plates of artificial teeth, regard must be had for their metallic character; for example, a plate containing aluminium is said to be affected by a corrosive sublimate solution more readily than by carbolic acid.

A mouth wash containing 1 part of corrosive sublimate in 5000 can be made as follows: one grain of the perchloride of mercury and 1 grain of chloride of ammonium to be dissolved in 1 ounce of eau de cologne, and a teaspoonful of the solution to be mixed with two thirds of a wineglassful of water.

501. **Experiments of Miller:**

Experiments were made by Miller with various antiseptics, to ascertain which would answer best to retard or to prevent fermentation in the mouth. The following are the results:

The fermentative action is

	Prevented by 1 in	Arrested by 1 in
Corrosive sublimate	500,000	100,000
Silver Nitrate	100,000	50,000
Iodine (in Alcohol)	15,000	6,000
Iodoform	10,000	5,000
Naphthalin	9,000	4,000
Ess. Oil Mustard	5,000	2,000
Permang. Potassium	2,000	1,000
Oil Eucalyptus		600

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* A coal tar substance called *creolin* is claimed to exceed carbolic acid in deodorizing efficiency. Its exact chemical composition is a trade secret. It is a powerful styptic and is said to be non-poisonous.

	Prevented by 1 in	Arrested by 1 in
Carbolic Acid	1,000	500
Hydrochloric Acid	1,000	500
Sodium Carbonate	200	100
Salicylic Acid	125	75
Alcohol, absol	25	10

These results are of considerable interest not only to dentists, but also for the preparation of efficient tooth powders.

Miller claims to sterilize the mouth, cavities in carious teeth, etc., by the following mixture:

Thymol	4 gr.
Benzoic Acid	45 gr.
Tincture of Eucalyptus	3½ fl. dr.
Water	25 fl. oz.

The mouth is to be well rinsed with this mixture, especially just before going to bed, since most of the damage by fermentative and putrefactive processes in the mouth is done at night during sleep.

Miller has suggested a number of formulæ, most of which contain eucalyptus; he thinks the presence of corrosive sublimate necessary to insure efficiency. His mixtures are intended to serve as *foundations* for mouthwashes, since many of them are not palatable and need agents to be combined with them which shall disguise the burning taste, especially of thymol and of eucalyptus.

502. Deodorizers :—

For fetor of the breath, etc., chlorinated lime solution, chlorine water, chlorinated soda, permanganate of potassium solution, phenol sodique are used; also certain vegetable substances, as orris root. Various oils such as safrol, oil of Pinus Picea, oil of anise, oil of rose geranium, impart a pleasing fragrance to the breath; a drop or two in a glass of water, thoroughly stirred, is all that is necessary. Many persons tire of the taste of the oils of wintergreen and of sassafras. The use of orris has also been carried to excess. The author has found Miller's mouth-wash an excellent deodorizer.

503. Antiseptics of more recent use.

Alantol, $C_{20}H_{32}O$, liquid, powerful internal antibacterial and antiseptic.

Alpha-naphthol, solid, 1 in 10,000 prevents alcoholic fermentation of glucose. (Maximowitsch). In same strength prevents propagation of typhoid and tuberculous bacilli.

Betol, $C_6H_4(OH)CO_2.C_{10}H_7$, salicylo-beta-naphthylic ether, white powder, crystalline; insoluble in water, soluble in boiling alcohol and warm linseed oil. (Kobert).

Bismuth oxyiodide, BiOI, brownish powder, insoluble. Used dry. (Lister, Reynolds, and others.)

Creolin already mentioned, section 499, foot note.

Cresylic acid, said to be superior in antizymotic action to carbolic acid. (Dujardin-Beaumetz).

Iodine trichloride, ICl_3, orange-red powder, strongly irritating odor; 1 in 1,000, in aqueous solution, destroys bacillus-spores. (Riedel).

Mercuric albuminate contains 4 parts mercuric chloride in 12 of albumin and 984 of milk sugar.

Mercuric Oxycyanide, said to have six times the bactericidal force of mercuric chloride. (Chibret).

Oxy-naphthoic acid, alpha. Said to have five times the anti-zymotic action of salicylic acid. White microcrystalline powder almost insoluble in water, more soluble in solutions of the bicarbonates.

Sodium silico-fluoride, non-toxic, surgical antiseptic. (Thomson).

Sodium sulphite, benzoated, non-toxic, surgical antiseptic. (Heckel).

Tribrom-phenol, made by action of bromine on aqueous carbolic acid, energetic and reliable disinfectant in purulent and gangrenous processes. (Grimm).

New Antiseptics and Therapeutic Agents.

Aristol, $C_{20}H_{24}O_2I_2$, a thymol derivative, (page 234:) light chocolate-colored powder almost odorless and tasteless, used as substitute for iodoform; made by adding a solution of iodine in iodide of potassium to an aqueous solution of sodium hydrate containing thymol; contains about 46 per cent. of iodine; insoluble in water and glycerin, slightly soluble in alcohol, readily soluble in ether; is taken up by fatty oils when rubbed up in them; non-toxic.

Acetono-resorcin is a combination of two molecules of resorcin (page 38) with one of acetone. Occurs in the form of small anhydrous prisms, soluble in alkalies, insoluble in water, alcohol, ether, and chloroform.

Anisic acid, $C_6H_4(OCH_3)COOH$ is the phenol ester, (page 235,) of *p*-oxybenzoic acid. Colorless prisms, soluble in alcohol, insoluble in water. Antiseptic.

Acetophenone, phenylmethylketone, hypnone, $C_6H_5CO.-CH_3$, (page 235) is formed by distillation of calcium. acetate and benzoate in molecular proportions, thus

$$(C_6H_5.COO)_2Ca+(CH_3.COO)_2Ca= \\ 2CaCO_3+C_6H_5.CO.CH_3.$$

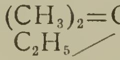
Acetal, diethyl-acetal, ethylidene diethyl ether, $CH_3.CH(OC_2H_5)_2$ is made by heating a mixture of aldehyde and alcohol to 100°. It is a colorless, limpid liquid, soluble in 18 parts water, of agreeable odor. Hypnotic. (See class IV page 224.)

Alumnol is an aluminium naphthol-sulphonate, (page 237) occurring as a white or pinkish powder, very soluble in water (with blue fluorescence) and in glycerin, less so in alcohol and in ether. Non-irritant, antiseptic.

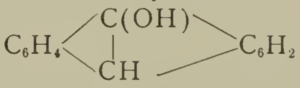
Asaprol, beta- naphthol-alpha-mono-sulphonate of calcium, page 237.

Acetico-tartrate of aluminium, astringent and disinfectant.

Aluminium boroformicate, astringent, disinfectant, slowly soluble in water.

Amylene hydrate, dimethylethyl-carbinol, tertiary amyl alcohol  $(CH_3)_2{=}C(OH)$, C_2H_5 see class II, p. 223. Limpid, colorless, hygroscopic liquid, of penetrating ethereal odor, soluble in alcohol, ether, chloroform, and in 8 parts water. Made from amylene, C_5H_{10}, by shaking this up with sulphuric acid and subsequently distilling. Hypnotic and anodyne.

Analgen. See page 238. Colorless crystals.

Anthrarobin, desoxyalizarin,  $(OH)_2$, page 237. Yellowish white powder, insoluble in water and in dilute acids, soluble in glycerin, in 5 parts alcohol, and in alkaline media. Substitute for chrysarobin.

Anticholerin:—Cholera antitoxine solution.

Antikamnia, a white, micro-crystalline, odorless, tasteless powder, nearly insoluble in water, readily soluble in alcohol and ether. Antipyretic, analgesic, and anodyne.

Antinervine, salicylbromanilid, salbromalide, a mixture of ammonium bromide, salicylic acid, and acetanilid.

Antisepsin, asepsin, mono or para bromacetanilid, (see page 233.) Colorless, prismatic crystals, insoluble in cold water, slightly soluble in alcohol, and in hot water.

Antithermin, see page 233. White powder, insoluble in water. Antiseptic, antipyretic, analgesic.

Argentamine, ethylene-diamine silver phosphate, an 8 per cent. solution of silver phosphate in ethylene-diamine (see page 230). Alkaline solution turning yellow. Antiseptic, astringent, does not coagulate proteids.

Benzacetin, acetamido-methyl-salicylate, see page 235; white crystals, soluble in alcohol, slightly so in water. Forms salts with bases. Antineuralgic.

Benzanilid, $C_4H_5.CO.NHC_6H_5$ phenyl-benzamide, see Class XIV, page 232. Pinkish white, crystalline powder, insoluble in water, soluble in 58 parts alcohol. Antipyretic.

Benzonaphthol, beta-naphthyl benzoate, see page 237, analogous to betol which is beta-naphthyl salicylate or $C_6H_4OHCOOC_{10}H_7$. White crystalline powder or long needles; of slightly aromatic odor, soluble in ether, chloroform, hot alcohol, almost insoluble in water. Intestinal antiseptic and diuretic.

Benzosol, $C_6H_4.OCH_3.OCOC_6H_5$. benzoyl-guaiacol, guaiacol benzoate. White aromatic powder, soluble in chloroform, ether, and hot alcohol. Almost insoluble in water. Antiseptic, antitubercular.

Benzoyleugenol, colorless, odorless, slightly bitter crystals. Antitubercular.

Betol, see page 237 and page 307.

Bismuth salicylate (page 235) basic, 64 per cent., is used as an antiseptic and disinfectant.

Bromamide, mono-brom-phenylacetamide; crystals insoluble in water, soluble in chloroform, ether, oils, and boiling alcohol. Antipyretic, analgesic, etc.

Bromol, tribromphenol, (page 233) white, crystalline powder almost insoluble in water. Disinfectant.

Carvacrol iodide, (page 234) made from oil of origanum. Yellowish-brown powder, insoluble in water, used like aristol and iodoform.

Chloralamid, see page 224; colorless, lustrous, slightly bitter crystals, soluble in alcohol, 3 parts glycerin, slowly in 20 parts water. Hypnotic.

Creolin is now said to be an emulsion of carbohydrates (?) from tar with rosin soap, or with creosol-sulphuric acids.

Creosotal, creosote carbonate is a clear oily liquid free from taste and odor of creosote. Antitubercular.

Cresolol, ortho-, meta-, and para-cresol salicylates, pages 234-235. Resembles salol physically. Intestinal antiseptic.

Cresoliodide, very light yellow powder, of disagreeable odor, insoluble in water. Antiseptic.

Chloral-carbol, chloral phenol, an oily liquid, mixture of equal parts chloral and carbolic acid. For toothache; counter-irritant.

Chloral-menthol, equal parts chloral and menthol; local disinfectant and anæsthetic.

Chloralose, anhydro-gluco-chloral, $C_8H_{11}Cl_3O_6$, fine, bitter, colorless needles soluble in warm water, slightly in cold. Anæsthetic, hypnotic. Made by heating chloral and glucose.

Chlorophenol (see page 233), ortho-mono-chlorphenol, antiseptic, volatile liquid.

Chloryl, a mixture of ethyl and methyl chlorides (see page 228), used as anæsthetic.

Diaphtherin: a compound of one molecule of orthophenol-sulphonic acid (aseptol) with two molecules of ortho-oxy-quinoline. A bright yellow powder readily soluble in water.

Dermatol, $C_6H_2(OH)_3COOBi(OH)_2$, is bismuth gallate or subgallate occurring as a saffron-yellow powder, insoluble in water, alcohol, or ether, but soluble in dilute acids.

Euphorine, phenyl-urethane, made by interaction of aniline and chlorocarbonic ethyl ether. Occurs in crystals with faint aromatic odor, insoluble in water, soluble in alcohol, strong and dilute. Antipyretic, etc.

Europhen, $C_6H_2.C_4H_9.CH_3.OH.C_6H_2.OH.CH_3.-C_4H_9.$ diisobutyl orthocresol-iodide, an amorphous bulky, yellow powder of faint saffron-like odor, resembling iodoform in solubilities.

Formalin, a 40 per cent aqueous solution of formaldehyde $HCO.H$, said to be a non-poisonous antiseptic of great power. Formaldehyde is made by leading a mixture of gaseous methyl alcohol and air over gently-heated copper oxide, and carefully fractioning the liquid. It is a gas of pungent odor.

Myrtol (section 384) is, according to Harlan, an excellent antiseptic in infected root canals. It is a volatile oil containing various terpenes, cineol (eucalyptol), and a camphor-like substance.

Potassium-sodium, a preparation of these metals in paraffin inserted into cavities for cleansing purposes, hydroxides being formed, and saponification taking place.

Pyrozone is a name given to accurate percentage solutions of hydrogen dioxide which is now obtained *absolute*.

The three solutions of pyrozone on the market are the 3 per cent. aqueous, the 5 per cent. ethereal, and the 25 per cent. ethereal. The 3 per cent. may be used freely as a mouth wash especially for habitual smokers. The 5 per cent. solution is a powerful antiseptic and a bleacher of teeth, as is also the 25 per cent. The 25 per cent. solution is used in pyorrhoea alveolaris; it is a caustic.

Salol (section 441) is used in dentistry as a root filling, when liquefied by heat.

Silver nitrate (section 175) is now used in dentistry in 10 per cent. solution, or weaker, in pyorrhoea alveolaris.*

Sodium ethylate, $C_2H_5.ONa$, is obtained by dissolving sodium in alcohol, and evaporating the solution in a stream of hydrogen. It is a colorless, hygroscopic substance rapidly absorbing carbon dioxide from the air, and immediately decomposed by water. *Liquor sodii ethylatis* is a solution of 19 per cent. of sodium ethylate.

It is used as a caustic for overhanging gums.

Sodium fluosilicate, Na_2SiF_6, also called sodium silicofluoride is prepared by neutralizing hydrofluosilicic acid with sodium hydrate or carbonate. According to Harlan it is especially valuable as a sterilizer. It is not very soluble in cold water. In medicine it is known as "salufer."

Sulpho-carbolates:—The sulpho-carbolate of zinc is used widely as an antiseptic, especially in typhoid fever.

Trichloracetic acid, (section 426) is also used in dilute solutions as an injection around roots of teeth to dissolve minute particles of calculi.

Other newer antiseptics, solids, soluble in water:—gallobromol, $C_6Br_2(OH)_3CO.OH$, dibromgallic acid; iodine trichloride, ICl_3; lactol (beta-naphthol lactate); lactophenin (lactyl-phenetidin); lysol; picrol; sodium chloroborate; sodium dithiosalicylate; sodium formate; sodium paracresotate; sodium sulpho-salicylate; sodium tetraborate.

Other new antiseptics, solids, only slightly soluble in water are camphoric acid, $C_8H_{14}(CO.OH)_2$; diaphthol; hydracetine (pyrodine, acetyl phenyl hydrazide), (page 233); hydroquinone, $C_6H_4(OH)_2$, page 234; loretin, $C_9H_4N.I.OH.SO_3H$, meta-iodo-ortho-oxy-quinoline-ana-sulphonic acid. Losophan, $C_6H.I_3.OH.CH_3$, tri-iodo-meta-cresol.

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*J. E. Craven.

Salacetol, 
$C_6H_4 \langle {COO.CH_2,COCH_3 \atop OH}$, salicyl-acetol; phenylacetic acid, $C_6H_5.CH_2.CO_2H$, alpha-toluic acid.

Other new antiseptics, solids, insoluble in water are cresalol, para—, $C_6H_4.OH.COO.C_6H_4.CH_3$, paracresol salicylate; di-iodoform, ethylene periodide, tetra-iodo-ethylene; europhen, $C_6H_2.C_4H_9.CH_3.OH.C_6H_2.OH.CH_3.C_4H_9$, di-isobutylorthocresol iodide; hydronaphthol; iodo-eugenol; iodo-phenacetine (iodo-phenine); sulphaminol (thio-oxy-diphenyl-amine); thioform (basic bismuth dithiosalicylate); thio-resorcin; piperonal (heliotropin).

Other new antiseptics in liquid form are formaline; phenosalyl (a mixture of carbolic, salicylic, and benzoic acids dissolved in lactic acid); tricresol; tricresolamine, a mixture of equal parts ethylene diamine and tricresol, used in 4 per cent. solution; kresin, a solution of cresylic acid in solution of sodium cresyloxy-acetate; lysol, a 50 per cent. solution (saponaceous) of cresols; resol.

New antiseptics used in treatment of tuberculosis:—cinnamic acid; phenyl-acetic acid; benzosol $C_6H_4.OCH_3.OCOC_6H_5$, benzoyl-guaiacol; benzoyleugenol; chlorophenol; creasotal, creasote carbonate; oleo-creasote; oleo-guaiacol; eucalyptol; guaiacol (methyl-pyrocatechol); guaiacol biniodide; guaiacol carbonate; guaiacol salicylate (guaiacol-salve); styracol (cinnamyl guaiacol).

Various other antiseptics or disinfectants are cresapol; listol (compound of thymol and iodine); iodocasein; iodoformin, a derivative of formaldehyde; malakin (salicyl-aldehyde paraphenetidin); sapocresol; solphinol (borax, boric acid, alkaline sulphites.) Volkmann's antiseptic liquor is said to be a solution of thymol in a mixture of alcohol, glycerin, and water.

Boro-lyptol is the name given to an antiseptic said to contain 5 per cent. aceto-boro-glyceride, and 0.1 per cent.

formaldehyde in combination with active antiseptic constituents of pinus pumilio, eucalyptus, myrrh, storax, and benzoin.

New local anæsthetics are erythrophleine hydrochlorate and eugenol-acetamide, both soluble in water. Pental (tri-methyl-ethylene) is an anæsthetic.

Pyoctanin, yellow, is used in dentistry in gingivitis, phagedenic pericementitis, and as an injection into salivary cysts. It is a local analgesic.

A new dental anodyne called *odontodol* is said to be a mixture of cocaine hydrochlorate, cherry laurel oil, tincture of arnica, and solution of ammonium acetate.

New hypnotics are acetal, (ethylidene diethyl ether); acetophenone; amylene hydrate; antispasmin; chloral-amid; chloral-ammonium; hyoscine; hypnal; hypnone; methylal; narceine; thymacetin; trional; uralium; urethane.

New antipyretics:—acetanilid (antifebrin); aceto-ortho-toluid; anisic acid; antikamnia; antinervin (salicyl bromanilid); antisepsin (mono or para bromacetanilid); antithermin (phenyl hydrazin levulinic acid); asaprol; benzanilid; bromamide (mono-brom-phenyl-acetate); chinol (quinoline monohypochlorite); euphorin; formanilid; hydracetine; hydroquinone; lactophenin; methacetin; neurodin; phenacetin; salocoll; sodium paracresotate; thermodin; tolypyrin.

New analgesics are acetanilid; antikamnia; antinervin; bromamide; chloral-caffeine; euphorin; exalgin; formanilid: hypnal; phenacetin; quinalgen; salipyrine; agathin; antikol; antithermin; asepsin.

New intestinal antiseptics or disinfectants, are benzonaphthol; betol; bismuth beta-naphtholate and salicylate; bismuth tribromphenol; bromol; cresalol, para-guaiacol salicylate; hydronaphthol; lactol (beta-naphthol lactate);

salacetol; sodium parac-resotate; zinc sulphocarbolate.

New diuretics are asparagin; benzonaphthol; diuretin (sodio-theobromine salicylate); scillipicrin; scoparine; symphorol (caffeine sulphonate nasrol); uropherin (lithium diuretin).

Uric-solvents not hitherto mentioned are tartarlithine, piperazine (page 230), lycetol (dimethyl-piperazine-tartrate), lysidin, tetra-ethyl-ammonium hydroxide (10 per cent. solution).

Tartarlithine (the lithium analogue of cream of tartar) is used as an antilithic to combat the morbific element in pyorrhœa alveolaris which, according to Drs. C. N. Pierce and E. C. Kirk, is uric acid in combination forming urates.

New mouth washes:—

Borine is a liquid said to contain the active constituents of benzoin, winter green, meadow-sweet, golden rod, and witch hazel with stearoptens of wild thyme, eucalyptus, and peppermint, with boracic acid; *glycothymoline* is a liquid said to contain sodium (?) borax, benzoin, salicylic acid, eucalyptol, thymol, menthol, oil of gaultheria, oil of pinus pumilio, glycerin, and solvents.

Miscellaneous.

Traumatol is an iodocresol of purple red color, substitute for iodoform.

Stypticine is the hydrochlorate of cotarnine, used in controlling menstrual hæmorrhages.

Eudoxin is said to be the bismuth salt of nasophen, or tetraiodophenolphthalein.

Hypnoacetin is acetophenonacetyl-paramidophenol ether.

Urotropin is a hexamethylene tetramine $(CH_2)_6N_4$

Benzoinol, Oleum Petrolatum Benzoinat, is a benzoated petroleum product used as vehicle for camphor, cocaine, carbolic acid, etc.

Blancoline, is a perfectly white, odorless, and neutral petroleum jelly.

Terraline is the name of a special petroleum jelly.

Vasogen, oxygenated vaselin, sulpholeated mineral oil miscible with water, used as vehicle.

CHAPTER V.

THE TEETH AND THE SALIVA.

504. **Structure:** the chief mass of a tooth consists of a substance called *dentine*, in the interior of which is the *pulp cavity*. The crown of the tooth is invested by a substance called *enamel*, which extends some distance down the neck, but the fangs are covered by a substance known as *cement* (*crusta petrosa*). Before describing the dental tissues further, we shall pay attention for a moment to the chemistry of bone.

505. **Bone** consists of an organic substance called *ossein*, which we have seen is a proteid substance belonging to the collagens, intimately combined with a mineral substance called *bone earth*, in proportion of about 30 of ossein to 70 of bone earth. The latter is a mixture of various salts, as calcium phosphate, calcium carbonate, calcium fluoride, and magnesium phosphate, of which the most abundant in quantity are the calcium phosphate and carbonate. Bone contains also water and fat. The os-

sein of bone resembles gelatin, and by boiling ossein with water it is changed into gelatin.

Hoppe-Seyler gives the general composition of normal, undried bone as:

Water	50.00 per cent
Fat	15.75 “ “
Ossein	11.40 “ “
Bone earth	21.85 “ “

Most of the water is combined in the ossein. Expressing the composition of bone in order to show the relative percentage of organic and inorganic substances we find it, according to Heintz, as follows:

Inorganic substances	69.53 to 68.88
Organic substances	30.47 “ 31.12

Analysis of the *ash* shows that of the inorganic substances tribasic calcium phosphate, $Ca_3(PO_4)_2$, constitutes from 83.89 to 87.70 per cent., calcium carbonate 8.9 to 13, 03, tribasic magnesium phosphate, 1.04 to 1.70 per cent., calcic fluoride and chloride, 0.76 to 4.90 per cent. Berzelius's analysis of bone resulted as follows:

Ossein	32.17
Calcium phosphate	51.04
“ fluoride	2.00
“ carbonate	11.30
Soda with sodic chloride	1.20
Magnesium phosphate	1.16
Vessels	1.13

506. The inorganic constituents of bone increase slightly with age and the bone becomes more porous. The *marrow* of bones is of different composition, according to locality, but in the long bones (yellow marrow) is 96 per cent. fat, with some cholesterin, hypoxanthin, albumin and, occasionally, lactic acid. *Red* marrow contains a small proportion of fat, much albumin and salts, and an acid resembling lactic acid. In diseases of

bone the inorganic salts change in quantity, and the organic constituents in quality.

ANALYSIS OF BONE IN CARIES OF VERTEBRA.

Calcium phosphate	33.91
" carbonate	7.60
Magnesium phosphate	1.93
Soluble salts, chiefly NaCl	0.61
Ossein, etc	19.58
Fat	1.22 (Valentin).

ANALYSIS OF BONE IN NECROSIS.

Calcium phosphate, etc	72.63
Calcium carbonate	4.03
Magnesium phosphate	1.93
Soluble salts	0.61
Ossein	19.58
Fat	1.22

507. Turning now to the chemical constitution of the **teeth**, we find that the *cement* has a structure resembling bone, and its chemical composition is almost the same, namely organic substances 30 parts, inorganic 70 parts; of the latter nearly 65 parts of the 70 are composed of *phosphates* of calcium and magnesium and *carbonate* of calcium, as follows:

Calcium phosphate	60.7
Magnesium phosphate	1.2
Calcium carbonate	2.9 (Bibra).

508. The *enamel* of teeth is nearly all inorganic matter; in the enamel of some animals, as the dog, there seems to be no organic mat-

ter at all. In man, on an average, the inorganic constituents are from 95 to 97 per cent. in amount, the organic from 5 to 3; in the teeth of young infants, however, the inorganic matter is only from 77 to 84 per cent.

AVERAGE COMPOSITION OF THE ENAMEL.

Water and organic substances	3.6
Calcium phosphate and fluoride	86.9
Magnesium phosphate	1.5
Calcium carbonate	8.0

HOPPE-SEYLER'S ANALYSIS.

Calcium carbonate and phosphate, $Ca_{10}CO_3,6PO_4$	96.0
$MgHPO_4$ (neutral phosphate of magnesium)	1.05
Organic substances	3.60

509. The *dentine* is more like bone than the enamel is, but less like it than the cement. It is composed of animal matter impregnated with earthy salts. It averages from 26 to 28 per cent. organic substances to 74 to 72 of inorganic matter.

ANALYSIS OF DENTINE.

	Woman.	Man.
Organic matter—ossein and vessels	27.61	20.42
Calcium phosphate	66.72	67.54

ANALYSIS—*Continued.*

Calcium carbonate	3.36	7.97
Magnesium phosphate	1.08	2.49
Other salts (NaCl, etc.)	0.83	1.00
Fat	0.40	0.58

ANALYSIS OF HOPPE-SEYLER.

$Ca_{10}CO_3, 6PO_4$	72.06
$MgHPO_4$	0.75
Organic substances	27.70

The organic matter of the dentine resembles the ossein of bone, but, according to Hoppe-Seyler, the walls of the canaliculi are invested with a body resembling *keratin* or *elasticin*. [Keratin is a proteid substance and is the chief component of epidermic structures. It is noticeable for the large amount of sulphur it contains. It is closely related to albumin, yielding leucin and tyrosin when decomposed. Its percentage composition is C=50 to 51.6, H=6.4 to 7.2, N = 16.2 to 17.9, S=0.7 to 5.0, O=20 to 22.4. It is insoluble in alcohol and ether, swells up in boiling water, and is soluble in the caustic alkalies. It is not liable to decomposition, and melts when heated.

Elasticin is related to keratin, and is the substance composing the fibres of yellow elastic tissue. It is sometimes called *elastin*. It yields leucin but not tyrosin. Its percentage composition is C = 54.32, H = 6.99, N = 16.75, ash = 0.5].

Dentine contains 4 per cent. less water than bone. Its specific gravity, according to C. Krause, is 2.080. The walls of the canaliculi do not yield gelatin, but the ground substance of dentine may be transformed into gelatin, when heated in a Papin's digester. The globules of dentine are not convertible into gelatin, and resist the action of acids better than any other portions of the tissue do.

Of the three substances of which the teeth are composed we find that the enamel is the hardest, the dentine next, and the cement the least. The enamel is hard and brittle.

If the enamel be treated with dilute hydrochloric acid the calcium phosphate is dissolved, and there remain prismatic fibres which resemble epithelium and are not attacked by boiling water. If the cement be treated with an acid, its inorganic constituents are dissolved and there remains an organic residue which is said by Hoppe-Seyler not to yield gelatin; [according to some authors this substance *does* yield gelatin]. If the dentine be treated with acids, organic matter is left, most of which yields gelatin, but some does not. According to Bibra, molar teeth appear to contain more mineral matter than incisors.

510. Various analyses (tabulated for reference).

CEMENT OF TOOTH.

	Of ox (Fremy).	Of man (Bibra).
Ash (containing an average of) 67.1 per cent		70.58 per cent.
Calcic phosphate		60.70 "
Magnesic		1.20 "
Carbonate of lime		2.90 "

DENTINE OF TOOTH, (HOPPE-SEYLER).

$Ca_{10}CO_3, 6(PO_4)$	72.06
$MgHPO_4$	0.75
Organic substances	27.70

DENTINE (BIBRA).

	Adult woman.	Adult man.
Organic matter, ossein and vessels	27.61	20.42
Phosphate of lime	66.72	67.54
Carbonate "	3.36	7.97
Phosphate of magnesia	1.08	2.49
Other salts (NaCl, etc.)	0.83	1.00
Fat	0.40	0.58

ENAMEL OF TOOTH.

Water and organic substances	3.6
Calcic phosphate and fluoride	86.9
Magnesic phosphate	1.5
Calcic carbonate	8.0

It is thus given by Hoppe-Seyler:

$Ca_{10}CO_3\ 6(PO_4)$	96.00
$MgHPO_4$	1.05
Organic substances	3.60

ENAMEL AND DENTINE COMPARED—OX (AEBY).

	Enamel.	Dentine.
Organic substances and water	3.60	27.70
Inorganic “	96.40	72.30
In 100 parts ash—		
Calcic phosphate	93.35	91.32
“ carbonate	4.80	1.61
“ oxide	0.86	5.27
Magnesic carbonate	0.78	0.75
Calcic sulphate	0.12	0.09
Oxide of iron	0.09	0.10

DENTINE, CEMENT, AND ENAMEL COMPARED.

	Ash.	Calcium Phosphate.	Magnesium Phosphate.	Calcium Carbonate.
Dentine	76.8	70.3	4.3	2.2
Cement	67.1	60.7	1.2	2.9
Enamel	96.9	90.5	traces.	2.2

Minute amounts of chlorine and fluorine are found, especially in the enamel. (Fremy.)

CEMENT AND DENTINE COMPARED, (AEBY).

	Cement.	Dentine.
Calcium phosphate	61.32	63.35
“ oxide	5.27	0.86
“ carbonate	1.61	4.80
“ sulphate	0.09	0.12

CEMENT—*Continued.*

Magnesium carbonate........	0.75	0.78
Ferric oxide................	0.10	0.09
Organic substances..........	27.70	26.00

ANALYSIS OF TEETH BY BERZELIUS.

Organic matter.........................	28.0
Calcium phosphate........	64.4
Magnesium phosphate..................	1.0
Calcium carbonate.....................	5.3
Sodium " and chloride...........	1.3
Water, animal matter, alkali (traces)......	0.0
	100.0

511. **Action of Various Substances on the Teeth:—**

Owing to the solubility in acids of the phosphates and carbonates of magnesium and calcium, it stands to reason that a great part of tooth structure may be destroyed when brought into contact with substances either themselves acid or of strongly acid reaction.

According to many authorities as Westcott, Allport, Mantegazza, Magitot, Leber and Rottenstein, etc., the strong mineral and vegetable acids act promptly upon the teeth. Leber and Rottenstein found that in time a solution of *tartaric acid*, 1 in 1000 attacked the enamel, as did also *crushed grapes*, or a 1 in 1000 solution of *acetic acid*, of *oxalic acid*, or 1 in 100 solution of *alum*, or 1 in 1000 of *lactic acid*. According then to Leber and Rottenstein, as also to Westcott, Allport, and Mantegazza, all the vegetable acids without distinction attack the enamel of the teeth. It is well to bear in mind such substances in daily use as are either acids or have an acid reaction, and hence should not be allowed to come constantly into contact with the teeth; these are the *mineral acids*, as sulphuric, nitric, hydrochloric, phosphoric, etc., the *vegetable acids*, as oxalic, acetic, tartaric, lactic, benzoic, salicylic, tannic, etc,, *many compounds of the metals*, as ferric chloride ("tincture of iron"), acid phosphates of calcium, magnesium, etc., etc., alum, arsenic, corrosive sublimate, zinc chloride, cream of tartar (acid potassium tartrate), the sulphate and subsulphate of iron, chromic anhydride (chromic "acid" so-called). Solutions of hydrogen dioxide are acid in reaction; some preparations of it contain much less acid than others.

C. A. Brackett has examined a number of substances used in dentistry and finds the following, among many other substances, to be acid in reaction:

Ordinary alcoholic tincture of myrrh (the specimen was some months old).

A solution of 1 part chloride of zinc to 2 parts glycerine.

Glycerine, 2 parts, tincture of aconite root, 1 part.

He found also, as might be expected, that the liquid portion of various "cements" was acid in reaction.

Among substances *but feebly acid* in reaction may be mentioned boracic acid.

Among substances which, *if pure*, should be neutral in reaction we find silver nitrate, carbolic acid. Among articles of diet which tend to attack the teeth may be mentioned acidulated drinks, foods readily becoming acid, and saccharine articles, shown by Miller to be converted into lactic acid.

512. **Chemistry of caries:** three theories have been advanced to account for caries, namely, *the chemical theory*, *the vital theory*, and *the germ theory*. According to the **chemical theory**, the substance of the tooth is decomposed by an acid; this acid acts more readily on

dentine than on enamel, hence the tendency to the enlargement of the cavity toward the internal portions of the tooth. The origin of the acids thus supposed to produce caries has been a subject of much inquiry. For a time the saliva was supposed to furnish them, but it was shown that decay occurred in mouths in which the saliva was habitually normal, and did not occur in some mouths in which the saliva was habitually acid. (Black). The hypothesis that the acid is furnished on the spot, through the decomposition of the food, seems much more feasible, and the production of the acid, if coming through fermentation, decomposition, or remoleculization of the substances lodged about the teeth, makes it easy for one to "glide from the old acid theory to the new germ theory." (Black).

The **germ theory** of caries sets forth, according to Miller, that no less than five different fungi exist in carious human teeth. These fungi have the power of causing fermentation in solutions containing fermentable carbohydrates and producing, as one of the products, optically inactive *lactic acid.* Free oxygen is not required for the production of this fermentative action, though it is probably accessory to the life and growth of the fungi. They have the power to invert sugar, that is, to convert infermentable cane sugar into fermentable glucose. When sound teeth are exposed to the action of these fungi, they are rapidly deprived of lime, and, on microscopic examination, large masses of bacteria will be found in the dental channels. The equation for the production of the lactic acid has already been given.

The **vital theory** supposed caries to result from an inflammation of the structure of the dentine, terminating in the final breaking down of the part; and as the structure is incapable, as is well known, of physiological repair, a cavity is the inevitable result. According to Black, it is still very uncertain whether any of the theories in regard to caries are correct, but the phenomena are explained by more than one with sufficient accuracy to be of great value, both in the prevention and treatment. Whatever may be the theories, it is claimed that the teeth deteriorate as an effect of mental overwork; among the hard-worked pupils of the Paris public schools, the teeth become deteriorated in a few weeks after entry. According to Parker, increased decay and increased sensibility of the dentine are apparent in men training for athletic trials. Williams has shown that any mental strain shows itself in the teeth in a short time.

THE SALIVA.

513. **The Saliva:** the saliva is the product of the combined secretion of the parotid, submaxillary, and sublingual glands. In the mouth these secretions are mixed together, and, also with it the mucus secreted in the oral cavity.

Physical characteristics of mixed saliva: *taste*, none; *color*, none; *odor*, none; *specific gravity*, 1002 to 1006; *reaction*, alkaline; *appearance*, generally turbid; *consistence*, glairy, viscid, frothy. On standing for some hours in a cylindrical glass vessel, an opaque, whitish deposit collects at the bottom, while the supernatant fluid becomes clear and of a faint, bluish tinge.

The *average daily amount* excreted has been placed at 1500 grams (about three pints); according to Ralfe this is probably too high, and 800 to 900 grams (less than a quart) is nearer the mark.

The specific gravity, according to some authors, may range normally as high as 1009. Saliva from different individuals may show a constant difference in alkalinity, but it varies only within narrow limits, and, while showing within certain limits in the same individual a constant degree of alkalinity, there is a decided and constant difference in different individuals, but no constant corresponding difference in diastatic action, according to Chittenden. (Charles). The *solids*, present in saliva, form only about one half of one per cent. of it; half nearly of these solids are salts, the rest proteids, namely ptyalin, globulin, and serum albumin.

The alkalinity would seem to depend on the presence of alkaline bicarbonates and phosphates with, possibly, help from a combination of the ptyalin with soda. The *sediment* consists of epithelial cells and salivary corpuscles —the latter resembling the colorless blood corpuscles and probably derived therefrom ; under the microscope, they present the same appearance as lymph cells, which have become swollen in water and within their bodies, as long as they are uninjured, a lively movement of small molecules may be perceived.

514 **Chemical composition of saliva:** the most important constituents of saliva are the diastatic ferment or

ptyalin, as it is called, *mucin*, and the chlorides of sodium and potassium; in addition are found traces of albumin, fat, *potassium sulphocyanide*, sulphates and phosphates of the alkalies and alkaline earths, chiefly calcium phosphate, also calcium carbonate, and oxide of iron. Sometimes, even in normal saliva, urea and ammonium nitrite are found. Saliva contains small quantities of nitrogen and oxygen, and an abundance of carbonic acid. The following are analysis of the mixed saliva:

FRERICHS.

Water	994.10	
Solids	5.90	
Epithelium and mucus		2.13
Fat		0.07
Mucin and traces of alcoholic extract		1.41
Potassium sulphocyanide		0.10
Chlorides of sodium and potassium, phosphates of sodium, potassium, and oxide of iron		2.19

JACUBOWITSCH.

Water	99.51	
Solids	0.48	
Soluble organic bodies, ptyalin, etc		0.130
Epithelium		0.160
Inorganic salts		0.182
Potassium sulphocyanide		0.006
Potassium and sodium chloride		0.084

SIMON.

Water	991.22	
Solids	8.78	
Ptyalin		4.37
Mucin		1.40
Sulphocyanide		1.40
Salts		1.40

BERZELIUS.

Water	992.9	
Solids	7.1	
Ptyalin		2.9
Mucin		1.4
Sulphocyanide		1.4
Salts		1.9

HAMMERBACHER.

Water	92.42	
Solids	0.58	
Epithelium and mucin		0.220
Ptyalin and albumin		0.140
Inorganic salts		0.220
Potassium sulphocyanide		0.004

IN 100 PARTS SOLIDS.

Epithelium and mucin	37.98
Ptyalin and albumin	23.97
Inorganic salts	38.03

IN 100 PARTS ASH.

Potash	45.71
Soda	9.59
Lime	5.01
Magnesia	0.16
Phosphoric anhydride	18.85
Sulphuric “	6.38
Chlorine	18.35

Enderlin gives in the 100 parts ash 92.37 as soluble and 5.51 as insoluble, of which sodium chloride (common salt) = 61.93, sodic phosphate = 28.12, calcium phosphate and carbonate = 5.51, and sodium carbonate = 2.31.

The **functions** of the saliva are mechanical and chemical: fats are feebly emulsified and soluble substances, as sugar, are dissolved in it. Starch is converted into sugar:

$$\underset{\text{Starch}}{3(C_6H_{10}O_5)}+3H_2O=\underset{\text{grape sugar}}{C_6H_{12}O_6}+\underset{\text{dextrin}}{2(C_6H_{10}O_5)}+2H_2O=\underset{\text{grape sugar.}}{3(C_6H_{12}O_6)}$$

According to Mering the starch yields dextrin and maltose and later grape sugar.

515. **Parotid saliva:** the following is Hoppe-Seyler's analysis of human parotid saliva:

Water	99.32	
Solids	0.68	
Mucin, epithelium and soluble organic bodies		0.34
Potassium sulphocyanide		0.03
Inorganic salts		0.34

It is a clear liquid, not viscous, but slightly alkaline. It gives no reaction for mucin, but contains albumin, ptyalin, and sulphocyanide of potassium.

Among more or less peculiar constituents we find paraglobulin, caproic acid, urea, and traces of sulphates. The reaction of the first secreted parotid saliva is less alkaline than that secreted later, although according to Astachewsky, it has a faintly acid reaction that gives place to an alkaline reaction, when the mucous membrane of the mouth is slightly irritated.

On standing, the parotid secretion becomes turbid, owing to the escape of carbonic acid and the consequent precipitation of calcium carbonate. Parotid saliva varies in quantity during the day, less being secreted immediately after a meal. (Charles).

516. **Submaxillary saliva:** in the dog, this saliva contains 99.44 water and 0.59 solids. Of the latter, mucin and epithelium form 0.066 parts, soluble organic bodies 0.17, inorganic salts 0.43. The character of submaxillary

saliva depends on the exciting stimulus to its secretion; stimulation of the *chorda tympani* nerve causes a normal, rich alkaline secretion, as noticed when acids are applied to the surface of the tongue, but in it no pytalin is found; with long continued stimulation the organic solids diminish somewhat, though at first the mucin is especially increased; stimulation of the *sympathetic*, as on application of pepper or alkalies to the tongue, produces a strongly alkaline secretion, of high specific gravity, 1.007 to 1.018, but viscid, turbid, slowly flowing, rich in mucus and irregularly formed cell elements.

In *chordal saliva* (submaxillary), Heidenhain gives the solids as 3 per cent., 2.5 organic and 0.5 inorganic; but other authorities give 1.2 to 1.4 per cent. In *sympathetic saliva* (submaxillary) Heidenhain gives 5.8 per cent. solids, Eckhard 2.7 per cent. In paralysis of the nerves supplying the gland very watery saliva is found, containing little solids or mucus. *In general, it may be said of saliva that it contains a comparatively large quantity of mucin dissolved in an alkaline fluid, together with a sugar-forming ferment, and potassium sulphocyanide.* Submaxillary saliva is comparatively poor in ptyalin, while parotid is rich in it; submaxillary saliva is rich in mucin, while parotid is poor in it. The submaxillary saliva is more alkaline than parotid and more viscid. Its average specific gravity is from 1.002 to 1.003. It contains much more carbonic acid than is found in venous blood, but is poorer in nitrogen. (Pflueger).

517. **Sublingual saliva:** this saliva is very viscous and thready, strongly alkaline, rich in mucus and salivary corpuscles, and would appear to be the richest in solids of all salivas. Heidenhain found 2.75 per cent. of solids in the dog. Traces of cholesterin and fat have been found. (Charles).

518. **Buccal mucus:** the amount of this is inconsid-

erable and it contains, according to Bidder and Schmidt, 99 per cent. of water. Its reaction is said to be acid; it contains numerous form elements, flattened epithelial cells, and salivary corpuscles. Claude Bernard found buccal mucus alkaline; the acid reaction would appear to be due to alteration.

519. **Circumstances favoring the diastatic action of saliva:**—

I. Quality of saliva (parotid acting more slowly than submaxillary); quality of starch.

II. Presence of acid *up* to 0.005 per cent.

III. Dilute alkaline solutions at 104 F.°

520. **Circumstances** *interfering with or suspending* **diastatic action:**

I. Strong alkalies, acids, temperatures above 158°F.

II. Temperature at or near freezing point.

521. **Changes in the saliva:** the *quantity* is not constant even normally. Its secretions may be excited by the sight or even thought of food, by the movements of mastication, by vapors of ether or acetic acid, or by electric excitation. If Jacobson's nerve be stimulated, a watery secretion occurs with diminished ptyalin, albumin, and salts; if there is stimulation of the sympathetic at the same time, a copious secretion is obtained, in which the organic constituents are in abundance, with a slight increase of the salts.

Circumstances which increase the quantity in twenty-four hours:

I. Dry food and tooth-filling.

II. Debility; confluent small-pox; at end of typhoid fever; ague.

III. Certain drugs: mercury, pilocarpine, eserine.

IV. Dentition.

V. Pregnancy.

VI. Hysteria; facial neuralgia; idiocy; hemiplegia from cerebral cause.

VII. Water-brash; organic diseases of the stomach or abdominal viscera.

VIII. Stomatitis; ulceration of buccal mucous membrane.

IX. Injury from mineral acids taken internally.

Among the drugs which have been known to produce salivation are bromine, arsenic, antimony, lead, prussic acid, nux vomica, gold, cantharides, digitalis, conium, belladonna, opium, iodide of potassium particularly, iodine, copper, croton oil, colchicum. In mercurial ptyalism, *fetor* of the breath and *sponginess* of the gums are common, but these characters have been observed in salivation from arsenic and bismuth. Extremely minute doses of mercury will, in some persons, rapidly bring on salivation.

Certain substances, as bark of pyrethrum, tobacco, etc., excite the buccal mucous membrane and lead to salivation.

522. **Circumstances decreasing the quantity of saliva:—**

I. Fevers and inflammatory diseases.

II. Certain drugs, particularly belladonna and atropine.

523. **Circumstances rendering the saliva acid in reaction:—**

I. Decomposition of organic substances in the mouth.

II. Diabetes. (Saliva acid when secreted, and sometimes contains lactic acid).

III. Catarrh of the mouth and intestinal tract.

IV. Acute rheumatism.

V. Mercurial salivation.

VI. Occasionally in carcinoma of the liver and in typhus fever, in muguet, and frequently in dyspepsia, though in the last possibly due to acid mucus. Changes in the reaction of the saliva due to decomposition of food in the mouth must be carefully distinguished from changes due to disease. In the former case the saliva may be secreted of alkaline reaction, but in the latter case it comes acid from the ducts.

524. **Circumstances giving rise to odor in the saliva:**—

I. Gingivitis.
II. Scurvy.
III. Mercurial salivation.
IV. Angina.

A fetid odor has been noticed in the above named diseases.

525. **Circumstances increasing the amount of solids in the saliva** or producing abnormal solid constituents:

I. Mercurial salivation.
II. Bright's disease, (urea abundant).
III. Hysteria, (leucin found).
IV. Phlegmasia.

526. **Circumstances decreasing the amount of solids:**—

I. Chlorosis, (water increased).

527. **Tartar:** while the secretions of the mouth remain alkaline, there is a tendency to deposit lime compounds on the teeth. This constitutes *tartar*, and, although it protects the body of the tooth, it has an injurious effect on the gums. When the secretions of the mouth become acid, tartar is no longer deposited, and the decay of the teeth usually hastened. (Leffman).

Soft tartar, such as is found at the necks, especially of the back teeth of youth, is destructive, holding acids *in loco*. (Chandler).

Tartar is of grayish, yellowish, or brownish color; *leptothrix buccalis* is found in it; it consists chiefly of calcium phosphate, with a little calcium carbonate, and phosphate of iron. According to Charles its average composition is as follows:

	Per cent.
Calcium phosphate	55 to 64
" carbonate	7 to 8
Ferric phosphate	1 to 3
Residue: organic matter, salts of alkalies, silica, etc	24 to 28

Magitot held that tartar in the region of the parotid was almost wholly carbonate, other tartar, phosphate. Alfred Vergne on the contrary claims that molar tartar has less phosphate than incisor, but that the carbonate is about evenly divided.

528. **Salivary Calculi:** saliva exposed to the air becomes covered with a film of calcium carbonate. Concretions of this substance are often found in the salivary ducts, in which case they are known as *salivary calculi.* These are of an elongated form, dirty white color, and formed in concentric layers. They vary in size, appearance, and composition. They contain no *leptothrix.* Their average composition is, according to Charles, as follows:

	Per Cent.
Calcic phosphate	30 to 80
" carbonate	11 to 15
Organic matter	5 to 25

Magnesium oxide, iron oxide, sodium chloride, sulphates, and potassium sulphocyanide, have all been found in salivary calculi.

529. *Uric acid* calculi have been found in the ducts in patients of an uric acid diathesis. Acids dissolve the ordinary salivary calculi very rapidly, considerable gas being given off owing to the abundance of calcium carbonate present.

CHAPTER VI.

EXPERIMENTS ILLUSTRATING GENERAL PRINCIPLES OF CHEMISTRY.

530. Apparatus and Manipulations.—*Test-Tubes* (fig. 1) are conveniently about four inches long and five-eighths of an inch in diameter. Longer and narrower ones are sometimes useful. Test-tubes are small, thin, glass tubes closed at the rounded end, and slightly flared at the mouth.

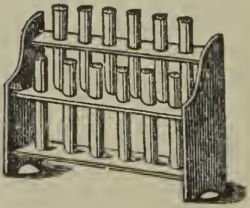

Fig. 1.

Care is to be taken not to crush the tubes between the fingers, not to drop them on the floor or into the sinks, not to push the brush (fig. 2) through them when cleaning, and not to crack or break them by hold- them steadily in a hot flame, not even when full of liquid, nor to let any flame touch any part of them, unless they are filled with liquid. Care should also be taken not to pour any liquid into them when they are broken, *especially at the bottom.* They should always be set in their place in the rack, when filled with liquid, and, when empty, should be inverted, after cleaning, over the pegs. *The good student in chemistry may be recognized by the good condition of his test-tubes and racks.*

Fig. 2.

Funnels (fig. 3) used are of glass; those three or four inches in diameter across the top are of convenient size.

Filter paper is unsized paper; the best is called Swedish, and may be bought already cut in circular form. Filter papers, seven and a half inches in diameter, fit well into the funnels above described. In order to fold a filter so as to fit it into the funnel, first fold it in two, then turn the right half over the left. In this way a funnel shape is given to the paper. Fit it into the funnel, and the edges should not project over the rim of the latter. Set the funnel into a test-tube with a slip of paper between the funnel and the tube, so as to allow free passage of air. The test-tube must, of course, stand in the rack. If large quantities of a liquid are to be filtered, the funnel should be set in *a ring* on the ring stand (fig. 3) or supported by *a clamp* with a beaker under it, the lower end of the funnel touching the beaker so that the liquid runs down its side gently. The liquid which runs through the filter is called the *filtrate*, and, as a rule, the filter-paper should be wet with water and the water allowed to run through, before adding the liquid to be filtered.

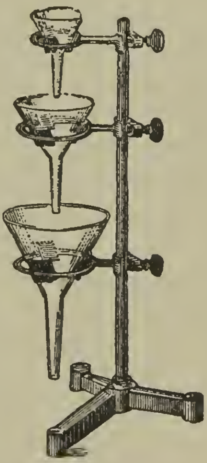

Fig. 3.

A *beaker* (fig. 4) is a thin, glass vessel with a flat bottom. Those holding 100 c.c. to 150 c.c. are convenient to use, and *watch glasses* serve well as covers. Beakers are commonly sold in *nests*, as in the figure.

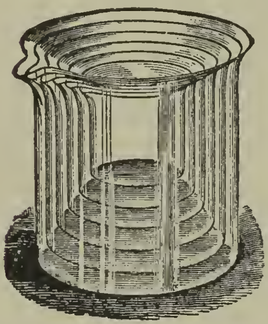

Fig. 4.

A *burette* (fig. 5) is a long, narrow tube, provided with a stop-cock, or pinch-cock, to control flow of liquid from it. Burettes are to be had graduated in the metric system in cubic centimeters, provided with glass stop-cocks, and are, when used, held by what is known as the *burette holder or support* (fig. 6).

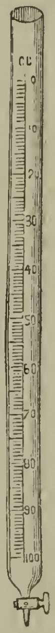

Fig. 5.

A *pipette* (fig. 7) is the name given to the simplest form of burette, which is merely a glass tube filled by suction, and the liquid returned by pressure of the finger on the top of the tube, the flow of liquid being controlled by the finger.

The *washing-bottle* (fig. 8) consists of an ordinary bottle or flask, provided with a doubly perforated stopper through which pass two pieces of glass tubing. Blowing into the shorter tube throws the water out in a stream from the longer one.

Glass-tubing may be bent by using the flaring flame, obtained by means of the wing-top of the Bunsen burner. After the glass softens in the flame it should be removed from it, and gently bent into any shape required. While heating the glass, rotate it slowly in the flame. Glass tubes are drawn out by heating in the non-luminous Bunsen flame.

Glass rods may be cut by use of a triangular file. Make one sharp, deep scratch and break off with the thumb and fingers of each hand, placed on each side of the scratch.

Iron ring stands (fig. 3), or *supports*, consist of an iron rod, inserted into a base of the same material, and provided with rings, which slide up and down the rod, being fastened by means of a screw at any desired height. Into the rings may be set funnels or beakers, the latter protected from the naked flame below, when used, by interposition of a sand-bath, wire gauze, or asbestos sheet.

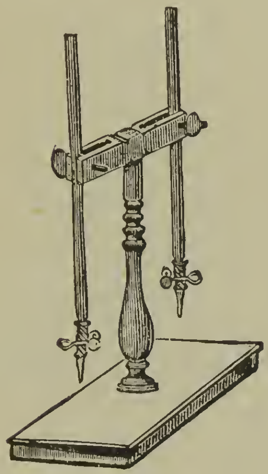

Fig. 6.

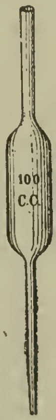

Fig. 7.

The *sand-bath* is merely a shallow iron dish filled with sand.

The *mortar with pestle* (fig. 9) is used for pulverizing substances, and the *spatula* (fig. 10) is useful for removing powder which sticks to the mortar.

Fig. 8.

The *Bunsen burner* (figs. 11 to 19) is an important piece of apparatus. Figs. 11–19 show different kinds, of which fig. 14 is the ordinary. It is attached to a gas jet by means of rubber tubing. The openings at the lower part of the Bunsen tube allow air to enter, and cause more perfect combustion of the gas, which results in the production of a non-luminous,

Fig. 9.

Fig. 10.

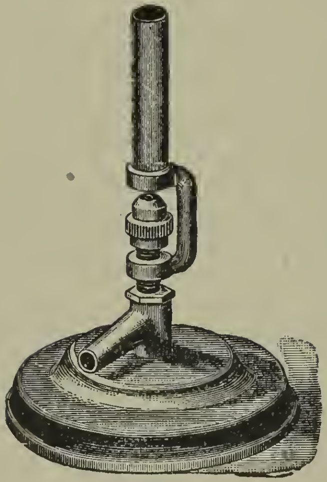

Fig. 11.

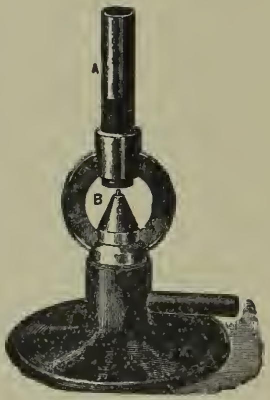

Fig. 12.

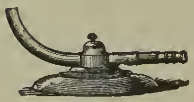

Fig. 15.

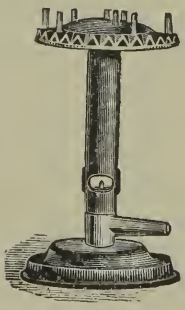

Fig. 13.

Fig. 14.

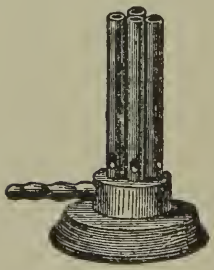

Fig. 16.

smokeless flame. In order to light the Bunsen burner turn on the gas from the gas jet, light a match, and, with an *upward* movement of the hand, raise the lighted match quickly up past the tip of the Bunsen. *Do not light the burner by slowly lowering the lighted match from above downward.*

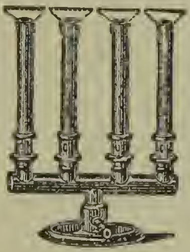
Fig. 17.


Fig. 18.


Fig. 19.

In case the flame, without change in the collar, suddenly becomes luminous, after being non-luminous, "running back" has taken place, and it will be seen that the gas is also burning *below*. Turn out the gas and light over again as above, taking the precaution also to close the revolving collar *partially*.


Fig. 20.


Fig. 21.


Fig. 22.

The wire triangle, (fig 20), one corner of which is thrust through a cork, is useful for observing the action of heat on substances, the cork being held in the hand while heating the substance on the triangle.

The cork-borer (fig. 21) consists of metal tubes with cutting edges perforated at one end. Through the perforation a small rod of metal being thrust a handle is thus made. After the cork has been bored, a fragment of it remains in the metallic tube. Remove now the rod and push the piece of cork out of the tube with it.

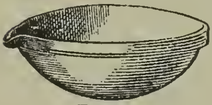

Fig. 23.

Corks may also be bored by piercing with a small round file, and filing the aperture made to any desired size.

The spirit-lamp (fig. 22) is useful when but slight heat is needed. Put the flame out, when necessary, by covering with the cap.

The porcelain dish (fig. 23) is useful for evaporating purposes. As long as there is liquid in the dish, it may simply rest in the ring in the iron ring-stand, but if the evaporation is to be carried to dryness, use *the water-bath.* The latter (fig. 24) is usually made of copper, and is a roundish vessel, provided with a series of concentric rings. The size of the evaporating dish, to be placed on the water-bath, regulates the number of rings to be used as support for the dish.

Fig. 24.

Platinum wire is useful for heating, or fusing substances in the Bunsen flame. The wire is moistened and dipped into a powder, which adhering to the wire may be fused in the flame, and the color imparted by it to the colorless flame thus noticed.

Fig. 25.

Platinum foil is of use in observing the action of heat on substances, as is also the *platinum dish.* A platinum dish, (fig. 25) which holds about 15 c.c. or half a fluid ounce, weighs about 10 grammes and costs about $5.00. Platinum materials withstand the Bunsen flame and also the mineral acids, except aqua regia, hence can be kept clean by use of acid, as hydrochloric. They may be brightened by polishing with fine, white sea sand.

Litmus and turmeric papers are used to distinguish acids from alkalies. Litmus paper is of two colors, blue and red. Blue litmus is turned red by acid solutions, and red

Fig. 26.

Fig. 27.

libmus turned blue by alkaline solutions. Litmus paper in quantity must be wrapped up carefully, and kept away from light and air. For use in the laboratory small, narrow slips of it, kept in a wide-mouthed bottle tightly corked and covered over with paper, are convenient. Turmeric paper is yellow and is turned brown by alkalies.

Acids do not affect it. It is used chiefly for detection of borax (see Qualitative Analysis).

Glass stoppered reagent bottles (figs. 26 and 27) which are now used in laboratories have the chemical names and formulæ in raised letters, ground in the surface. When of a capacity of four ounces they cost about $1.75 a dozen, eight ounces $2.50 a dozen.

The following is a list of those commonly used:

INORGANIC.

Formula.	Label.	Commercial Name.
HCl	Hydric chloride	Hydrochloric acid *or* muriatic acid
H_2SO_4	Hydric sulphate	Sulphuric acid *or* oil of vitriol
$H\,NO_3$	Hydric nitrate	Nitric acid *or* aqua fortis
H_2S	Hydric sulphide	Sulphuretted hydrogen
H_4NHO or NH_4HO or $AmHO$	Ammonic hydrate or hydroxide	"Ammonia." (Aqua)
$(NH_4)_2MoO_4$	Ammonic molybdate	
NH_4Cl	Ammonic chloride	Sal ammoniac.
$(NH_4)_2CO_3$	Ammonic carbonate	Sal volatile.
$(NH_4)_2S$	Ammonic sulphide	
NH_4HS	Ammonic hydro-sulphide or sulphydrate	
$NaHO$ or OH	Sodic hydrate or hydroxide	Caustic Soda.

INORGANIC—Continued.

Formula.	Label.	Commercial Name.
Na_2HPO_4	Di-sodic hydric phosphate	Phosphate of sodium.
Na_2CO_3	Sodic carbonate	Carbonate of sodium.
K_2CO_3	Potassic carbonate	Carbonate of potassium.
KI	Potassic iodide	Iodide of potassium.
KHO	Potassic hydrate or hydroxide	Caustic potash, potassa.
K_2CrO_4	Potassic chromate	Chromate of potash.
$K_2Cr_2O_7$	Potassic acid chromate or dichromate	Bichromate of potash.
$AgNO_3$	Argentic nitrate	Nitrate of silver
$BaCl_2$	Baric chloride	Chloride of barium.
$BaCO_3$	Baric carbonate	Carbonate of barium.
$Ba(HO)_2$ or $BaOH_2O$	Baric hydrate	Caustic baryta.
$CaCl_2$	Calcic chloride	Chloride of calcium.
$Ca(HO)_2$ or CaH_2O_2	Calcic hydrate	(Slaked lime, lime water, etc.).
$CaSO_4$	Calcic sulphate	Sulphate of calcium or sulphate of lime.

INORGANIC.—Continued.

Formula.	Label.	Commercial Name.
$MgSO_4$	Magnesic sulphate	Sulphate of magnesium or sulphate of magnesia or "Epsom salts."
$CuSO_4$	Cupric sulphate	Blue vitriol.
$HgCl_2$	Mercuric chloride	Corrosive sublimate.
$FeSO_4$	Ferrous sulphate	Green vitriol or copperas.
Fe_2Cl_6	Ferric chloride	Perchloride of iron.
$PtCl_4$	Platinic chloride	

ORGANIC.

Formula.	Label.	Commercial Name.
K_4FeCy_6	Potassic ferrocyanide	Yellow prussiate of potash
K_3FeCy_6	Potassic ferricyanide	Red prussiate of potash.
$KCyS$	Potassic sulphocyanide	
$(NH_4)_2C_2O_4$ or $(H_4N)_2C_2O_4$ or $Am_2C_2O_4$	Ammonic oxalate	
$Pb(C_2H\ O_2)_2$	Plumbic acetate	Sugar of lead.
$C_4H_{10}O$	Ether	Sulphuric ether

ORGANIC—Continued.

Formula.	Label.	Commercial Name.
C_2H_6O or C_2H_5HO or C_2H_5OH	Alcohol	
$H(C_2H_3O_2)$	Hydric acetate	Acetic acid.

The bottles in question are either wide-mouthed and provided with mushroom stoppers (preferably in the case of solids) or with flat stoppers usually in the case of liquids. Mushroom stoppers when removed may be placed upside down on desk, but flat stoppers should be held between the second and third finger of the hand in which the bottle is taken, except in case of acids. When the bottle contains an acid, hold the flat stopper upright in the hand which holds the test-tube.

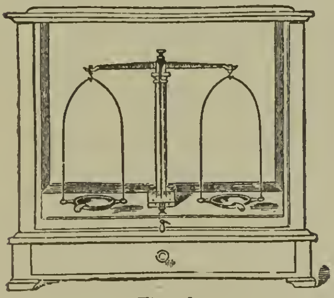
Fig. 28.

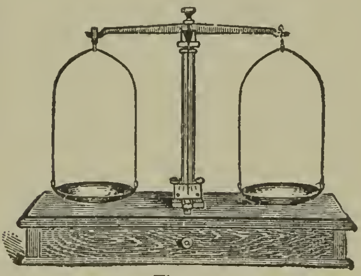
Fig. 29.

Liquids may be poured out of these bottles, drop by drop, by loosening the stopper slightly and then preventing the stopper from falling out by use of the fore-finger.

Solids may be poured from the wide-mouthed bottles by gently rotating in a horizontal position.

The *blow-pipe and its uses* are described in full in the chapter on Analytical Chemistry.

The *chemical balance* for ordinary weighing in experimental work need not be expensive. An ordinary hand-balance serves most purposes but a more exact form of balance is shown in figures 28 and 29. Such balances are to be had all brass with steel bearings, movable pans, and sensitive to $\frac{1}{20}$ grain. *Metric weights* will, however, be needed for the experiments herein described. For most purposes the set of metric weights from 20 grams down to 1 centigram is sufficient. Weights should be handled always with the forceps, and, to prevent corrosion of the pans, slips of glazed paper of equal weight may be used in each It is often necessary to weigh the various vessels used in

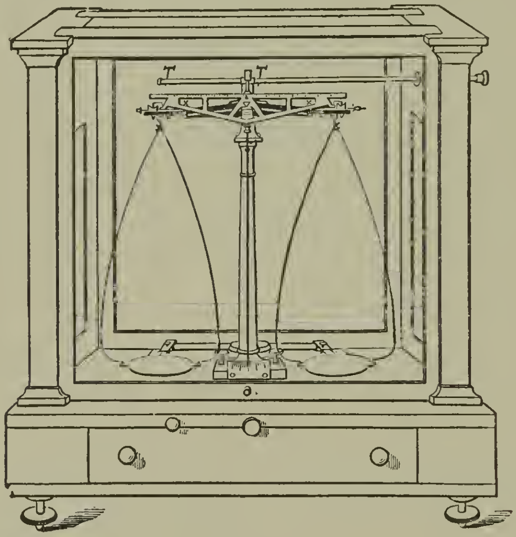

Fig. 30.

an experiment; for that purpose *counterpoising* is more convenient. Counterpoise the empty vessel with fine dry sand, fill the vessel as required and weigh. The weights used represent the weight of the contents of the vessel.

Figure 30 represents a chemical balance of improved type, for accurate quantitative work.

Graduates (fig. 31) for measuring liquids are very convenient to have on hand, and should be of several sizes. The metric unit of liquid measurement is the cubic centimeter, abbreviated to c. c. or cc., which represents distilled water of sufficient volume to weigh one gramme or 15.43 grains Troy, at 15° Centigrade, (60° Fahrenheit). The most convenient graduates are those with the double graduation in c. c. and fluid ounces, up to 1,000 c. c., 32 fluid ounces. Minim graduates (fig. 32) occasionally come in handy, and also those holding, say, 40 c. c., and 200 c. c. Remember that 30 c. c. equals about one fluid ounce. Special apparatus such as gas generators, endiometers, and U-tubes will be described under the particular heading where they are mentioned.

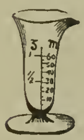

Fig. 32.

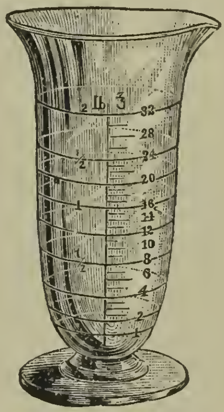

Fig. 31.

Various Manipulations:—In dealing with liquids the following manipulations are common:—

1. Boiling:—Liquids may be boiled in test-tubes over the Bunsen flame, when but small quantity is to be used and the boiling not to be prolonged. Cut out a strip of paper and wrap it round a test-tube, holding by the projecting ends, during the process of boiling. Point the tube away from every person near-by, including yourself, so that if sudden or violent boiling takes place, no one may suffer from it Do not remove the hot liquid quickly from the flame, and then look down into the tube, lest it suddenly boil up into the face. To prevent too vigorous boiling rest the lower end of the test-tube on the rim of the tube of the Bunsen burner, remembering that the hottest part of the Bunsen flame is the *top* of the *inner* cone of flame. What is known as a *clamp* (fig. 33) is useful for holding the test-tube; for prolonged boiling use a *clamp-stand* or *support* (fig. 34).

Fig. 33.

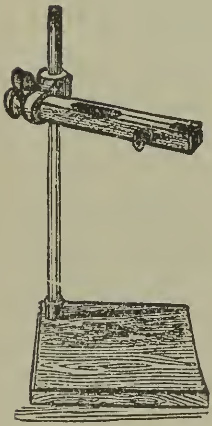

Fig. 34.

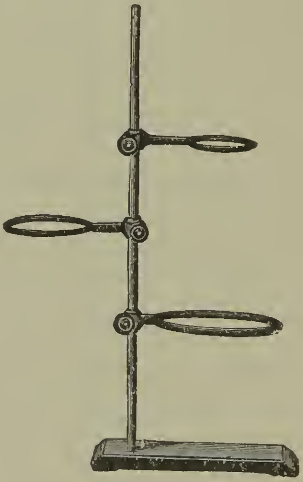

Fig. 35.

To boil larger quantities of liquids, above 15 c.c. (half an ounce), *beakers* are to be used; resting as stated before on asbestos sheets or gauze, and placed on the rings of the *ring stands* (fig. 35).

2. **Pouring**:—To pour liquids from one vessel to another hold a glass rod or tube vertically close to the

lip of the containing vessel, and the liquid will follow the rod rather than spill.

In pouring large quantities of liquid from one vessel to another see that the liquid strikes the *side* of the vessel into which it is poured, rather than the bottom. In this way *splashing* is avoided. Great care is thus to be taken in pouring acids and strong ammonia water from one vessel to another.

In mixing sulphuric acid and water the acid must be poured *in small quantities only* into the water, and not water into the acid, since great heat is evolved, and the mixture may boil with explosive violence.

In mixing acids with strong alkalies or dissolving the latter in water, heat is generated. Take care that the containing vessel does not crack during the process, and that the hands are not burned or the clothing injured.

Opening bottles:—

In opening bottles whose stoppers resist the strength of the fingers, first tap the stopper near its neck with anything convenient; as a glass rod, and then twist; if now it does not come out, put the neck of the bottle into hot water for a short time and try tapping again. If this is not successful, *gently* heat the neck of the bottle over the alcohol flame, rotating with great care. If this fails to loosen the stopper, take a sharp file and file thoroughly about the neck, then hit the head of the bottle a sharp rap with a comparatively heavy substance, as a small hammer or pestle end, and the neck and stopper will be knocked off without damage to the body of the bottle.

Bottles containing sodic hydrate should have their glass stoppers *paraffined*, which is done by simply dipping the lower part of the stopper into melted paraffine. This prevents adhesion of the stopper to the neck of the bottle.

List of Apparatus Required.*

The apparatus required to perform the experiments next to be described is as follows:—

1. Test-tube racks, each with a dozen test-tubes, which are four inches long by five-eighths of an inch in diameter

2. Test-tube brushes, two for each student.

3. Glass funnels, one or two for each rack.

4. Filter papers, cut in packages of 100 each.

5. Beakers, one or two for each student with watch glasses for covers.

6. Hard glass tubes, small with closed ends (ignition tubes), say two and one-half inches long; several for each student.

7. Wash-bottles, one for each rack.

8. Glass rods, two for each student.

9. Glass tubing, *ad lib.*

10. Pipettes, one or two for each student,

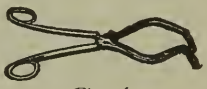

Fig. 36.

11. Burettes, one or two for each student.

12. Graduated burettes, one for every three or four students.

13. Iron ring stands, or tripods, one for every three or four students with sand bath, or asbestos sheets, or wire gauze.

14. Mortar and pestle.

15. Bunsen burners, one for each student, with rubber-tubing and wing-top.

16. Crucible tongs (fig. 36), and wire triangles.

17. Shears, pincers, files, knives.

18. Cork-borers, spatulas.

19. Alcohol lamps.

20. Porcelain evaporating dishes.

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*To be had of dealers in chemical apparatus as E. H. Sargent, Chicago.

21. Platinum foil, wire, and dishes in quantity according to means.

22. Water-baths, in convenient number, according to means.

23. Litmus and turmeric paper.

24. Sponges.

25. Bottles of various kinds; a set of glass-stoppered reagent bottles for each student or pair of students; a couple of wide-mouthed bottles for each student, provided with cork or rubber stoppers, one perforated, the other not.

26. A blow-pipe and charcoal for each student, or pair of students.

27. A chemical balance with metric weights of precision.

28. Graduates, for measuring liquids, of 1,000 c.c. capacity.

29. A good-sized blackboard.

30. Aprons, rubber gloves, protection glasses, soap, and towels.

For the benefit of those who are inexperienced it may be said that the *more expensive articles* in the above list are the graduated burettes with glass stop-cocks, the porcelain evaporating dishes (according to size), all platinum materials, water baths, the glass-stoppered reagent bottles, the 1,000 c.c. graduates, and the chemical balance.

Everyone working in a chemical laboratory should provide himself with an apron. Stains from chemicals are usually seen on the coat-sleeves, and on the trousers just above the knee, so that these parts should be protected. Loose, flapping coats should not be worn, but close fitting buttoned-up sack coats are most suitable. Overcoats and hats should never be brought into the laboratory as they are likely to be ruined. Each student should have his towel, soap, and apron in the drawer at his desk. Desks should be wiped clean with the sponges at the close of each exercise. Instructors should consider the condition of the student's desk and outfit in grading him for his years' work.

Special care should be taken of the *eyes.* The strong acids hydrochloric, nitric, sulphuric, glacial acetic, hydrofluoric, the caustic alkalies (ammonia, caustic soda solutions, caustic potash solutions) bromine, and oil of mustard are perhaps the most dangerous agents, considered with reference to the eyes. In removing the stopper from a large bottle of the acids, ammonia water, or bromine there is quite frequently a puff of vapor which may be dangerous, if received directly into the eyes. Even the dilute ammonia water of pharmacy, used for inhalations, has been known to cause blindness through accidental contact with the eyes. Protection glasses should be worn by those handling large quantities of these substances.

Explosive mixtures will not, as a rule, be made in the course of the work outlined here, but a word or two of comment may not be amiss. Chemicals which, either directly or indirectly, may give rise to explosions are most commonly the following:—

Potassium chlorate,
The hypophosphites,
Potassium permanganate,
Certain iodides and iodoform,
Nitric acid,
Chromic acid,
Bromine.

Potassium chlorate must not be rubbed up or triturated with organic substances as, for example, *tannin* or *saccharin* nor with certain sulphides, as *antimony sulphide*, nor with *the hypophosphites*, *nitrates*, or *salts of iron.*

The hypophosphites explode when triturated with chlorate of potassium and when heated.

Potassium permanganate is very easily decomposed, and explodes when rubbed up with glycerin and alcohol.

Iodine associated with a liquid containing large quantities of *ammonia* will give rise to formation of *iodide of nitrogen*, a highly explosive compound. (An organic compound of iodine called iodoform explodes, when combined with glycerin and silver nitrate.) Moreover iodine mixed with certain volatile oils, as *spirit of turpentine*, gives rise to explosion.

Chromic acid forms an explosive mixture with glycerin.

Bromine gives use to explosive compounds when combined with either alcohol or oil.

Nitric acid should not be mixed with organic compounds, as glycerin, or carbolic acid, and all substances having strongly acid reaction should not be mixed incautiously with glycerin, particularly if the acidity is due to presence of nitric acid.

Hydrogen gas mixed with air is explosive (exercise 25). If water is poured into sulphuric acid the mixture *boils* violently.

In using sulphuric acid in gas generators, as for example in generating sulphuretted hydrogen, take care lest through violent action in the flask, the acid liquid is not *spurted upward* through the thistle tube.

Sodium hydrate (caustic soda) when dissolved in water gives rise to *great heat.*

Acids poured in excess on alkalies, their carbonates or sulphides cause *great effervescence.*

Inflammable substances are *alcohol*, *ether*, *gasoline*, *kerosene.* Metallic *potassium* burns in water and must be kept in oil. *Phosphorus* is a highly inflammable substance and students have been dreadfully burned by it. It must be kept under water.

Poisonous or toxic substances used in the laboratory are numerous. Those most dangerous are *arsenic, potassic cyanide, corrosive sublimate, carbolic acid, morphine, and strychnine.* Ordinary illuminating gas is a dangerous poison to inhale; students are in danger from it at night, during sleep, when the gas has been blown out by some ignorant person, or when the gas fixtures leak. Arseniuretted hydrogen generated in the Marsh test for arsenic is a dangerous poison to inhale. (See Marsh test).

The concentrated mineral acids burn the skin terribly. If an accident of this kind happens, wash thoroughly with a *large* volume of water, then apply solution of bicarbonate of sodium, and subsequently oil. Every student should know where a solution of bicarbonate of sodium is to be had in the laboratory.

Experiments Illustrating General Principles of Chemistry.

Exercise 1. Solution.

A. Take up a little potassium nitrate on the point of a pen knife, and drop it into half a test-tube full of distilled water. Shake to and fro. The salt slowly disappears. The action is known as *solution;* potossium nitrate is said to be *soluble* in water, and to form a *colorless solution.* Now add a little more of the salt, shaking as before, and then a little more, and so on. After a certain amount has been added, it will not completely dissolve, not even if the tube be shaken long and vigorously. In other words the water has dissolved all the salt it can, and the solution is then said to be *saturated.* Now boil the liquid and keep up the boiling some little time; the undissolved salt is finally dissolved, hence *potassic nitrate is more soluble in hot than in cold water,* a property common to many substances. Let the solution cool, and note that, as the tube grows cold, the salt is less soluble and finally separates in the form of glistening *crystals.* Finally when the solution is cold, pour off the liquid into an evaporating dish, and evaporate to dryness over the water-bath. A whitish substance is obtained, thus showing that the salt is still dissolved in the water, even after cooling and separation of a part of the salt. The residue obtained is called *residue after evaporation.* Test the solubility of potassic iodide, and magnesic sulphate.

B. Solutions of reagents:—

It is customary, for sake of convenience, to use chemical substances in form of solution for experiments and tests. These solutions are known as *reagents*, and are to be made with cold distilled water. Make solutions of the following substances and keep them in the reagent bottles, being careful to make no mistake in regard to the contents of each bottle:—ten per cent. solutions of ammonic chloride; of sodic hydroxide, carbonate, phosphate, and acetate; potassic chromate, and dichromate. To make a ten per cent. solution weigh out 10 grammes of the solid substance and dissolve it in 90 cubic centimeters of distilled water (155 grains in about three fluid ounces of water). If the reagent bottles are the eight-ounce size, dissolve 20 grammes of the substance in 180 cubic centimeters of water (310 grains in about six ounces of water). Prepare also ten per cent. solutions of magnesic sulphate, baric chloride, and calcic chloride.

Prepare five per cent. solutions (5 grammes of solid to 95 c. c. of water) of ammonic oxalate, potassic iodide, ferrocyanide, ferricyanide, and sulphocyanide; also of ferric chloride, plumbic acetate, argentic nitrate, mercuric chloride, and platinic chloride.

Other reagents required need special description, and will be referred to in the chapter on Analytical Chemistry.

Notice that not all the solutions are colorless: potassic chromate, for example, is *yellow*, the dichromate reddish-yellow, the ferrocyanide greenish-yellow. After a little practice the eye becomes so accustomed to the colors of the solutions that a desired reagent can be found quickly, and time thus saved in work. Effort, should, therefore, be made to identify the various reagents by help of the color of the solutions, as soon as possible, but care is to be used not to confuse solutions of similar color.

N. B. To determine whether a substance is soluble in water: digest it with distilled water, filter, and evaporate filtrate to dryness in porcelain dish over the water bath. If anything has been dissolved, a residue will be left in the dish.

Exercise 2. Inorganic substances insoluble in water:—

A. Take up a very little black oxide of manganese on the point of a pen-knife, pour it into half a test-tube full of water, and shake as before.

It does not dissolve. Boil the water, and still it is not dissolved. The black oxide of manganese is then said to be *insoluble* in water.

This is true also of a large number of other oxides of the elements, but the oxides of potassium, sodium, ammonium, barium, and strontium are soluble; the oxides of calcium and arsenicum are soluble *with difficulty*, that is, require relatively a large amount of water to dissolve a small amount of solid: thus, arsenous oxide requires from 30 c. c. to 80 c. c. of cold water and 15 c. c. of boiling water to dissolve 1 gramme of the solid. Try to dissolve ferrous sulphide (used in making sulphuretted hydrogen) and it will be found to resemble the black oxide of manganese. The same is true of many other sulphides, but those of sodium, potassium, ammonium, barium, and strontium are soluble like the oxides of these same elements. The sulphide of calcium, likewise, is soluble with difficulty.

B. Test the solubility of calcium phosphate, carbonate and oxalate, cupric arsenite, plumbic chromate, and magnesium borate: they will be found to resemble the oxides and sulphides.

From the above two experiments may be deduced the following:

RULE FOR SOLUBILITY.

A Chlorides, iodides, sulphates, and nitrates of the elements are soluble in water. Exceptions:—plumbic, mercurous, argentic, antimonic, and chromic chlorides, and iodides; barium, strontium, calcium, plumbic, bismuthic, mercuric, and antimonic sulphates; bismuthic nitrate. N. B. Calcic sulphate is slightly soluble in water.

B. Oxides, sulphides, carbonates, phosphates, arsenites, chromates, borates, and oxalates are insoluble in water. Exceptions:—all compounds thus far mentioned of potassium, sodium, and ammonium are soluble in water. The oxides and sulphides of barium, and strontium are soluble and of calcium difficultly soluble. Certain chromates are soluble, as those of magnesium, manganese, and iron (ferric); those of strontium and calcium are difficultly soluble. The oxalate of chromium (chromic) is soluble, the oxalates of iron difficultly.

Exercise 3. Inorganic substances insoluble in water but soluble in acids:—

A. Put a very little calcic carbonate into half a test-tubeful of water, shake, and it does not dissolve but makes a milky liquid. Now add a few drops of hydrochloric acid, or nitric acid. Bubbling takes place (*effervescence*) and the substance dissolves. Calcic carbonate is insoluble in water but readily soluble (with effervescence) in hydrochloric, or nitric acids. N. B. Care must be taken in performing this experiment not to provoke too violent effervescence by addition of too much acid.

B. Test the solubility in acids of the oxides insoluble in water as, for example, magnesium oxide or magnesia, and they will be found readily soluble in hydrochloric or nitric acids, except those of chromium (—ic) and tin, which are soluble with difficulty. Test the solubility in acids likewise of the sulphides insoluble in water as, for example, ferrous sulphide, and they will be found soluble in hydrochloric or nitric acids, except mercuric sulphide. The same is true of all other salts mentioned under Rule B, except plumbic chromate, which is soluble with difficulty in acids.

N. B. In some of the tests above described it will be necessary to use undiluted (concentrated) acids.

Exercise 4. Inorganic substances insoluble in both water and acids.

Test the solubility of barium sulphate and it will be found insoluble in both water and acids. Calcium sulphate will be found to be soluble with difficulty in strong acids; so also plumbic chloride and iodide, mercurous chloride, chromic chloride, plumbic chromate.

Exercise 5. Substances insoluble in water but soluble in alcohol.

Place in each of two test-tubes a small piece of ordinary rosin. Now fill one tube half full of water and the other half full of alcohol. No solution takes place in the first tube but, in the second tube, after a time some of the rosin is dissolved. Now pour the contents of the second tube into the first, and a turbid liquid results; since the rosin is insoluble in alcohol diluted with water, it separates out into a finely divided condition, and is said to be in *suspension*, as it does not settle on standing. Moreover the rosin is said to be *precipitated*, from its solution in alcohol, by the water in which it is insoluble.

Exercise 6.. Natural waters contain substances in solution:—

A. Bore a hole through a cork, insert a bent glass tube through it, and fit into a flask. Connect the end of the glass tube by rubber tubing with a long, straight, glass tube, the end of which is above a dish. Cover the long glass tube with cloth wet with cold water. Fill the flask less than half full of hydrant water and boil.

The steam given off by boiling *condenses* to water again in the cool glass tube, and flows out into the dish. Water thus formed is said to be *distilled*, and the process is called *distillation*. Continue the process until but little water is left in the flask, then either set the flask over the water bath or cautiously use a very small flame, so as not to crack the flask, until all the water has evaporated. There will be left in the flask a slight whitish residue, known as *residue on dis-*

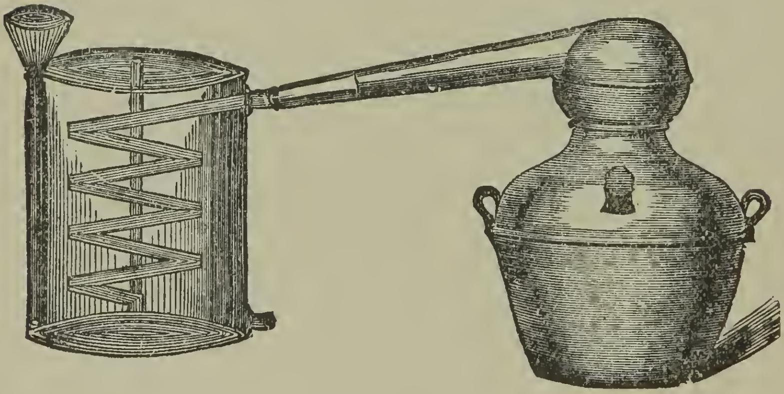

Fig. 37.

tillation, and composed chiefly of salts of lime and magnesia (calcium and magnesium) contained in solution by the water.

B. Test various waters in this way, to see which is freest from mineral matters in solution.

That which condenses and drips from the long, cool tube is known as the *distillate* and is comparatively free from impurities. (See Water.)

By distillation a volatile or easily evaporated liquid may be separated from a less volatile or non-volatile one. For the distillation of large quantities, copper stills are used with head and condenser of tin, or large glass retorts. (Figure 37.)

Exercise 7. Sublimation:— Place at the bottom of one of the small, hard tubes (ignition tubes) previously described, a little arsenic, in quantity size of a pea. Heat, and the powder gradually disappears as vapor, but collects again on the cooler part of the tube. This change of a solid into a gas, and back again into a solid, is called **sublimation,** and the solid deposited in the upper part of the tube is termed a **sublimate.**

Exercise 8. Precipitation:--

To half a test tube full of the argentic nitrate solution, already made, (*Ex. 1 B.*) add a drop or two of hydrochloric acid. A white *precipitate* is formed which settles in time to the bottom of the tube. Save it for exercise 10.

Exercise 9. Chemical Change:--

Carefully weigh out a small quantity of reduced iron, heat it, let cool, weigh again, and it will have gained weight. It has *changed* by taking up something from the air which has combined with it. Do the same with the oxide of zinc; it turns *yellow* but, on cooling, is the same as before, not having gained weight. It underwent *physical* change merely.

Exercise 10. Circumstances favoring chemical change.

A. Set the test tube containing the precipitate obtained in experiment 8 in direct sunlight, and, after a time, it will become *violet-colored.* Try the precipitation experiment again, but this time wrap tube in dark cloth. The precipitate will not change color. This experiment illustrates the influence of **light** on chemical change. (For equation see *Exercise 22*, *Reduction.*)

B. The influence of *heat* on chemical change has already been shown by exercise 9 first part. Union with oxygen is chemical change, and this is favored by *heat.* Bring a match *close* to a hot surface and it is inflamed, at a longer distance it is not. This shows that heat, in order to bring about change must not act over *too great a distance.*

C. Mix powdered cupric sulphate with potassic ferrocyanide on a piece of paper, taking care that both are *dry*, and that *no pressure* is brought to bear in mixing. No visible change takes place.

Now rub them up together in a mortar, and a *red color* appears. This experiment shows that *intimate contact* favors chemical action.

D. Heat to redness in one of the small, hard tubes some ferrous oxalate and, in another, some reduced iron, using about a gramme of each. After heating invert the tubes: from the one originally containing the oxalate will come iron, in so finely divided a state, as to take fire spontaneously as it falls through the air, combining in other words rapidly with oxygen. From the other tube will come merely an iron oxide, which does not inflame.

This experiment shows that *physical condition* has to do with chemical change, iron, in condition of the finest powder, combining more rapidly and quickly with oxygen than otherwise. An iron wire heated under similar circumstances is only superficially coated with oxide.

E. Mix as in C some tartaric acid with bicarbonate of sodium. Nothing visible happens. Now pour the mixture into a beaker of water, and effervescence at once takes place.

This experiment illustrates the influence of *solution* on chemical action. Solution is a condition in which bodies come into more intimate contact with one another than is possible in the case of the finest powder, the particles of the bodies being separated and diffused among those of the dissolving liquid.

For this reason we use reagents in *solution* so far as possible.

Exercise 11. Physical solution and chemical solution:—

A. Dissolve a little sugar in water. Evaporate carefully to dryness over the water-bath, and the sugar is recovered unchanged.

This experiment shows that *no chemical change* took place when the sugar was dissolved, for we get it back with the same taste and properties as before it was dissolved.

B. Next dissolve in a dish some of the copper of a cent by means of nitric acid. A blue liquid results. Evaporate to dryness, and a blue solid is obtained.

This experiment illustrates *chemical solution*: the solid obtained on evaporation is very different from the copper originally in the cent. *Chemical change* has taken place.

Exercise 12. Chemical combination:—

A. Rub together in a mortar a quantity of mercury with a small quantity of iodine, adding a little alcohol to control the action by keeping down the heat.

B. Rub together a quantity of mercury with a larger quantity of iodine, adding a little alcohol.

The above experiments illustrate *chemical combination*: Mercury, the fluid of silver-like appearence, and iodine, a blue-black solid, combine to form new substances totally unlike either mercury or iodine. Notice that according to the *proportions* used, bodies essentially different are produced, a greenish substance being formed in the first case, and a scarlet-red one in the second.

The substances thus formed from the union of elements are known as *compounds*, and, from the union of two elements, *binary compounds.*

Moreover the same two elements may form different binary compounds according to the proportions in which the elements are used. *Under different conditions, then, the same two elements form different compounds.*

The combinations illustrated above are examples of what are known as *direct combinations.*

Exercise 13. Decomposition of Compounds: —A. Place some mercuric oxide in an ignition tube, provided with a cork through which passes a bent delivery tube dipping under water; invert over the end of the delivery tube a test-tube filled with water. Heat the ignition tube to redness and collect the gas given off in the inverted test-tube. Notice the *sublimate* on ignition and delivery tubes.

This experiment illustrates the *decomposition*, or breaking up, of a binary compound into its constituent elements by heat. Mercuric oxide, the solid is decomposed by heat into metallic *mercury*, which is the sublimate on the tube, and *oxygen*, which is the gas bubbling up under water. Recognition of the oxygen may be undertaken by the means employed in the experiments on Oxygen, which see.

B. Heat a piece of zinc amalgam in a tube and collect the mercury given off.

C. Heat some limestone in a crucible over the blow-pipe flame. It is decomposed into lime and carbonic acid, thus:—

$$CaCO_3 = CaO + CO_2$$

Limestone (calcium carbonate) is a *ternary* compound containing three elements, and is decomposed by heat into two binary ones, calcium oxide and carbonic oxide, the former being a white solid, the latter a gas.

D. Decomposition by *light* has already been shown in exercise 10. A.

E. Pass an *electric current* through water. It is decomposed into its two elements, hydrogen and oxygen. (This experiment will be shown in full further on.)

Exercise 14. Direct decomposition by mutual action of substances on each other:

Put a few pieces of zinc into a flask, and then add diluted sulphuric acid. The zinc is dissolved, hydrogen gas given off, and zinc sulphate formed.

This experiment illustrates the direct decomposition of the acid by the zinc as follows:—

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

The experiment may be omitted here as it will be performed in exercise 25, when reference to this exercise should be made.

Exercise 15. Double Decomposition:—A. Dissolve some calcium chloride in water in a beaker; in another beaker dissolve some sodium carbonate. Mix the two and a white precipitate is formed.

This experiment shows that two substances soluble in water may produce a third substance quite insoluble in water.

Calcium chloride and sodium carbonate, both soluble, produce calcium carbonate (chalk) and sodium chloride (common salt.) The equation is as follows:

$$CaCl_2+Na_2CO_3=CaCO_3+2NaCl$$

Decomposition of this kind is known as *double decomposition*, the general rule for which has been already given. (See Berthollet's laws.)

B. In Exercise 3 there is double decomposition, hydrochloric acid and calcium carbonate forming calcium chloride and carbonic acid, thus:—

$$2HCl+CaCO_3=CaCl_2+CO_2+H_2O$$

One very practical application of the laws of chemical decomposition is to be found in pharmacy where solutions are so often to be mixed. The following rules* will aid the pharmacist:—

1. Two salts in solution may form, by the interchange of their acids and bases, two insoluble salts, which are precipitated.

2. When two salts in solution form, by the interchange of their acids and bases, a soluble and an insoluble salt, the latter will generally be precipitated, or may form with the soluble salt a double salt.

Given two clear solutions, one of barium chloride and the other of sodium sulphate. On adding one to the other a copious precipitate is formed; this is insoluble barium sulphate. Filtering the clear liquid, we find it to be a solution of sodium chloride.

3. When two salts in solution do not give rise to an insoluble salt no precipitate will result, though there may be decomposition.

4. An acid will decompose a salt:

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*Griffith

a. If the acid added be more fixed or more soluble than that of the salt.

b. If the acid added can form an insoluble or a less soluble compound with the base of the salt.

c. If the acid added possesses a greater affinity for the base of the salt.

d. If the acid of the salt be gaseous.

5. Oxides of the alkalies decompose salts of the metals proper and of the alkaloids, and precipitate their bases, or the base may be soluble in excess of the alkali.

Given a solution of sulphate of zinc. If a little liquor potassæ be added to it a precipitate of oxide of zinc will result; and on adding more of the liquor potassæ, the precipitate becomes dissolved.

6. Metallic oxides combine with acids to form salts,

7. Vegetable substances containing tannic or gallic acids precipitate albumin vegetable alkaloids, and most of the metallic oxides, and form with salts of iron inky solutions. Substances containing tannic acids also precipitate gelatin.

8. Many glucosides are incompatible with free acids or emulsions.

Exercise 16. Nascent State:—Warm a piece of gold leaf in chlorine water. No visible solution takes place. On the other hand mix 40 c.c. of nitric acid with 180 c. c. of hydrochloric, fill a test-tube half full of the mixture and add gold leaf. Warm the mixture. The gold rapidly dissolves.

This experiment shows that gold is soluble in chlorine in *the nascent state* as it is called. The mixture of acids mentioned above sets chlorine free which, when just set free, has energy enough to combine with gold, forming auric chloride. But a solution of chlorine in water already made is without action on the gold.

The expression *nascent state* is used of elements at the moment when their atoms leave molecules, and have not yet had time to re-enter into combination. In this state the atoms have much greater energy to combine than after having entered into a combination with other atoms of either the same kind or of another kind.

Exercise 17. The properties of acids;—

Take any acid at the desk and dilute it with water, 1 part of acid to 10 of water. Notice that it has the following properties:—

A. Acid or sour taste.

B. Changes the color of many vegetable substances, as litmus from blue to red.

C. Contains hydrogen. (This experiment may be omitted till hydrogen is taken up, exercise 25.)

D. It attacks various metals as tin, lead, silver, copper, especially when heated with them. Undiluted it burns and stains the skin and clothing.

E. All acids are not liquids. Examine glacial phosphoric acid for example.

Exercise 18. The properties of bases or basic substances:—

Take any hydroxide at the desk as, for example, solution of sodium hydroxide. Dilute it with water 1 to 10. Note that it has the following properties:—

A. The taste of lye or an alkaline taste.

B. A soapy "feel" when rubbed between the fingers.

C. Restores the color of organic substances, changed red by acids, to blue.

D. When acted on by an acid forms a neutral substance.

Dilute 5 c. c. of hydrochloric acid by adding say 20 c.c. of water to it and pour into a burette. Underneath the burette set a beaker containing 5 c. c. of sodium hydroxide. Drop into it a slip of litmus, which is at once turned blue. Now let the dilute acid drop in from the burette, drop by drop, until a faint red color shows on the litmus. Evaporate the liquid to dryness and note *salty* taste of residue, which is common salt:—

$$NaHO+HCl=NaCl+H_2O$$

Dry the residue and it will when dissolved in distilled water affect neither litmus paper being neutral in reaction.

E. Next neutralize sulphuric acid with magnesia and note *bitter* taste of the residue, magnesium sulphate being formed:—

$$H_2SO_4+MgO=MgSO_4+H_2O$$

F. Strong solutions of the bases are corrosive, burn the clothing, face, and hands. Vinegar or dilute acetic acid may be used to counteract their influence. Ammonium hydroxide is very destructive to the eyes, and the vapor of concentrated ammonia water is dangerous.

Substances having neither acid nor basic properties are called neutral and are very numerous. Water is an example, also common salt, silver nitrate, and a host of other substances,

CHAPTER VII.

PRACTICAL CHEMISTRY OF THE ELEMENTS AND THEIR INORGANIC COMPOUNDS.

In this chapter the non-metals and their compounds will be considered first, followed by the metals. Reactions characteristic of elements and compounds will be given in the chapter on Chemical Analysis, this chapter being devoted entirely to experimental work.

Exercise 19. Oxygen: Heat five grammes of potassium chlorate in a dry flask holding about 100 c. c. (3 fl. oz.). The flask should be provided with a perforated cork through which runs a bent glass tube (fig. 38) leading under the surface of water. The chlorate after a time melts, and, on further heating, effervesces, When the presence of gas in the water is shown by bubbling, fill a large test-tube full of water, and invert it over the mouth of the delivery tube. Gas rises, and displaces the water in the tube. In this way collect several test-tubes full of gas. Take the end of

Fig. 38.

the delivery tube from the water, before withdrawing the flame. Apply a lighted taper to one of the tubes full of oxygen, and observe that the gas will not burn, but that the taper burns more brilliantly than in air. Blow out the flame of the taper leaving the end of it still glowing, and again plunge it into another tube full of oxygen. Notice that it is re-ignited.

Oxygen is incombustible, but is an active supporter of combustion.

Oxygen may be made on a large scale in a metallic retort (fig, 39) by using a mixture of four parts potassic chlorate and one part manganese dioxide. The object of the mixture is to obtain the gas at a lower temperature, and without fusing the chlorate. No change takes place in the manganese dioxide, and the exact action is not understood.

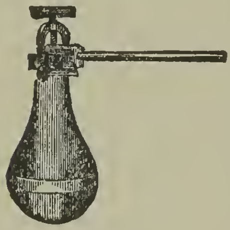

Fig. 39.

Oxygen, for use in therapeutics and commerce, is produced at low cost by the Brin process, which, as now perfected, consists in heating a porous barium oxide to 700° C. in closed vertical retorts, into which purified air is forced under a pressure of ten or fifteen pounds more than that of the atmosphere. Barium peroxide is formed, and, when the air pressure is reduced to fourteen pounds below atmospheric, oxygen is rapidly given off.

Exercise 20. Oxidation and reduction:—Hold some zinc turnings in the Bunsen flame using the tongs. Notice that they ignite, and turn into a white powder which is zinc oxide. The addition of oxygen to the zinc is called **oxidation.** The oxygen added to the zinc is derived from the air. The equation is as follows:

$$Zn+O=Zn\,O.$$

Now place a small quantity of silver oxide in one of the small, hard, ignition tubes and heat gently. A bright mass of silver is formed. The oxygen of the oxide is set free, and the silver is *reduced*, as the term is. The removal of oxygen from any compound is called *reduction.*

Exercise 21. Equations illustrating oxidation:—

The class at this point should consider various equations illustrating oxidation. The oxygen may be derived either from the air or from oxidizing agents, as nitric acid, as follows:

$$C+O_2=CO_2$$
$$P_2+O_5=P_2O_5$$
$$2FeO+O=Fe_2O_3$$
$$H_2S+2O_2=H_2SO_4$$
$$2H_2S+O_2=2H_2O+S_2$$
$$2Cu_2O+O_2=4CuO$$
$$FeSO_4+2NaHO=Na_2SO_4+Fe_2(HO)_2$$

and

$$2[Fe_2(HO)_2]+O+H_2O=Fe_2(HO)_6$$

N. B. The above equation illustrates the formation of ferr*ous* hydroxide and the oxidation of it into ferr*ic* hydroxide.

$$3PbS+8HNO_3=3PbSO_4+8NO+4H_2O$$

N. B. The above equation shows the oxidation of metallic sulphides into sulphates by strong acids (oxygen containing bodies). No sulphur separates in this case.

$$Hg_2Cl_2+2Cl=2Hg\,Cl_2$$

N. B. In the above equation the mercur*ous* chloride

Hg_2Cl_2 is said to be "oxidized" by chlorine into mercur*ic* chloride. The term oxidation is thus sometimes broadly used to denote change from an —ous compound (lower) to an —ic one (higher).

Some common oxidizing agents are potassium chlorate, chromic acid, nitric acid, chlorine, iodine, potassium dichromate, potassium ferricyanide, and manganese dioxide.

$$MnO_2+4HCl=MnCl_2+2H_2O+Cl_2$$

In the above equation the hydrogen of the HCl is oxidized by the oxygen of the MnO_2, water being formed and chlorine set free. See exercise 40.

In the act of oxidation the substances formed are called *oxides.* There are three classes of oxides, namely, basic oxides, neutral or indifferent oxides, and acid-forming oxides also called anhydrides.

Basic oxides are those which plus water yield bases (hydroxides) thus $K_2O+H_2O=2KHO$. They neutralize acids and with them form salts as $K_2O+H_2SO_4=K_2SO_4+H_2O$. *Neutral or indifferent oxides* are those which yield neither bases nor acids with water; examples MnO_2,PbO_2.

Anhydrides are those which plus water yield acids; examples SO_3,N_2O_5. Thus $SO_3+H_2O=H_2SO_4$.

The more common basic oxides are K_2O, Na_2O, CaO, BaO. Basic oxides, insoluble in water, yet serving to neutralize acids and to form salts, are Al_2O_3,PbO,MnO,CuO. Thus Al_2O_3 neutralizes sulphuric acid and forms a salt with it, according to the equation:—

$$Al_2O_3+3H_2SO_4=Al_2(SO_4)_3+3H_2O$$

As a rule the fewer the oxygen atoms the more basic the oxide; thus, of the four oxides of manganese, MnO is strongly basic, Mn_2O_3 weakly basic, MnO_2 indifferent, and MnO_3 an anhydride. Some common neutral, or indifferent oxides are MnO_2, H_2O,PbO_2.

The more common anhydrides are SO_2, SO_3, P_2O_3, P_2O_5, Cl_2O, Cl_2O_3, Cl_2O_5*, Cl_2O_7*, N_2O_3, N_2O_5, I_2O_5, As_2O_3, As_2O_5, Sb_2O_5, CO_2, CrO_3, SiO_2. The last is *in*soluble in water yet forms salts when treated with hydroxides, thus $SiO_2+2KHO=K_2SiO_3+H_2O$.

Anhydrides are oxides of negative elements, but all oxides of negative elements are not anhydrides; thus, there are three oxides of the negative element chlorine, and four acids containing it, namely chlorine monoxide Cl_2O, chlorine trioxide Cl_2O_3, and chlorine peroxide Cl_2O_4; also hypochlorous acid $HClO$, chlorous acid $HClO_2$, chloric acid $HClO_3$, and perchloric acid $HClO_4$. The monoxide and trioxide then are *anhydrides*, since by adding H_2O to their formulæ those of the first two acids are obtained. But chlorine peroxide does not form any of the four acids on addition of water, nor have the anhydrides, corresponding to these acids, ever been isolated. Therefore chlorine peroxide is not an anhydride. Again there are five oxides of nitrogen, namely nitrogen monoxide N_2O, nitrogen dioxide $N_2O_2=2(NO)$, nitrogen trioxide N_2O_3, nitrogen tetroxide $N_2O_4=2(NO_2)$, and nitrogen pentoxide N_2O_5. Of these the first, third, and fifth are anhydrides, combining with water to form hyponitrous, nitrous, and nitric acid respectively, but the second and fourth are not anhydrides.

Exercise 22:—Equations illustrating reduction:—

$$CuO+\text{heat}+H_2=Cu+H_2O$$

Note:—this equation illustrates the reduction of a metallic oxide by hydrogen. *Most of the metallic oxides are reduced at a red heat by hydrogen.*

$$Fe_2O_3+3H_2=Fe_2+3H_2O$$

Iron thus formed is known as *reduced* or Quevenne's iron.

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*Not in separate state.

$$Fe_2Cl_6+Zn=2FeCl_2+ZnCl_2$$

This equation illustrates reduction by *zinc.*

$$2Fe_2O_3+3C_2=2Fe_2+6CO$$
$$CaSO_4+2C=CaS+2CO_2$$
$$2As_2O_3+3C=4As+3CO_2$$

The above three equations illustrate reduction by *carbon* so often used in metallurgy.

Other equations illustrating reduction:—

$$2HgO+heat=Hg_2+O_2$$
$$Fe_2Cl_6+H_2S=2FeCl_2+2HCl+S$$
$$Cu_3+8HNO_3=3Cu(NO_3)_2+4H_2O+N_2O_2$$
$$2AgCl+light=Ag_2Cl+Cl$$

The term reduction is now also used to signify removal of a negative element, thus, ferr*ic* chloride under certain circumstances is said to be "reduced" to ferr*ous.*

Reducing agents are sulphurous acid, sodic hyposulphite, oxalic acid, ferrous oxide, arsenous anhydride, stannous chloride, potassium ferrocyanide, and zinc, or magnesium.

Carbon and carbon monoxide are used as reducing agents in metallurgy.

Glucose is an example of an organic reducing agent. Organic reducing agents will be discussed under the heading of Organic Chemistry.

Exercise 23. Hydric Dioxide:—

A. Take the reaction of a sample of commercial "peroxide," as it is called and notice that it is strongly acid.

Acids in small quantities are added to it in order to prevent decomposition, as follows: $2H_2O_2=2H_2O+O_2$, oxygen being readily given off.

B. Obtain some pus from a suppurating surface and add to it a little of the peroxide. Notice the "foaming" or effervescence, oxygen gas being given off. Try the same experiment in the mouth, in a suppurating cavity.

C. Show the bleaching properties of hydric dioxide by adding it in excess to a solution, say, of logwood which has been rendered alkaline by a few drops of ammonia water.

D. Show its action in decolorizing permanganate by adding it to a solution of the latter, acidified with sulphuric acid. Oxygen is evolved as follows:—

$$5H_2O_2+2KMnO_4+3H_2SO_4=8H_2O+2MnSO_4+K_2SO_4+O_{10}$$

E. Show the method by which it is prepared by mixing in a test tube 20 drops of sulphuric acid and 3 c.c. of water. Also mix a little piece of baric dioxide, BaO_2, with enough water to make a thick paste, using a dish. Take up with a glass rod small portions of this paste, and dip them into the tube containing the dilute H_2SO_4. Keep the tube cool, by immersing it in a larger vessel containing ice water. The equation is as follows: $BaO_2+H_2SO_4=BaSO_4+H_2O_2$.

F. Medical and dental students should note the requirements of the United States Pharmacopœia with reference to hydrogen dioxide as follows: There should be no hydrofluoric acid in it, barium should be absent, and 50 c.c. of it should not require more than 0.5 c.c. of potassium hydrate (volumetric solution) to render it alkaline.

Exercise 24. Ozone:—

A. Gradually add baric dioxide in small portions to a little cold sulphuric acid undiluted. Oxygen is given off which is tolerably rich in ozone:

$$3\,H_2SO_4+3BaO_2=$$
$$3\,BaSO_4+3H_2O+O_3$$

B. Note the peculiar odor of ozone, penetrating, chlorine-like (or phosphorus) odor, and its action on potassium-iodide-starch paper, which is colored blue.

C. Note that hydric dioxide also turns the potassium-iodide-starch paper blue but that ozone, in addition, blackens bright strips of silver foil.

A complete apparatus for the generation of ozone with baric dioxide and sulphuric acid may be purchased ready made.

Exercise 25. Hydrogen:—

A. Make hydrogen gas by placing about 10 grammes of granulated zinc in a flask of about 200 c.c. capacity, provided with a twice perforated cork or rubber stopper, through which are inserted two tubes, one a straight (thistle) tube, the other a bent tube. The thistle tube goes nearly to the bottom of the flask, the bent tube only a short distance through the cork. Cover the zinc in the flask with water, insert the stopper with its tubes, and pour into the thistle tube a little sulphuric acid, adding more from time to time when evolution of gas ceases. Effervescence takes place around the zinc. Collect the gas over water as usual in several test-tubes, and reserve for further experiments. The equation has already been given, page 392.

B. Remove the first test-tube of gas, mouth downward, to a flame near by. An explosion takes place, showing that hydrogen mixed with air driven off from the flask is explosive.

C. Repeat the experiment with the second or third tubes, and notice that hydrogen not mixed with air burns quietly, but that if a taper is pushed up into the tube the flame is extinguished.

Hydrogen is combustible but does not support combustion.

D. Hold another tube filled with gas mouth upwards for a few moments and notice that the gas escapes, hence is lighter than air. That the gas escapes may be proved by igniting it it *above* the tube and noting absence of ignition *in* the tube.

E. After a time ignite the gas directly at the mouth of the ignition tube whence the hydrogen was derived, and notice that it burns with a colorless flame.

F. Evaporate to dryness the liquid in the flask after the experiment is concluded and notice that a salt-like substance in crystals is obtained. This is zinc sulphate. The equation of its formation has already been given.

Exercise 26. Water:—

A. Show that water is a compound of hydrogen and oxygen by decomposition with electricity.

Fig. 40.

Two tubes, (Fig. 40) closed at one end and filled with water, are suspended with their mouths beneath the surface of some water acidulated with sulphuric acid, contained in a glass dish below. Through the sides of this dish pass two wires, each terminating in a plate of platinum seen beneath the open ends of the tubes. On connecting these wires with a battery, (Grove's) of 6 or 8 cells, a torrent of gas-bubbles rises from each platinum plate into the tube above it. Notice that the tube over the negative electrode fills twice as rapidly as the other; test the gas in each, when the tubes are both filled, and note that the gas in this tube is hydrogen while that in the other is oxygen. In other words water contains 2 volumes of hydrogen to 1 volume of oxygen. Since oxygen is 16 times heavier than hydrogen the ratios by weight are as 2:16 or as 1:8; that is, water is composed of 88.89 per cent. of oxygen, and 11.11 per cent. of hydrogen.

The apparatus for electrolytic decomposition of water can now be had ready made at a small cost.

B. Show that water is formed by the union of oxygen and hydrogen by use of Ure's eudiometer. (Fig. 41). This is simply a glass U-tube closed at one end, this end being graduated and also pierced near its extremity by two platinum wires. Fill this limb with water, and then introduce 20 c.c. of pure oxygen from a delivery-tube and then 40 c.c. of hydrogen. Make the measurements when the level of the liquid is the same in both limbs. Then close the open end with the thumb, leaving a cushion of air between it and the water, and pass a spark through the mixed gases by means of the platinum wires. A slight flash appears on the passage of the spark, and suction is immediately felt by the thumb. Remove the latter carefully, fill the open limb with the additional amount of water necessary, and the gases in the closed limb will be found to have disappeared, in other words 20 volumes of oxygen have united with 40 of hydrogen to form water.

Fig. 41

Exercise 27. Nitrogen:—

A. For preparation of nitrogen use the same apparatus as that employed for oxygen. Place in the flask about 10 grammes of potassium nitrite, and almost an equal weight of ammonium chloride. Add water, sufficient to dissolve the solids and apply heat which must be well-regulated or else too violent evolution of gas will take place. The equation is as follows:—

$$KNO_2+NH_4Cl=KCl+N_2+2H_2O$$

B. Collect the gas in test-tubes, as in case of oxygen, and show that it is neither combustible nor a supporter of combustion, using taper as before.

Exercise 28. The Air:—

A. Show that the air is a mixture essentially of nitrogen (four-fifths) and oxygen (one-fifth) by placing a graduated glass tube, containing a measured volume of air, mouth downward in a dish containing mercury. Introduce a small ball of phosphorus on the end of a wire, and let it remain in contact with the air for several hours, when it will gradually combine with the oxygen, and the mercury will rise, to fill the space previously occupied by the oxygen. Knowing the original volume of the air, the loss in volume represents oxygen, and the volume remaining is chiefly nitrogen.

B. Show that the air contains something else besides these two gases, by passing a measured volume of it through two U-shaped glass tubes (fig. 42) the one filled with calcium chloride,* the other with potassium hydroxide, each tube and contents having been weighed separately. After the experiment is over it will be found that

Fig. 42,

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*These substances should be in solid form, not in liquid.

each tube has gained in weight, the one containing calcic chloride retaining all the *moisture* in the air, on account of the affinity of this substance for water, and the other all the carbon dioxide.

For determining the precentage of carbon dioxide and moisture in air with accuracy, expensive apparatus is required.

Exercise 29. Compounds of Nitrogen:—

I. AMMONIA.

A. Prepare ammonia gas, NH_3, by mixing equal weights, about 10 grammes each, of slaked lime (calcic hydroxide) and sal ammoniac (ammonium chloride) in a flask of 200 c.c. capacity and covering with water. Set the flask on an asbestos sheet. Insert into its mouth a perforated stopper, carrying a bent tube dipping under water. Apply heat. Ammonia gas is given off according to the equation.

$$2(NH_4Cl)+Ca(HO)_2=CaCl_2+2H_2O+2NH_3$$

Note the odor, and the alkaline reaction on litmus of the water in which the gas is dissolved.

B. Take the mouth of the bent tube out of water, connect it by rubber tubing to another glass tube, turn the latter upwards, and hold an empty test-tube over it. After a few minutes withdraw the test-tube and, holding it mouth down, place in a vessel of water. The ammonia gas in the test-tube is rapidly absorbed, and the level of the water rises at once to the top of the tube, ammonium hydroxide being formed according to the equation

$$NH_3+H_2O=NH_4HO$$

NOTE. By removing the test-tube from the water, when the latter has risen about a quarter of an inch, corking quickly, and shaking well a *stronger solution* of ammonium hydroxide is obtained, which responds to the tests for bases already given. After this has been shown bring an uncorked bottle of hydric chloride (hydrochloric acid) near to it, and note the dense white fumes. Put a drop of each in a watch-glass, invert over one another, and note the white solid formed. This last experiment shows that ammonia gas is always given off from strong solutions of the hydroxide, and that it unites with the chlorine of the hydrochloric acid to form ammonium chloride according to the equation

$$HCl+NH_3=NH_4Cl$$

II. NITROGEN MONOXIDE OR LAUGHING GAS (NITROUS OXIDE.)

Place in the same apparatus used for generating oxygen about 10 grammes of ammonium nitrate, without water. Instead of a bent tube leading under water one leading through a perforated card or paper, placed on top of a beaker or tumbler, will do. Apply heat to the flask. The salt melts and gives off nitrous oxide, which being heavier than air collects in the beaker. Note that combustion is supported by it more actively than by air, using paper as before.

The equation of its preparation is given on page 187

For use in dentistry it is liquefied by pressure of about 50 atmospheres and the liquefied compound sold in wrought-iron cylinders.

III. NITROGEN DIOXIDE, N_2O_2 OR NO.

Formed when nitric acid acts on metals as the copper cent of a previous experiment. Collecting the gas by displacement with water, it is colorless (after the air has been driven off) but in presence of air unites directly with the oxygen of the air forming $N_2O_4=2(NO_2)$ nitrogen tetroxide, which has deep-red color and is poisonous. Evaporate to dryness the blue solution, and note that it is a crystalline solid, cupric nitrate, formed according to the equation

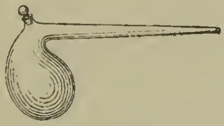

Fig. 43.

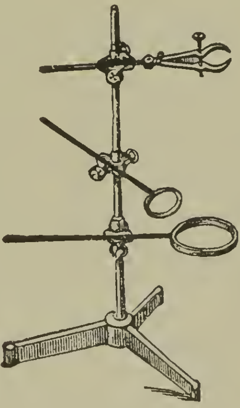

Fig. 44.

Fig. 45.

$$3Cu+8HNO_3=3Cu(NO_3)_2+N_2O_2+4H_2O$$

IV. Nitric Acid.

Place in a retort (fig. 43) of about 250 c.c. capacity, 50 grammes of nitre (potassium nitrate) and the same *weight* nearly of sulphuric acid. Fix the retort by a clamp on the ring of a ring-stand (fig. 44) resting it on wire gauze, the mouth being inclosed by a wide-mouthed flask (receiver), (fig. 45) kept cool by surrounding with ice. Nitric acid is evolved and distils over into the receiver. Test it by its action on copper as before.

The equation has been already given on page 189.

Nitric acid and the nitrates are strong oxidizing agents: place in a test-tube a small piece of tin foil, and add a little nitric acid; energetic action takes place, the tin is oxidized, and the nitric acid reduced, according to the equation

$$2HNO_3+Sn+H_2O=Sn(HO)_4+N_2O_3$$

The action of nitric acid on metals as a rule is two-fold: first the metal is oxidized and second the oxide or hydroxide formed is dissolved in the excess of acid, forming in turn a nitrate and water, but, in the action of nitric acid on tin, the oxygen compounds formed are both insoluble in excess of acid, hence nitrate of tin is not formed. In the action on copper, however, we have first

$$3Cu+2HNO_3+2H_2O=3Cu(HO)_2+2NO$$

second

$$3Cu(HO)_2+6HNO_3=3Cu(NO_3)_2+6H_2O$$

the whole action being represented by the one equation already given above.

Tests for nitric acid will be given in the chapter on Analytical Chemistry.

Exercise 30. Carbon:—

A. Heat starch or sugar on platinum foil. A blackened residue is obtained resembling charcoal.

B. Treat sugar with sulphuric acid in a dish. A similar substance is obtained.

C. Heat a piece of a match or tooth-pick to redness in an ignition tube; charcoal will be left in the tube, and the vapors given off will burn at the mouth of the tube.

D. Heat a piece of bone in the same way, noting offensive odor.

These experiments show that organic substances contain carbon, and blacken when heated, if non-volatile.

E. Obtain some solution of sulphuretted hydrogen, used in the laboratory as reagent, and add two drops of it to half a test-tube full of water. Note the odor of rotten eggs. Now weigh out, say, five grammes of powdered charcoal, pour it into the tube, cork and shake. Let stand fifteen minutes to half an hour, and note that the odor has disappeared.

This experiment shows how charcoal (carbon) absorbs gases and hence acts as a *deodorizer.*

Exercise 31. Carbon monoxide:—

A. Prepare this gas by treating 10 grammes of oxalic acid with 55 grammes of concentrated sulphuric acid in a flask, connected with two Woulff's flasks (fig. 46) containing solutions of caustic soda. Set the original flask on asbestos and heat gently. Collect gas given off over water. Note that it is combustible and, that if passed over heated copper oxide in an ignition tube, will reduce it.

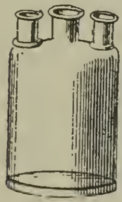
Fig. 46.

The equation of its production is as follows:—

$$H_2C_2O_4{}^{*}+H_2SO_4=H_2SO_4.H_2O$$
$$+CO_2+CO$$

Most of the illuminating gas now used is essentially carbon monoxide, made on a large scale by decomposing steam by red hot coal thus:—

$$H_2O+C=H_2+CO$$

Mixed with hydrocarbons it is used for illuminating purposes. Since carbon monoxide is poisonous, deaths from "blowing out the gas" are thus explained.

Exercise 32. Carbon Dioxide:—

A. Prepare this substance by use of the same apparatus as that for generating hydrogen. Place about 20 grammes of marble dust† in the flask, cover well with water, insert cork and tubes, allow delivery tube to dip to the bottom of a tumbler through a card covering the top, and add about 5 c.c. of hydrochloric acid. Carbon dioxide is evolved, and being heavier than air collects at the bottom of the tumbler. The equation is as follows:–$CaCO_3+2HCl=CaCl_2+H_2O+CO_2$

B. Into the gas collected as above introduce

---

*Oxalic acid or hydric oxalate.

†Calcium carbonate.

a lighted taper. The flame is extinguished, showing that carbon dioxide does not support combustion.

C. Note the weight of the gas (high specific gravity with reference to air) by pouring quickly from one tumbler to another, and testing the second with the taper as above.

D. Shake up lime-water with the gas in one of the tumblers, and note that it becomes turbid from formation of calcium carbonate, according to the equation:—

$$Ca(HO)_2+CO_2=CaCO_3+H_2O$$

E. Blow air exhaled from the lungs through a glass tube into lime water, and notice that the same thing happens, showing that the breath contains carbon dioxide.

F. Remove the end of the delivery tube from the tumbler, and let it bubble through a solution of litmus. A red color is produced, showing that carbon dioxide has an acid reaction, hence was formerly called *carbonic acid gas.*

F. Mix 2 or 3 grammes of powdered copper oxide, CuO, with about a quarter of a gramme of powdered charcoal, heat in an ignition tube provided with perforated cork stopper and bent tube passing into lime water. Carbon dioxide is evolved, shown by the turbidity in the lime water; the copper oxide is *reduced* to metallic copper, shown by action of nitric acid on residue. The equation has already been given.

Exercise 33. Sulphur:—

A. Heat a small piece of sulphur in an ignition tube, and notice the **sublimation** after melting.

The sublimate is flowers of sulphur (sublimed sulphur). Pour the melted sulphur into water and let cool. Plastic sulphur, a brownish, elastic substance is formed.

B. Treat dilute ammonium sulphide with a few drops of any acid.

Precipitated sulphur is formed which is more finely divided than sublimed sulphur and almost white in color. The pharmaceutical preparation is made by boiling calcium hydroxide with sulphur and water, and precipitating with HCl.

C. Boil a mixture of flowers of sulphur and water with some bright silver foil and note that the latter is tarnished, according to the equation

$$2Ag+S=Ag_2S$$

silver sulphide being formed. Compare with so-called "oxidized silver" jewelry.

Exercise 34. Sulphurous oxide:—

A. Prepare by acting on 8 or 10 pieces of sheet copper, 1 to 2 inches long and half an inch wide, in a 500 c.c. flask with 15 to 20 c.c. concentrated sulphuric acid. Arrange as if for making oxygen. Heat. As soon as the gas is given off, regulate evolution by lowering flame. Collect the gas and also pass it into water. The solution is called sulphurous acid, and will *bleach* solution of logwood. (Use a drop or two of weak, alkaline solution of logwood). The equation is as follows:—

$$Cu+H_2SO_4=Cu(HO)_2+SO_2$$

and

$$Cu(HO)_2+H_2SO_4=CuSO_4+2H_2O$$

B. Show by use of taper that the gas does not support combustion, nor is combustible.

C. Show its reducing action by adding solution of permanganate of potassium to a solution of the gas in water, and noticing that the purple color of the permanganate is destroyed as fast as added.

Exercise 35. Sulphuric acid:—

A. On a very large scale sulphuric acid is manufactured by passing into large leaden chambers simultaneously, the vapors of sulphur dioxide, SO_2,(obtained by burning sulphur or pyrites in air) nitric acid, and steam, a supply of atmospheric air also being provided for. The following are equations:—

$$2SO_2+H_2O+2HNO_3=2H_2SO_4+N_2O_3.$$

The nitrogen trioxide, N_2O_3, next takes up sulphur dioxide, SO_2, water, and oxygen forming what is known as nitrosyl-sulphuric acid, as follows:—

$$2SO_2+N_2O_3+2O+H_2O=2(SO_2.OH.NO_2).$$

Steam decomposes this substance as follows:—

$$2(SO_2.OH.NO_2)+H_2O=2H_2SO_4+N_2O_3.$$

The nitrogen trioxide again forms nitrosyl-sulphuric acid, and the process thus goes on indefinitely though it is necessary to add small portions of nitric acid daily, since there is unavoidable loss of small portions of it or of the oxides of nitrogen in the process.

The oxides of nitrogen serve as agents in this process for the transfer of atmospheric oxygen, only a portion of the oxygen necessary being derived from the nitric acid directly.

The manufacture of sulphuric acid may be illustrated in the laboratory by means of an apparatus consisting of a large balloon flask (fig. 47) fitted with a stopper having five openings, and connected by tubes with three small flasks or retorts, from which are supplied steam, sulphur dioxide, and oxides of nitrogen. Air is supplied by a bellows.

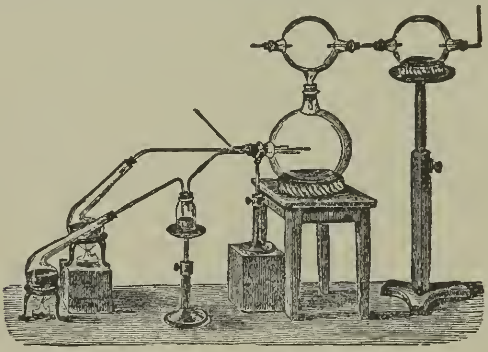

Fig. 47.

B. Add one c.c. of sulphuric acid to 1,000 c.c. of water and note that it still reddens litmus. This experiment shows the strongly acid character of sulphuric acid.

C. Place in a test-tube a few drops of sulphuric acid, and add the same amount of water. Hold the tube at the bottom, and note development of heat. This experiment shows the strong affinity of sulphuric acid for water, and the danger which attends careless mixing of it with water.

D. Go back now to experiment 30.B., and explain the carbonizing of the sugar by the abstraction of water from it on part of the sulphuric acid, bearing in mind that sugar is composed of hydrogen and oxygen, in proportion to form water, plus carbon.

E. Note the heavy, oily character of the acid and thus account in part for the name "oil of vitriol."

F. Note the action of this acid on various metals as tin, copper, iron, zinc. Dilute with water say about one-third and note action. (See page 159)

G. Note the action of sulphuric acid on hemp paper, reducing it to pyroxylin. (see page 159)

H. Put a small, thin piece of bone into a dish and act on it with sulphuric acid, noticing that it is dissolved. (See page 159).

Exercise 36. Hydric sulphide, H_2S:—

On account of the fetid odor of this gas there should be in every laboratory special apparatus for its preparation. The apparatus often employed is that of Kipp (fig. 48), by use of which the disagreeable odor is avoided.

A. Make sulphuretted hydrogen by placing about 20 grammes of ferrous sulphide in small lumps* in a flask (provided with twice perforated cork, thistle tube, and delivery tube, the latter passing into water) covering with water, and

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*The powdered sulphide slowly changes on exposure to air. Hard lumps should be procured.

pouring into the thistle tube sulphuric acid *in small quantities at a time* until brisk effervescence takes place. When the evolution of the gas becomes slow, add a little more acid. More exactly dilute the acid in the start with six times its volume of water and pour upon the dry ferrous sulphide, adding more acid as evolution of gas becomes slow. Too much acid forms a sulphate and retards action.


Fig. 48.

Hydrochloric acid may be used instead of sulphuric, in which case 10 or 12 grammes of ferrous sulphide will need 2 or 3 teaspoonfuls of strong hydrochloric acid to begin with, and more after the disengagement of gas slackens. The equations are as follows:—

$$FeS+H_2SO_4=H_2S+FeSO_4$$

and

$$FeS+(HCl)_2=H_2S+FeCl_2$$

B. Note that when washed in a *little* water, it is dissolved in part in the latter, the solution turning blue litmus paper slightly red.

C. Note that the gas is combustible, burning with a blue flame. Hold a cold plate to the flame and note deposition of sulphur on it.

D. Make a solution of the gas in water, pour into a tube and let stand uncorked a few days.

Note that the solution becomes muddy, deposits sulphur, and loses its odor, according to the equation.

$$2H_2S)+O_2=2H_2O+S_2.$$

E. Pass some of the gas into ammonia water and note the change in color to yellow and the disgusting odor, according to the equation

$$2NH_3+H_2S=(NH_4)_2S$$

F. Drop a drop of the solution of the gas on a piece of metal, and notice the *blackening* that occurs, from formation of metallic sulphides. Thus in case of silver

$$2Ag+H_2S=Ag_2S+H_2$$

G. Expose an amalgam plug to the action of the gas or solution of it, and also to the action of decaying food, such as would be found in the mouth, and notice the blackening.

Exercise 37. Carbon disulphide, CS_2.

A. Note the disgusting odor, and colorless, volatile, highly refractive character of this substance.

B. Note that it is almost insoluble in water, but soluble in alcohol. Note that it dissolves sulphur, iodine, phosphorus,* some of the alkaloids, also volatile and fixed oils. Perform this experiment according to the time at your disposal.

C. Note that carbon disulphide is inflammable.

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*See next experiment.

Exercise 38. Phosphorus*:—

A. Place a *small* fragment of phosphorus carefully on a dish, and allow it to remain thus exposed to the air. It first becomes hot from oxidation, then takes fire. This experiment shows that phosphorus combines with oxygen at ordinary temperatures, hence must be kept under water. Note the garlic-like odor of the fumes and the whitish vapors given off. Take another small piece on a dish into a dark closet, and note that the vapors are luminous.

B. Using very small pieces and working rapidly note that phosphorus is but little soluble in alcohol, but is very soluble in chloroform, and carbon disulphide.

C. Pour the solution of phosphorus in carbon disulphide on filter paper, and let dry. Note that as soon as the carbon disulphide has evaporated, the phosphorus takes fire.

D. Combine phosphorus and iodine directly, by bringing together in a dish a little of each. Note the light and heat accompanying the action.

E. Seal up in an ignition tube a few pieces of phosphorus and heat the tube gradually to 300° C. Notice that it is gradually converted to a *red* powder. Open the tube and notice that this form of phosphorus does not take fire as readily as ordinary phosphorus, and is not as soluble in carbon disulphide.

Exercise 39. Phosphoric acid.

A. Dry a small piece of phosphorus quickly between folds of filter paper, place it in a small, porcelain dish, which is set on a glass plate. Touch the phosphorus with heated

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*Inexperienced persons should not attempt this exercise.

wire. It is at once inflamed. Cover over the dish with a bell jar (fig. 49). Note that the white vapors of phosphoric oxide condense into flakes, and fall on the glass plate. Dissolve the flakes in a few c.c. of water, using a glass rod to collect them. The solution has an acid reaction, and is meta-phosphoric acid*, HPO_3 according to the equation

$$P_4+(O_2)_5=2(P_2O_5)$$

and

$$P_2O_5+H_2O=2HPO_3$$

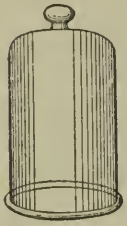

Fig. 49.

B. To a little of the solution of meta-phosphoric acid thus formed add solution of white of egg. The latter is coagulated.

C. Evaporate the solution of meta-phosphoric acid formed in experiment A and notice that it becomes *syrupy*.

D. Take some of the syrupy acid, dilute with a little water, and add solution of white-of-egg. The latter is not coagulated. The liquid has been converted into ortho-phosphoric acid.

These experiments show that, if phosphorus is burned in air, phosphoric oxide is formed which, uniting with water, forms meta-phosphoric acid, which in turn is converted into ortho-phosphoric acid on boiling. Read carefully the sections on phosphoric acid pages 183 to 187.

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*Called glacial phosphoric acid.

Exercise 40. Chlorine:—

A. Prepare chlorine by heating black oxide of manganese with hydrochloric acid (fig. 50). Weigh out about 50 grammes of manganese dioxide. Cover with hydrochloric acid, and shake well. Heat and collect gas in dry bottles by downward displacement. Note the yellowish-green color and extremely penetrating, suffocating odor, producing violent coughing and inflammation, so that it should be made either in a fume chamber or where there is a strong current of air. Several bottles may be filled with the gas.

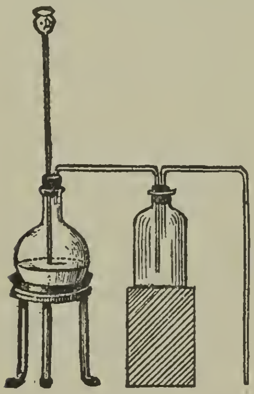

Fig. 50

The equation of its formation is as follows:—

$$MnO_2+4HCl=MnCl_2+2H_2O+Cl_2$$

The method depends on the oxidation of the hydrogen of hydrochloric acid by the oxygen in the manganese dioxide. Fig. 51 shows an apparatus for making chlorine water, ammonia or hydrochloric acid, provision being made for washing the gases by means of Woulff's bottles.

B. Collect the gas in water noticing that it is soluble, forming a *greenish-yellow* liquid. The solution has bleaching properties shown by pouring it on colored flowers.

C. Fill a test-tube, half with chlorine gas and half with hydrogen. Wrap the tube in cloth and bring it close to a naked flame. Combustion rapidly takes place and with explosive violence, the two gases uniting.

$$H_2+Cl_2=2HCl$$

This experiment shows the intense affinity of chlorine for hydrogen. Its affinity for other elements is also great, and may be illustrated by the following experiments.

Experiment C. quantitatively performed requires the apparatus of fig. 54.

D. Powder antimony and drop some of the finely powdered metal into a bottle of chlorine. Note that each particle of metal burns while passing through the gas, forming a white substance.

$$Sb+3Cl=SbCl_3$$

E. Paper moistened with *warm* oil of turpentine dropped into a bottle containing chlorine inflames, owing to the intense affinity of the chlorine for the hydrogen, evolving so much heat that the whole takes fire, dense clouds of smoke being formed.

F. Fill a test-tube full of water, and add one drop of solution of hydric sulphide. Pour in some chlorine water, and notice that the odor of the sulphuretted hydrogen is destroyed.

The equation is

$$H_2S+2Cl=2HCl+S$$

Chlorine acts as a deodorizer and disinfectant by combining directly with hydrogen or by decomposing water with liberation of oxygen, which, when *nascent*, has strong tendency to oxidize other substances.

Exercise 41. Hydrochloric acid:—

A. Prepare the gas by use of an apparatus (fig. 50 or 51) similar to that in which ammonia is generated but provided with a funnel tube. Place in the flask about 20 grammes of sodium chloride, add about 30 c.c. of concentrated sulphuric acid, mix well, heat, and pass into water. Note that the gas is colorless, very irritating to the air passages, and that it reddens litmus. The equation has been already given.

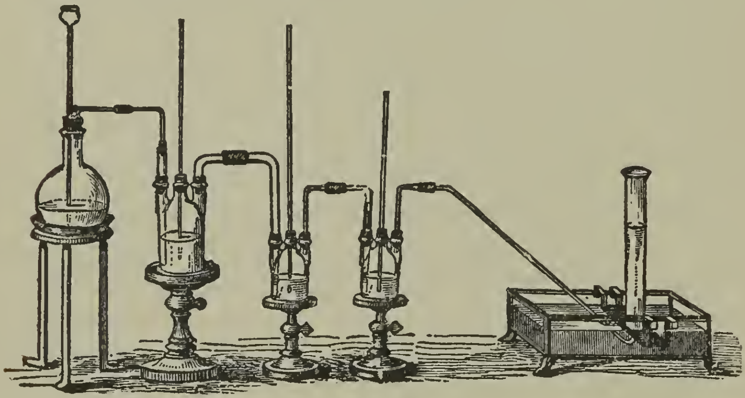

Fig. 51.

B. Note the white clouds which arise from the solution in water, due to the affinity which the acid has for the aqueous vapor in the air, the clouds being formed of minute particles of hydrochloric acid. The solution in water is known to commerce as hydrochloric or muriatic acid, but the acid itself is a gaseous body.

C. Reconsider 29 B. Note equation at end.

Exercise 42. Bromine.

A. Put a very little black oxide of manganese, a small crystal of bromide of sodium, half a c.c. of water, and ten drops of sulphuric acid into a test-tube. Warm gently, and note red fumes of bromine given off, with odor resembling chlorine:—

$$MnO_2+2NaBr+2H_2SO_4=$$
$$MnSO_4+Na_2SO_4+Br_2+2H_2O$$

B. To 10 c.c. of a solution of 100 grammes sodium hydrate in 200 c.c. of water add 1 c.c. of bromine, taking it up out of a bottle by means of a nipple pipette, (fig. 53) graduated to 1 c.c. Note that the bromine unites with the sodium hydrate and that heat is given off. Sodium *hypobromite* is formed:—

$$2NaHO+Br_2=NaBrO+NaBr+H_2O$$


Fig. 53.

Exercise 43. Iodine:—

A. Prepare iodine by mixing 2 grammes of potassium iodide, 4 grammes of black oxide of manganese, and a little sulphuric acid in a flask of 1 or 2 liters capacity. Heat gently in a sand-bath, and note that the vessel will gradually be filled with the heavy violet vapor of iodine, which will condense in the upper parts of the flask in the form of grayish-black scales:—

$$2KI+MnO_2\quad 2_2SO_4=$$
$$K_2SO_4+MnSO_4+2H_2O+I_2.$$

B. Note that iodine is but sparingly soluble in water, but soluble in alcohol, and in an aqueous solution of potassium iodide.

C. Note that iodine is soluble in carbon disulphide, and in chloroform, and that the color of the solutions is *violet*, cause not known.

D. Cut a slice from a potato and drop a drop of tincture of iodine (solution in alcohol) upon it. A blue color is formed, due to the reaction of iodine and the starch in the potato.

E, To a solution of potassium iodide add carbon disulphide and shake well. No change in the color of the disulphide takes place.

Now add a drop of chlorine water, and shake again, and note that the carbon disulphide is colored violet by iodine, set free from potassium iodide by action of the chlorine water:—

$$2KI+Cl_2=2KCl+I_2$$

Exercise 44. Hydrofluoric acid:—

Heat a glass plate slightly and cover it with a thin layer of wax. Let cool, and scratch some figures through the wax, thus exposing the glass. Set the plate in the open air over a dish of lead in which sulphuric acid is mixed with equal weight of powdered fluor spar:—

$$CaF_2+H_2SO_4=2HF+CaSO_4$$

On removing the wax the glass will be found to be etched wherever its surface was exposed to the vapors of the acid. This experiment illustrates the action of hydrofluoric acid on silica in glass converting it into either a fluoride of silicon or into hydrofluosilicic acid.

Exercise 45. Potassium.

Drop a small piece of potassium into a dish containing water. Combustion takes place, and the flame is of a *violet* color, the former due to the setting free of the hydrogen of the water, the latter to the vapor of the potassium. The equation is as follows:—

$$K+H_2O=KOH+H$$

The liquid has now a soapy feel, and turns red litmus blue.

Exercise 46. Sodium.

Repeat experiment 45, using sodium instead of potassium. Note that there is less vigorous action and no flame, unless the metal is in contact with the glass when the characteristic *yellow* flame of sodium may be seen. The liquid becomes alkaline as before.

Exercise 47. Compounds of potassium and sodium.

A. Make a solution of potassium hydroxide in water in strength about 1 in 8, and add to it iodine scales until the brown color no longer disappears. Potassium iodide is formed according to the equation

$$6KHO+I_6=5KI+KIO_3+3H_2O$$

The resulting solution contains potassium iodide mixed with the iodate. The iodide may be separated by evaporation, deflagration with about 10 per cent. powdered charcoal, solution in hot water, and crystallization.

B. Heat excess of sodium sulphate with water at a temperature of about 33°C(91.4° F.). Filter the solution into small bottles and then cork. Remove the corks and shake well, when the salt will suddenly crystallize out.

C. In connection with sodium and potassium it is customary to consider compounds of the radical *ammonium*. For the present it will suffice to note the volatile character of compounds of this radical. Heat any one of them, as ammonium chloride, on foil and notice that it is volatilized at low red heat.

Exercise 48. Magnesium.

A. Take up with the tongs a piece of magnesium four or five inches long, and hold in the Bunsen flame. It burns rapidly, and white magnesium oxide is formed, according to the equation

$$Mg+O_2=MgO_2$$

B. Dissolve magnesium sulphate in hot water, and add a concentrated solution of sodium carbonate. Notice the white precipitate. Keep on adding the solution of sodium carbonate until no more precipitate is formed. Collect the precipitate on a filter, and dry at a low temperature. What is known as magnesia alba or light magnesia is obtained $(MgCO_3)_4.Mg(HO)_2.5H_2O$, according to the equation

$$5MgSO_4+5Na_2CO_3+6H_2O=$$
$$(MgCO_3)_4Mg(HO)_2.5H_2O+5Na_2SO_4+CO_2$$

Heavy magnesia is the name given to magnesium carbonate, when the precipitate obtained as above is separated by evaporation to dryness and washing out of the sodium sulphate.

Experiment 49. Calcium.

A. Make what is known as *lime-water* by adding 1 gramme of calcium oxide to 30 c.c. of distilled water, allowing the lime to slake and shaking occasionally for half an hour. Let settle, decant, and then add 300 c.c. of distilled water, place in a well-stoppered bottle, shake occasionally, and pour off for use.

B. Weigh out about 10 grammes of marble dust (calcium carbonate) in small pieces, place them in a dish, and add hydrochloric acid as long as any effervescence takes place. The equation is as follows:—

$$CaCO_3+2HCl=CaCl_2+CO_2+2H_2O$$

Filter, and obtain in the filtrate solution of calcium chloride. Now mix this solution with one of sodium carbonate, and obtain a white precipitate, according to the equation

$$CaCl_2+Na_2CO_3=2NaCl+CaCO_3$$

Note that the precipitate is a carbonate by collecting on filter, washing, drying, and adding hydrochloric acid, which produces effervescence, and the gas given off, if passed through lime-water, makes it turbid.

The above experiment illustrates the mode of preparation of precipitated calcium carbonate. It also illustrates double decomposition. To form an insoluble substance by double decomposition we must remember that the substances put together should be soluble. One should contain the metal of the insoluble compound required, and the other the acid radical of the same compound. Further, the decomposition must not result in the formation of any substance capable of holding in solution the substance which we wish to form, else no change will occur. In this case we wish to show the formation of calcium carbonate. Now the metal of calcium carbonate is calcium, hence we must take a soluble compound of calcium. (See Rules for Solubility page (70). The acid radical of calcium carbonate is found in all carbonates, and hence we must take a soluble carbonate. This reduces us to a choice of two of a few compounds. Thus we have:—

Soluble salts of Calcium.	Soluble Carbonates.
Calcic Chloride.	Hydric Carbonate.
" Bromide.	Potassic "
" Iodide.	Sodic "
" Hydrate.	Ammonic "

etc.

Any of these combinations may be used except that with hydric carbonate, which will form an acid (hydrochloric), which would hold the calcic carbonate in solution.

Thus $CaCl_2+H_2CO_3=2HCl+CaCO_3$.

But, on the other hand

$$CaCl_2+K_2CO_3=2KCl+CaCO_3,$$

and so on.

Exercise 50. Aluminium.

A. Procure any small article made of aluminium and compare its weight with that of an article of similar size of tin, lead, iron, and platinum.

B. Place a small piece of aluminium in each of two test-tubes. To one add hydrochloric acid and to the other add sodium hydroxide. Hydrogen is evolved in each case, and the chloride of aluminium and aluminate of sodium respectively formed. The equations are

$$Al_2+6HCl=Al_2Cl_6+3H_2$$

and

$$Al+3NaHO=Na_3AlO_3+H_3$$

Exercise 51. Iron:—

A. Test the solubility of iron in hydrochloric acid by acting on a small piece of iron wire with dilute hydrochloric acid. Note that the solution becomes green from formation of ferrous chloride, according to the equation

$$Fe+2HCl=FeCl_2+H_2$$

Now add nitric acid and note that the solution becomes yellow from formation of ferric chloride.

In order to obtain ferric chloride the operation should be conducted as follows:—dissolve by aid of heat 1 gramme of fine iron wire in about 4 c.c. of hydrochloric acid previously diluted with 2 c.c. of water. Filter, warm, mix with 2 c.c. more of hydrochloric acid and add slowly and gradually about O.6c.c. of nitric acid—The equation is

$$6FeCl_2+2HNO_3+6HCl=3Fe_2Cl_6+4H_2O+2NO$$

The solution as above is evaporated in a fume chamber as long as red vapors escape and, if it gives a blue precipitate with potassium ferricyanide, it is to be heated with a few drops more of nitric acid till it does not. Then mix with 4 c.c. of hot water and set aside, when it forms a solid mass.

B. To a solution of ferric chloride in a test-tube add some powdered zinc, and note that the solution becomes nearly colorless owing to the reduction of the ferric chloride to ferrous, according to the equation

$$Fe_2Cl_6+Zn=2FeCl_2+ZnCl_2$$

C. Dissolve iron in dilute sulphuric acid, evaporate, and crystallize, obtaining *green vitriol*, ferrous sulphate, according to the equation

$$Fe+H_2SO_4=FeSO_4+H_2$$

Exercise 52. Manganese:—

A. Heat in a porcelain crucible 2 grammes of the black oxide of manganese with 2 grammes of potassium hydroxide and 1 of potassium chlorate.

The fused mass turns green. Let cool, dissolve in distilled water, filter, and pass carbon dioxide into the filtrate. It turns purple from conversion of the green manganate of potassium into the purple permanganate, according to the equation

$$3MnO_2+6KHO+KClO_3=3K_2MnO_4+KCl+3H_2O$$

and

$$3K_2MnO_4+2CO_2=K_2Mn_2O_8+MnO_2+2K_2CO_3$$

Exercise 53. Chromium:—

Prepare chromic "acid," so-called, chromic trioxide, CrO_3, by dissolving a few grammes of potassium dichromate in water and adding 5 parts *by volume* of strong sulphuric acid to 4 parts *by volume* of the dichromate solution. Let cool. Chromic trioxide separates out in deep red crystals of a purplish hue. The equation is as follows:—

$$K_2Cr_2O_7+H_2SO_4=K_2SO+H_2O+2CrO_3$$

Collect the crystals on asbestos, wash with a little nitric acid, and dry by passing a current of warm, dry air through a tube in which they have been placed.

Chromic trioxide is an energetic oxidizing agent and must be kept away from glycerin, alcohol, sugar, tannin, and organic substances generally with which it forms explosive compounds.

Exercise 54. Zinc.

A. The solubility of zinc in various acids, strong and dilute, has already been noticed.

B. Note the rapid combustion of zinc in the Bunsen flame and the production of zinc oxide

$$Zn+O=ZnO.$$

C. Note the *physical change* in zinc oxide which takes place when the latter is heated, the color becoming *yellow*, but white again on cooling.

D. Experiments illustrating the *reducing power* of zinc have already been performed.

Exercise 55. Lead:—

A. Dissolve a little of the acetate or nitrate of lead in half a pint of water, and suspend in the centre of the solution a piece of zinc. Set aside and note the slow formation of crystalline metallic lead (*lead-tree*) on the zinc while the zinc goes into solution.

The equation is as follows:

$$Pb(NO_3)_2+Zn=Zn(NO_3)_2+Pb.$$

This experiment shows the expulsion of lead from its compounds by zinc, and illustrates *substitution.*

B. Melt together in a crucible 2 parts by weight of lead, 1 of antimony, and 1 of tin. The alloy is called *type-metal.*

C. Melt together 1 part lead and 2 parts tin. The alloy is called *solder.*

Exercise 56. Copper:—

A. Boil 1 part by weight of fine copper wire with 3 of concentrated sulphuric acid. Keep up the boiling till the action of the acid on the metal ceases, and most of the copper is dissolved. A blue solution is obtained. Dilute with the same amount of water as acid used, filter, and set aside in an open dish in a cool place for crystallization. Large, transparent, deep-blue crystals of cupric sulphate separate out.

B. Note that hydrochloric acid and sulphuric acids when diluted do not attack copper appreciably, not even when boiled, but that if copper foil be heated in the air till tarnished by formation of copper oxide, the dilute acids, on application of gentle heat, dissolve the oxide and thus *clean* the metal.

C. Dip a bright steel knife-blade into a solution of cupric sulphate, and note that the steel expels the copper, which is deposited on the blade:—

$$CuSO_4+Fe=FeSO_4+Cu.$$

Exercise 57. Bismuth:—

A. Prepare subnitrate of bismuth by dissolving with aid of heat about 1 gramme of the metal in 2 c.c, of nitric acid diluted with 1 c.c. of water. The equation is

$$Bi+4HNO_3=Bi(NO_3)_3+NO+2H_2O.$$

Evaporate the solution to about half its volume, so as to expel excess of acid, and pour it into large excess of water, say 100 c.c. A white precipitate of bismuth oxynitrate (subnitrate) or bismuthyl nitrate, as it is called, is formed according to the equation

$$Bi(NO_3)_3+2H_2O=BiONO_3.H_2O+2HNO_3.$$

Collect precipitate on filter, wash, dry, and note weight of the powder and its solubility in acids.

Exercise 58. Silver:—

Dissolve a dime in nitric acid, and note the *blue* solution obtained, due to presence of nitrate of copper along with the silver. Dilute with water, and add excess of solution of common salt. Note the precipitation of white silver chloride, according to the equation

$$AgNO_3+NaCl=AgCl+NaNO_3.$$

Filter, and add water to the precipitate, using the wash-bottle. After the precipitate has been well washed, remove the filtrate and replace the flask containing it by a clean, empty flask. Make a small hole in the filter paper, and wash the precipitate through into the flask, by means of the stream from the wash bottle. After it has settled, drain off the supernatant liquid, and let the precipitate dry. When dry, place in a small porcelain crucible and fuse at gentle heat. Let cool, and when cold, place a piece of sheet zinc on it, cover with water, to which a few drops of sulphuric acid have been added, and set aside for a day or two. *Spongy silver* will be formed from the decomposition of the silver chloride by the zinc, according to the equation

$$2AgCl+Zn=ZnCl_2+Ag_2$$

B. Drop a drop of a solution of sulphuretted hydrogen on a piece of silver, and note that it becomes tarnished, from formation of silver sulphide. Wash the metal, heat it to redness, and note that the metal is again bright, the silver sulphide being *reduced* to metallic silver.

C. Note that hydrochloric acid and *dilute* sulphuric acid attack silver but slightly. Add pot assium permanganate to dilute sulphuric acid, drop in a piece of silver, and notice that the metal is now dissolved.

Exercise 59. Mercury.

Into a solution of corrosive sublimate put a piece of bright copper foil, Heat for a few moments. Take out the copper and notice that it is covered with mercury. (This experiment also illustrates *substitution*, according to the equation $HgCl_2+Cu=CuCl_2+Hg$).

B. Dry the copper treated as in *Ex. 52* between folds of filter paper. Put it into the bottom of a narrow glass tube, closed at one end, and heat the copper to redness. The mercury will volatilize, and be deposited in the tube in microscopic globules. Examine with low power of microscope: the globules appear round and opaque by transmitted light, but shine like stars by reflected light.

C. Insert into the tube containing the volatilized mercury a small scale of iodine, and cork the mouth of the tube. Set aside for a day in a warm place. The iodine volatilizes and combines with the mercury, forming a red compound, mercuric iodide.

D. Amalgamate zinc by dipping it into mercury. Heat a piece of the amalgamated zinc in a tube and collect the mercury given off. Drop another piece of the amalgamated zinc into dilute sulphuric acid, and notice that little or no hydrogen is given off.

E. Heat mercuric nitrate in a porcelain dish placed in a current of air until red fumes no longer pass off. A red powder remains which is mercuric oxide:—

$$Hg(NO_3)_2 + \text{heat} = HgO + 2NO_2 + O$$

Continue the heating and the mercuric oxide is decomposed, thus:—

$$HgO = Hg + O$$

F. To illustrate the formation of mercurous nitrate proceed as follows:—heat about one gramme of mercury with 2 c.c. of nitric acid until no further reddish fumes are seen. Mercur*ous* nitrate is formed as follows:—

$$6Hg + 8HNO_3 = 3[(Hg_2(NO_3)_2] + 4H_2O + 2NO$$

If some of the mercury remains undissolved, the solution deposits crystals of the mercurous nitrate on cooling.

G. To prepare mercu*ric* nitrate take some of the solution obtained in F, or some of the crystals, and heat with an equal weight of nitric acid till reddish fumes are no longer given off. The solution should give no precipitate with hydrochloric acid; if it does, heat with more nitric acid until hydrochloric acid ceases to give precipitate. Then evaporate solution and set aside for crystallization. Mercu*ric* nitrate is formed according to the equation:—

$$3[Hg_2(NO_3)_2]+8HNO_3=6[Hg(NO_3(_2]$$
$$+4H_2O+2NO$$

Exercise 60. Arsenic:—

A. Mix any compound of arsenic with charcoal and dry potassium carbonate in a long narrow tube, and notice the deposit of metallic arsenic as a ring in the upper part of the tube.

B. Heat a little arsenous oxide in an ignition tube, and examine the sublimate formed with the microscope. Octahedral crystals will be observed.

C. Note the repellent action of arsenic on water, by causing arsenic in fine powder to float on the surface of water.

D. Heat arsenous oxide on a piece of charcoal with the blow pipe, and note the odor of garlic.

Exercise 61. Antimony:—

A. Boil a little black antimony sulphide in about 10 c.c. of hydrochloric acid until most of it is dissolved.

Antimony chloride is formed and remains in solution, according to the equation

$$Sb_2S_3+6HCl=3H_2S+2SbCl_3.$$

Let settle, pour off the clear solution, evaporate to about half its volume and add to 100 c.c. water. A white precipitate of oxychloride of antimony (powder of Algaroth) takes place, according to the equation

$$12SbCl_3+15H_2O=2SbCl_3.5Sb_2O_3+30HCl$$

Let settle, decant, add water again, let settle again and decant. Now add to the washed oxychloride an aqueous solution of a little sodium carbonate, about 1 gramme. The oxychloride is converted into the oxide according to the equation

$$2SbCl_3.5Sb_2O_3+3Na_2CO_3= \\ 6Sb_2O_3+6NaCl+3CO_2.$$

Collect on a filter after effervescence is over, wash, and treat while still moist with solution of potassium acid tartrate. *Tartar emetic* is formed according to the equation

$$2KHC_4H_4O_6+Sb_2O_3=2KSbO.C_4H_4O_6+H_2O$$

Tartar emetic is an *organic* compound. See page 300.

Exercise 62. Gold:—

A. Test the insolubility of gold in hydrochloric, nitric, and sulphuric acids.

B. Go back to Exercise 16 (Nascent State) and make solution of auric chloride. (Use this time 2 to 4 drops nitric acid, 5 or 10 drops hydrochloric, and a small piece of gold leaf).

C. Make a solution of ferrous chloride, as in Exercise 51, and add about one c.c. of it to the solution made in B. Note the precipitate of metallic gold.

CHAPTER VIII.

CHEMICAL ANALYSIS: THE BLOW-PIPE.

2. Next study **the blow-pipe and its use.**

536. The blow-pipe, as commonly used, is a small, hollow, cylindrical, brass instrument, curved at the narrower end; it serves to conduct a continuous, fine current of air into a gas flame, or into the flame of a candle or lamp. [Various improvements on the ordinary instrument have been devised; for example, the trumpet mouth piece, so called, is used so that the muscles of the lip may not be fatigued. Fletcher's blow-pipe is highly recommended by Essig for work in the dental laboratory; in this instrument the air-tube is coiled into a light spiral, over the point of the jet].

537. If the ordinary blow-pipe is used, the beginner must practice blowing a steady current through the blow-pipe *with the cheeks and not with the lungs.* Distend cheeks, take the blow-pipe between the lips, and practice quiet breathing for some little time. When sufficient readiness in producing the current is thus acquired, bring the blow-pipe to a flame and practice on what are called the **reducing flame** and the **oxidizing flame.** Note: a flame of gas, candle, or lamp, consists of three parts, (a) a dark nucleus in the centre, (b) a luminous cone surrounding

nucleus, and (c) a feebly luminous mantle encircling the whole flame. Fig. 4.

538. **The reducing flame** is produced by keeping the jet of the blow-pipe *just on the border* of a tolerably strong gas flame, and driving a moderate blast across it: the resulting mixture of the air with the gas is only imperfect and there remains, between the inner bluish part of the flame, and the outer barely visible part, a **luminous and reducing zone,** of which the hottest point lies somewhat beyond the apex of the inner cone. This flame serves, under certain circumstances hereafter to be explained, *to take away oxygen* from a metallic compound, *i.e.* to reduce it.

539. **The oxidizing flame** is produced by lowering the gas, pushing the jet of blowpipe a little farther into the flame, and increasing the strength of the current. This serves to effect an intimate mixture of the air and gas, and an inner, pointed, bluish cone, slightly luminous towards the apex, is formed, and surrounded by a thin, pointed, light-bluish, barely visible mantle. The hottest part of the flame is at the apex of the inner cone. Difficultly fusible bodies are exposed to this part to effect their fusion; but bodies to be oxidized are held a little beyond the apex, that there may be no want of air for their combustion. For an oxidizing flame, a small spirit lamp will in most cases be sufficient. Fig. 5.

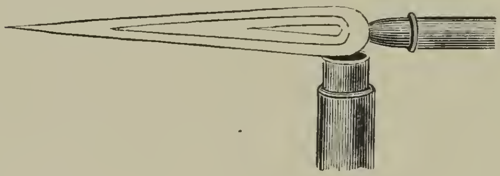

FIG. 5.

FIG. 4.

540. **Charcoal** is used for *reducing* processes: the substances to be operated on are put into small cavities in it, scooped out with a penknife, and the reducing flame of the blowpipe is directed upon them. The fusibility of bodies is also ascertained by use of charcoal as a support. *Incrustations* are often formed on the charcoal, composed of an oxide formed after reduction, when the metallic fumes pass through the outer flame, and become *re-oxidized*. Many incrustations have characteristic colors, leading to the detection of metals.

541. **Platinum wire** and sometimes **platinum foil** are used for *oxidizing* processes, and also when fusing substances with fluxes, in order to obtain what is called a **bead**, etc., etc. The wire is cut into convenient lengths, say 8 centimetres (a little over 3 inches) and twisted at both ends into a small loop. When required for use, the loop is moistened with a drop of water, then dipped into the powdered flux—if any is to be used, and the portion adhering fused in the flame of a gas or spirit lamp. When the bead produced, which sticks to the loop, is cold it is moistened again, and a small portion of the substance to be examined is put on, and made to adhere to it, by the action of gentle heat. The loop is then exposed to whatever flame is desired.

[Many kinds of supports have been devised, but when a small quantity of gold or silver is to be melted in the dental laboratory, the operation is usually performed on a support made of charcoal. Essig recommends that a good, solid, cylindrical piece of thoroughly charred pine coal be cut in halves vertically, by means of a saw. On the end of one half, a depression is cut for the reception of the metal to be melted, and on the flat side of the other half, extending to the end, the ingot mould is carved. The two halves are tied together with wire].

542. The simplest **self-acting blowpipe** is really the Bunsen gas-lamp, provided with a chimney. The flame is non-luminous, and burns without soot; Bunsen distinguishes six parts to the flame: the *base* near where the gas escapes from the burner, the *fusing zone* about one-third of the height of the flame from the bottom, and equidistant from the outside and inside, *the lower oxidizing flame* on the outer border of the fusing zone, *the upper oxidizing flame*, which is the non-luminous tip of the flame, *the lower reducing zone* in the inner border of the fusing zone, *the upper reducing flame* in the luminous tip of the dark inner cone. Many substances give characteristic tints to a colorless flame like the Bunsen. For instance, salts of sodium impart to flame a yellow tint, potassium a violet, lithium a carmine, etc., etc.

3. Having become familiar with the use of the blowpipe, the structure of flame, etc., etc., take a portion of the substance to be examined, place it with an equal weight of sodium carbonate in a little cavity in the charcoal, and expose for some minutes to the *inner* or *reducing* flame of the blow-pipe.

543. The following table* will serve to aid in the interpretation of results:

Cu.	Au.	Ag.
A red bead, somewhat difficult to fuse. No incrustation.	A yellow bead, easily malleable. No incrustation.	A white, malleable bead. No incrustation.

Pb.	Sn.	Sb.
Grayish-white globule, with yellow incrustation. Very soft.	White globules, not so readily reduced as Pb; malleable. Incrustation yellowish when hot, white when cold.	Gray, brittle globules which readily oxidize when hot. White incrustation.

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*Oldberg and Long.

544. **Short method for blow-pipe analysis.** I. Heat on charcoal equal weights of the substance to be examined and sodium carbonate. Use inner or reducing blow-pipe flame. Notice *odor, metallic globule, incrustation.* [If none, go on with II]. If a result is apparent, consult the following table:

Metallic globules.	Incrustation.	Probable metal.	Remarks.
Very brittle.	White.	Antimony.	Metal volatilizes.
None.	White.	Arsenic.	Garlic fumes.
Brittle.	Yellow.	Bismuth.	Metal easily fused.
Red, malleable.	Little or none.	Copper.	Difficult to fuse.
Soft, malleable.	Yellow.	Lead.	Marks paper.
Malleable.	Little or none.	Silver.	Not oxidizable.
Malleable.	Little or none.	Tin.	Easily oxidized and easily fused.
None.	Yellow when hot, white when cold.	Zinc.	Infusible, mass greenish-white.

Antimony gives off white fumes, and covers charcoal with incrustation. If **arsenic** is suspected, proceed as in V. If **bismuth** is apparently the metal, confirm as follows: heat a portion of the original substance on charcoal with a mixture of equal parts sulphur and potassium iodide: *bright red incrustation* on the cooler part indicates *bismuth.*

Copper may first be seen in the form of a reddish-brown substance, after heating in the inner flame. Now heat in the point of the blue inner flame, and a metallic globule of tough copper is obtained. If the substance is **brass,**

a yellow incrustation of oxide of zinc will be seen when the substance is hot, becoming white on cooling.

Lead may readily be recognized by its metallic globule of considerable size; the globule is soft, and may readily be flattened with a knife or cut. If the lead contain *silver*, the latter is detected by the use of bone-ash. Fill a bowl-shaped cavity in the charcoal with finely powdered bone-ash, pressed down well so as to fill the cavity with a compact mass, smooth, and slightly hollowed on the surface. In this bone-ash place a small piece of the lead, hold the charcoal horizontally, and direct the extreme point of the *outer* (oxidizing) flame upon the metal. The bone-ash absorbs the lead oxide formed, leaving a metallic globule of silver; the latter may be covered with a thin film of oxide, showing rainbow tints. When the colors cease, and the globule no longer diminishes in size, it is pure silver. The process is hindered by presence of tin.

Silver is easily reduced, but not readily fused to a globule. Sharp heat is required to accomplish the latter. When the globule is once formed, it is easily distinguished from all other metals by the fact that it retains a bright metallic surface, when fused at the point of the outer (oxidizing) flame, and shows a characteristic white color.

If **tin** be suspected, take a fresh quantity of the original substance and heat with potassium cyanide instead of sodium carbonate. A very liquid slag is obtained, in which a large globule of tin may be formed without difficulty.

Zinc is so readily volatilized, i. e., converted into vapor, by heat that no metallic globule is formed, but merely a yellow incrustation. Moisten the latter with a dilute solution of cobalt nitrate, heat strongly, and a *green* compound (of zinc and cobalt) is formed.

11. If nothing be found by proceeding as

in I, take a very little of the substance, reduce to powder, heat on borax bead, in a loop of platinum wire, in the outer (oxidizing) flame. Note the color when hot, let cool, and observe the color. Now expose to inner flame, noting color when hot and when cold, as before. Then consult the following table:

Metals.	Outer Flame.	Inner Flame.
Chromium.	Yellowish green.	Emerald green.
Cobalt.	Blue.	Blue.
Copper.	Blue.	Brown or colorless.
Iron.	Brownisn yellow.	Bottle green.
Manganese.	Purple or pink.	Colorless.
Nickel.	Brownish yellow.	Muddy gray.

III. If nothing distinct has been noted in procedure as by II, moisten a clean platinum wire with HCl, take a very little of the powdered substance on it, expose to inner blow-pipe flame. Observe any distinct color which may be imparted to outer flame. Consult the following table:

Metal.	Color imparted to outer flame.
Barium.	Green.
Calcium,	Red.
Copper.	Bluish-green.
Potassium.	Violet-blue.
Sodium.	Yellow.
Strontium.	Carmine.

IV. If no distinct color, other than yellow, be observed in III, proceed now as follows: heat a little of the powdered substance on charcoal at the point of the inner blow-pipe flame, until it leaves an infusible residue. Moisten this residue with a drop or two of cobalt nitrate. Heat strongly in point of inner flame. Consult the following table:

Metal.	Appearance.
Aluminium.	Blue mass.
Zinc.	Green mass.
Magnesium.	Pink mass.

V. Finally, if no color has been obtained by proceeding as in IV, mix a little of the powdered substance with dried sodium carbonate and a little charcoal, pour into a small tube closed at one end and heat. Consult the following table:

Metal.	Result.
Mercury.	Minute, gray globules, condensed on cooler part of the tube.
Arsenic.	Shiny, black sublimate.
Ammonium compounds.	Odor of ammonia given off. (Bloxam).

CHAPTER IX.

CHEMICAL ANALYSIS: REACTIONS OF THE METALS.

A. Compounds of Silver.

545. Dissolve 5 grammes of silver nitrate in 100 c.c. of distilled water in a beaker. When all is dissolved, pour the clear solution into an amber-colored bottle, cork, and label.

Of the solution thus made pour 5 c.c. into two different, *clean*, *dry* test-tubes, and add to each tube solutions of the following reagents in order:—

1. To the first add pure hydrochloric acid, plentifully, say 5 c.c., or solution of any soluble chloride, as common salt. Shake well, and set aside. A heavy, curdy, white precipitate is formed, silver (argentic) chloride*.

$$AgNO_3+HCl=AgCl+HNO_3.$$

Let settle, decant, pour precipitate in equal parts into four clean test-tubes, add (plentifully) nitric acid to one, ammonia-water to another, solution of potassium cyanide to the third, and expose the fourth to the sunlight. Shake the first three tubes well, and observe what happens

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*The instructor should propound problems in chemical arithmetic based on the equations given. The student should be required to explain the equations.

as follows: the first precipitate is undissolved, the second and third are dissolved; the fourth turns violet after a time.

These experiments show that a soluble salt of silver, as the nitrate, when dissolved in water gives a white curdy precipitate with hydrochloric acid, insoluble in nitric acid, soluble in ammonium hydroxide, and solution of potassium cyanide, and turned violet by the sunlight.

2. To the second tube containing solution of silver nitrate add either solution of hydrogen (hydric) sulphide, H_2S, (sulphuretted hydrogen, sulphydric acid) or ammonium sulphide (sulphydrate): a black precipitate, silver (argentic) sulphide is formed:—

$$2AgNO_3+H_2S=2HNO_3+Ag_2S.$$

B. Compounds of Lead:—

Dissolve 5 grammes of lead nitrate in 100 c.c. of water,* pour the solution in equal parts into two test-tubes, 5 c.c. in each, and test as follows:

1. To the first test-tube add plenty of pure hydrochloric acid, or solution of soluble chloride: a white precipitate is formed, lead chloride, $PbCl_2$ as follows:—

$$Pb(NO_3)_2+2HCl=2HNO_3+PbCl_2.$$

The precipitate is not affected by light. Pour the precipitate in equal parts into three clean test-tubes: boil one and it dissolves. Pour a little of the contents of the second into a large beaker full of water, and it is dissolved. To the third add ammonia-water: it is not dissolved. In other words the precipitate is not entirely insoluble, hence is not formed in dilute solutions.

2. To the second test-tube, with or without hydrochloric acid, add solution of hydric sulphide or (without

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*Save any not used, for future work.

HCl) ammonium sulphide; if strong solution of the above is added plentifully, a black precipitate of lead sulphide, PbS is formed:—

$$Pb(NO_3)_2+H_2S=2HNO_3+PbS)$$

(If the lead solution contains much hydrochloric acid, a *red* precipitate is formed, $PbCl_2+3PbS$, converted into PbS on further addition of H_2S).

Warm the tube containing the black precipitate, let settle, decant, and treat the precipitate, divided into two equal parts, with hot, strong nitric acid, and hot hydrochloric acid. The nitric acid decomposes the precipitate forming nitrate or sulphate of lead, or both, according to strength of acid used. Thus

$$3PbS+8HNO_3=3Pb(NO_3)_2+4H_2O+2NO+3S$$

if the acid is dilute; or

$$3PbS+8HNO_3=3PbSO_4+8NO$$

if the acid is fully concentrated. The precipitate is not affected by hydrochloric acid.

The above tests are sufficient to recognize even small quantities of lead; in the case of very dilute solutions a current of washed sulphuretted hydrogen gas is passed into the acidulated solution to be tested. Lead in minute quantities in drinking water is thus detected by a brownish precipitate, which settles in the course of a day or so.

C. Mercurous Compounds.

Dissolve 5 grammes of mercurous nitrate crystals in 45 c.c. of water, to which 5 c.c. of nitric acid have been added. Pour the solution thus made in equal parts into two test-tubes, 5 c.c. in each, and test as follows:—

1. To the first test-tube add a drop or two of pure

hydrochloric acid or solution of soluble chloride; shake the tube, and a white precipitate mercurous chloride, is formed:

$$Hg_2(NO_3)_2+2HCl=2HNO_3+Hg_2Cl_2.$$

Add water till the tube is half full, and then further add ammonia water and mix well: the precipitate blackens.

The white precipitate formed with hydrochloric acid is calomel. Addition of ammonia water converts it into mercurous-ammonium chloride, NH_2Hg_2Cl.

2. To the second test-tube add solution of hydric sulphide or ammonium sulphide: a black precipitate is formed which is mercuric sulphide and mercury, HgS,Hg, thus:—

$$Hg_2(NO_3)_2+H_2S=2HNO_3+HgS+Hg$$

Let the precipitate settle, decant, treat precipitate with warm, dilute nitric acid, and it is not dissolved. Treat another portion of the precipitate with ammonia water and ammonium sulphide, and it is not dissolved.

D. Mercuric Compounds:—

546. Dissolve 2 grammes of mercuric chloride, (corrosive sublimate) in 100 c.c. of water. Pour the solution in equal parts into eight test-tubes, 5 c.c. in each, and test as follows:

1. To the first tube add plenty of pure hydrochloric acid: no precipitate is formed.

2. To the second tube add hydrochloric acid as above, and also solution of sulphuretted hydrogen (or ammonium sulphide without hydrochloric acid). A mottled precipitate is formed which may be white or gray at first, then yellow or orange, and finally black, when sufficient strong solution of sulphuretted hydrogen is added. The change in colors is best seen by adding

little of the reagent at a time, and shaking. The whitish precipitate is a combination of the sulphide and the undecomposed chloride, $HgCl_2+2HgS$; the final black precipitate is mercuric sulphide, HgS, thus:—

$$HgCl_2+H_2S=HgS+2HCl$$

Let the precipitate settle, decant, and treat residue with warm, dilute HNO_3, and it is not dissolved.

3. To the third test-tube add cautiously a drop or two of solution of potassium iodide:—a yellow precipitate, mercuric iodide, HgI_2, quickly turning scarlet-red, is formed. Shake the tube: the precipitate disappears,

$$HgCl_2+2KI=HgI_2+2KCl.$$

4. To the fourth tube add plenty of solution of sodium or potassium hydroxide:—a yellow precipitate of mercuric oxide is formed:—

$$HgCl_2+2KHO=HgO+2KCl+H_2O.$$

5. Add the contents of the fifth tube to ammonia-water, taking care that the mixture, after stirring well, still smells of ammonia; a white precipitate is formed, mercuric-ammonium chloride, NH_2HgCl, that is, ammonium chloride, NH_4Cl, in one molecule of which two univalent atoms of hydrogen are substituted by one bivalent atom of mercury:—

$$HgCl_2+2NH_4HO=NH_2HgCl+NH_4Cl+2H_2O$$

6. To the sixth test-tube add solution of potassium chromate:—a yellowish-red precipitate, mercuric chromate is formed.

7. To the seventh tube add solution of sodium or potassium carbonate:—a brownish-red precipitate of basic mercuric carbonate, $HgCO_3.3HgO$, is formed.

8. Into the eighth tube dip a piece of copper wire, and it becomes white from deposition of mercury. This reaction is the same for mercur*ous* compounds also.

Furthermore, heat dry mercuric chloride on platinum foil and notice that it is volatilized. If the experiment be performed in a test-tube with charcoal and sodium carbonate, a mirror of sublimed mercury will be formed on the sides of the tube.

E. Compounds of Copper:—

Make a solution of 5 grammes of cupric sulphate in 100 c.c. of water, rubbing up in the mortar to hasten solution. The solution is blue, and turns blue litmus red. Pour 5 c.c. of this solution into each of seven test-tubes, and test as follows:—

1. To the first tube add *pure* hydrochloric acid plentifully. No precipitate is formed.

2. To the second tube add hydrochloric acid as above and strong solution of sulphuretted hydrogen plentifully (or a few drops of ammonium sulphide to the solution without hydrochloric acid): a brownish-black precipitate, cupric sulphide, CuS,* is formed:

$$CuSO_4+H_2S=H_2SO_4+CuS.$$

Warm the tube, let settle, decant, pour the precipitate in equal parts into two test-tubes, add a little nitric acid to one, hydrochloric to the other, and boil both. The cupric sulphide dissolves in nitric but not in hydrochloric acid. In the nitric acid solution may be seen a scum of *grayish sulphur.*

3. To the third test-tube add sodium or potassium hydroxide: a blue precipitate is formed, cupric hydroxide, $Cu(HO)_2$; boil, and the hydrate is decomposed, becoming black anhydrous oxide, CuO.

4. To the fourth test-tube add a few drops of ammonia-water without shaking:—a blue precipitate is formed,

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*Insoluble in ammonium sulphide.

cupric hydroxide, $Cu(HO)_2$; add ammonia-water plentifully, and the precipitate is dissolved, forming an azure-blue solution, containing an ammonio-copper compound.

5, Pour out the solution in the fifth tube, and without cleaning, draining, or letting dry, fill with water, and add a drop of ammonia-water. Shake well, and a faint blue color is seen, showing the delicacy of the test. The few drops of copper solution, adhering to the inside of the tube, are sufficient, even when largely diluted, to react with a single drop of ammonia-water.

6. Perform the same test as in 5 and in the same way using, however, solution of potassium ferrocyanide, instead of ammonia; a reddish-brown precipitate, cupric ferrocyanide, $Cu_2Fe(CN)_6$ is formed.

7. Into the seventh tube dip the point of a pen-knife, after adding a drop of hydrochloric acid. The knife becomes coated with copper:—

$$CuSO_4+Fe \quad FeSO_4+Cu$$

F. Compounds of Bismuth:—

Dissolve about 7 grammes of crystallized nitrate of bismuth, $Bi(NO_3)_3$ in 15 c.c. of strong nitric acid, and dilute with water to make 100 c.c. Pour 5 c.c. into each of three *dry* test-tubes, and test as follows:—

1. To the first tube add 10 drops of hydrochloric acid, or 10 drops of strong solution of sodium chloride, and no precipitate appears. The solution should be clear before the acid is added.

2. To the second tube add directly strong solution of sulphuretted hydrogen or ammonium sulphide:—a dark-brown precipitate, bismuth sulphide, Bi_2S_3, is formed:—

$$2Bi(NO_3)_3+3H_2S=Bi_2S_3+6HNO_3$$

Let precipitate settle, decant, add ammonia-water and ammonium sulphide, and precipitate is not dissolved. (Differentiation from arsenic and antimony).

3. Take up water in a nipple pipette and let it trickle down the side into the contents of the third tube: a white precipitate, bismuthyl oxynitrate, $BiONO_3.H_2O$, is formed:

$$5(Bi3NO_3)+8H_2O=$$
$$4(BiONO_3.H_2O)+Bi3NO_3;8HNO_3.$$

The liquid contains bismuth nitrate in acid.

547. G. Arsenous Compounds:—

I. Boil 1 gramme of white arsenic, As_2O_3, in a solution of 2 grammes of pure hydrochloric acid in 25 c.c. of distilled water, until the arsenic is dissolved. Filter, and pass enough distilled water through the filter to make 100 grammes by weight. N. B. For analytical purposes 100 c.c. will suffice. The solution made by weight as above is the *Liquor Acidi Arsenosi* of the U. S. P.

Pour 5 c.c. of the solution into each of three test-tubes and test as follows:—

1. To the first test-tube add pure hydrochloric acid plentifully. No precipitate is formed.

2. To the second add hydrochloric acid, as above, and strong solution of sulphuretted hydrogen plentifully. A bright, lemon-yellow precipitate is formed, arsenous sulphide, or trisulphide, As_2S_3:—

$$As_2O_3+3H_2S=3H_2O+As_2S_3$$

If it is true that, when white arsenic is dissolved in water, arsenous acid is formed, we have

$$As_2O_3+3H_2O=2H_3AsO_3$$

in which case, when sulphuretted hydrogen is added, we have

$$2H_3AsO_3+3H_2S=6H_2O+As_2S_3$$

Let the precipitate settle, decant, divide into two parts, and treat with ammonium sulphide, and strong hydrochloric acid respectively. It dissolves in the first but not in the second.

3. To the third test-tube add ammonium sulphide: result same as in 2.

Note: it is absolutely necessary, in order that tests 2 and 3 may succeed, that the solution of arsenic to be tested contain free acid, as hydrochloric.

II. Next warma little white arsenic in a test-tube full of water for about 15 minutes. Pour half the solution obtained into another test-tube and proceed as follows:

To one of these last two tubes add a few drops of a solution of argentic nitrate: further add a few drops of diluted ammonia water, one drop at a time until the solution is neutral; a yellow precipitate is formed, silver arsenite, Ag_3AsO_3; add more ammonia-water, and the precipitate is dissolved.

To the other tube containing the solution of arsenic in water, add a few drops of a solution of cupric sulphate, and then dilute ammonia-water as before: a green precipitate, cupric arsenite,* $CuHAsO_3$, is formed. Add more ammonia water, and the precipitate is dissolved with formation of a blue color.

N. B. It is absolutely necessary for the success of these last two tests, that the solution containing arsenic be of neutral reaction, as the precipitates are soluble in both acids and alkalies.

H. Arsenic Compounds. (Arsenates).

Dissolve 5 grammes of sodium arsenate,

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*Known as Scheele's green.

$Na_2H As O_4$, in 100 c.c. of water. Pour 5 c.c. of the solution into each one of six test-tubes and test as follows:—

1. To the first tube add hydrochloric acid plentifully. No precipitate is formed.

2. To the second tube add hydrochloric acid, as above, and strong solution of sulphuretted hydrogen plentifully:—a yellow precipitate is slowly formed, which is a mixture of arsenic trisulphide and sulphur, according to the equation

$$2Na_2HAs O_4+5H_2S=6H_2O+2Na_2O+ As_2S_3+S_2.$$

3. To the third tube add hydrochloric acid and sulphuretted hydrogen as in 2, but this time boil the mixture:—a yellow precipitate, arsenic pentasulphide, As_2S_5, is formed, according to the equation

$$2Na_2H As O_4+5H_2S=6H_2O+2Na_2O+ As_2S_5.$$

Let the precipitate settle, decant, and treat the precipitate with ammonium sulphide, and it is dissolved.

4. Take the reaction of the liquid in the 4th tube:—it is alkaline. Add cupric sulphate solution, drop by drop; at first a white precipitate is formed which becomes slightly greenish as more of the copper salt is added. Add the cupric sulphate solution plentifully, and the precipitate is dissolved.

5. Take the reaction of the liquid in the 5th tube:—it is alkaline, add solution of silver nitrate, and a reddish-brown precipitate of silver arsenate, Ag_3AsO_4 is formed.

6. To the sixth tube add solution of ammonium molybdate, and heat: a yellow precipitate, ammonium arseno-molybdate, $(NH_4)_3AsO_4.10MoO_3$, is formed.

I. Special tests for both arsenous and arsenic compounds:—

HEAT TESTS.

1. Place a little white arsenic at the bottom of a narrow test-tube, cover it with half an inch or so of dry charcoal,

and hold the tube nearly horizontally in the flame, covering the mouth of the tube loosely with the finger. Let the bottom of the tube at first project slightly beyond the flame, so that the charcoal may become nearly red-hot; then heat the bottom of the tube. The arsenic will sublime, and being deoxidized by the charcoal with formation of carbonic oxide, metallic arsenic, As, will be deposited in the cooler part of the tube, as a dark, mirror-like metallic incrustation. An odor of garlic is noticed during the process.

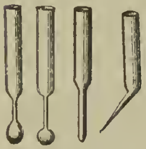
Fig. 55.

2. If the above test be performed by mixing a very little of any dry arsenical compound with a well made and perfectly dry mixture of charcoal and potassium carbonate in the bulb of what is known as a Berzelius tube, (fig. 55) the arsenic condenses as a metallic ring in the constricted part of the tube.

Reinsch's Test.

Make the solution of arsenous oxide described in G. I. and into it dip a bright piece of thin copper, about a quarter of an inch wide and half an inch long. Heat the solution and the copper becomes coated with a dark, steel-gray deposit of metallic arsenic. Pour off the supernatant liquid, wash, dry by passing through flame, place in the Berzelius tube, and sublime, as in the last reaction.

The Marsh Test For Arsenic.

Generate hydrogen in the customary manner, but this time in a special apparatus (fig. 56), consisting of a flask provided as usual with a funnel-tube and delivery-tube, bent at right angles, the latter being connected with a wider tube filled with plugs of asbestos; this drying tube is further connected with a piece of hard glass tube, about one foot long and ¼ inch in diameter, drawn out to ⅛ inch in diameter at intervals of about 3 inches. After the hydrogen has been generated, by the action of sulphuric acid on zinc, apply a flame to one of the wide parts of the glass tube, and heat for upwards of half an hour. If the materials used are free from arsenic no trace of a metallic mirror will be found on the constricted parts just beyond the heated point.

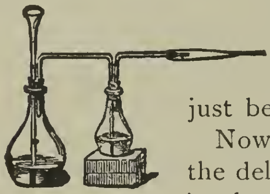

Fig. 56.

Now ignite the hydrogen escaping from the delivery tube, and note that the flame is almost colorless. Next pour down the thistle tube any solution containing arsenic, except a sulphide, and the flame becomes a dull, livid blue, and emits a garlic odor, while above it there is seen a white cloud*. Hold a piece of cold porcelain to the flame, and it becomes coated with a brown stain of metallic arsenic, the arseniuretted (arsenetted) hydrogen, H_3 As, formed in the flask, being decomposed by the heat of the flame, and the arsenic, in the centre of the flame, being in the metallic state, since all the oxygen there is taken up by the hydrogen.

$$As_2O_3+12H=2H_3As+3H_2O.$$

Treat the stain on porcelain with solution of bleaching powder, (calcium hypochlorite) and it readily dissolves. (Solutions of compounds of antimony give the same stain, but it is insoluble in hypochlorite solutions).

Further, hold a cold test-tube over the flame and its walls will be covered with a white deposit of crystals. Examine them under the microscope, and they will be found to be octahedral.

Lastly examine the glass tube heated, as described, at one of its wide parts, and a blue-black metallic mirror is seen at the constriction beyond.

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*Due to formation of arsenous oxide: $2H_3As+6O=As_2H_3+3H_2O$.

FLEITMANN'S TEST.

Generate hydrogen by heating in the test-tube to near the boiling-point, a strong solution of caustic soda or potash, and some pieces of zinc, according to the equation

$$Zn+2NaHO=H_2+Na_2ZnO_2*.$$

Now add a drop of arsenical solution, and spread over the mouth of the tube a cap of filter-paper, moistened with one drop of solution of silver nitrate. Again heat the tube, taking care that the liquid itself shall not spurt up on the cap. A plug of cotton wool may even be placed in the mouth of the test-tube to prevent this spurting. The arsenic is reduced to the metallic state, As, and arseniuretted hydrogen is formed, which, passing up through the cap, reacts on the silver nitrate, giving rise to the formation of a purplish-black spot (silver).

$$H_3As+3H_2O+6AgNO_3=H_3As\ O_3+6HNO_3+3Ag_2.$$

This test is of value in distinguishing arsenic from antimony.

Arsenic as an impurity in acids or in tartar emetic and other compounds may be recognized by

BETTENDORFF'S TEST.

To a solution of stannous chloride, in a liquid saturated with hydrochloric acid gas, add a very small quantity of any arsenical solution. Heat, and metallic arsenic, As, separates, giving the mixture a yellowish, and then brownish hue, or a grayish-brown turbidity or precipitate.

J. Compounds of Antimony.

Add 5 grammes of antimonous chloride to 100 c.c. of water and stir well. The solution is turbid from separation of white oxychloride of anit-

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*Sodium zincate.

mony, SbOCl, powder of Algaroth. Pour 5 c.c. of the turbid mixture into each of seven test-tubes and test as follows:

1. To the first tube add hydrochloric acid plentifully. No precipitate is formed but the liquid becomes clear.

2. To the second tube add HCl as before and also strong solution of sulphuretted hydrogen plentifully: an orange-red precipitate of amorphous antimony sulphide, Sb_2S_3, is formed. Let settle, decant, treat with ammonia water and with ammonium sulphide. The precipitate is dissolved. Add hydrochloric acid to the solution and re-precipitation takes place.

3. To the third tube add ammonium sulphide. The same orange-yellow precipitate is formed.

4. To the fourth tube add enough hydrochloric acid to dissolve the precipitate of oxychloride and to make a clear liquid: then add strong solution of sodium hydroxide carefully until the acid is neutralized, and again a white precipitate is formed, metantimonous acid, $HSbO_2$. Add more sodium hydroxide solution and the precipitate is dissolved.

5. Repeat the above, using ammonia water and notice that the precipitate is not dissolved in excess of ammonia,

6. Into the sixth tube drop a piece of copper foil, and boil. A black deposit of antimony is formed on the copper. Remove the copper, and heat in the Berzelius tube: the antimony is volatilized, and deposits as a white crust, Sb_2O_3, on the glass.

7. Pour a few drops of the contents of the seventh tube into the Marsh apparatus, and test as for arsenic: the stain is insoluble in hypochlorite.

Now make a solution of four grammes of tartar emetic, $2KSbO.C_4H_4O_6$, in 100 c.c. of water. Pour into seven tubes and test as above.

1. Note:—To the first tube add *a few drops only* of hydrochloric acid: a white precipitate, antimony oxychloride, is formed; add 5 c.c. of acid, shake, and the precipitate is dissolved.

In the fourth and fifth tubes no hydrochloric acid will be necessary.

K. Stannous Compounds.

Add 5 grammes of stannous chloride to 100 c.c. of water. A turbid mixture results. Pour 5 c.c. of it into each of four test-tubes and proceed as follows:—

1. To the first tube add hydrochloric acid plentifully. Some turbidity still remains.

2. To the second tube add strong solution of sulphuretted hydrogen plentifully: a dark-brown precipitate, stannous sulphide, SnS, is formed:—

$$SnCl_2+H_2S=2HCl+SnS.$$

Let precipitate settle, decant, treat with ammonia water and warm (not boiling) ammonium sulphide; the precipitate is dissolved.

3. To the third tube add a few drops of ammonium sulphide:—the same precipitate is formed as in 2.

4. To the fourth tube add strong solution of sodium hydroxide in small quantity; an abundant white precipitate, stannous hydroxide, $Sn(HO)_2$, is formed. Add slight excess of the sodium hydroxide solution, shake, and the precipitate is dissolved leaving, however, a slightly turbid solution as before. Now boil and a flocculent precipitate, SnO, separates. Let stand and it will soon be seen to be of dark color.

In order that this last experiment shall succeed, as above described, use small quantities of sodium hydroxide solution both to precipitate and to dissolve.

L. Stannic Compounds.

Make a solution of 5 grammes of stannic chloride in 100 c.c. of water. Notice that the turbidity seen in K is absent. Pour 5 c.c. of the solution into each of four test-tubes and test as follows:

1. To the first tube add hydrochloric acid plentifully. No precipitate is formed.

2. To the second add solution of sulphuretted hydrogen plentifully:—a yellow precipitate, stannic sulphide, SnS_2, is formed. Let settle, decant, treat precipitate with ammonia-water to neutralize acid, and add ammonium sulphide; it is dissolved.

Dilute the solution in ammonium sulphide with water and add hydrochloric acid. The sulphide is reprecipitated.

3. To the third tube add water, till half full, then a few drops of ammonium sulphide, and the same precipitate as in 2 is formed.

4. To the fourth tube add solution of sodium or potassium hydroxide; a white precipitate is formed, stannic acid, H_2SnO_3. Dissolve the precipitate by adding excess of alkali, *filter, if necessary*, and boil. No reprecipitation takes place. (Differentiation from stannous compounds.)

M. Compounds of Gold:—

Make a solution of 1 gramme of auric chloride, $AuCl_3$, in 20 c.c. of water. Pour 5 c.c. of it into each of four test-tubes and test as follows:—

1. Add hydrochloric acid to the first tube. No precipitate is formed.

2. To the second tube add strong solution of sulphuretted hydrogen plentifully: a brown precipitate, auric sulphide, Au_2S_3, is formed:—

$$2AuCl_3+3H_2S=Au_2S_3+6HCl$$

Let settle, decant, and treat precipitate with yellow ammonium sulphide. It is dissolved.

3. To the third tube add solution of ferrous sulphate, and set aside for a few hours; metallic gold is precipitated as a dark powder. Filter the solution, wash from the filter paper, let settle, decant, boil with hydrochloric acid, let settle again, filter, wash, and dry. Mix with equal weight of borax, and fuse in a furnace. A button of metallic gold is obtained.

Note:—Gold residues of laboratory operations may be worked up in this way, by dissolving the fragments in aqua regia, which is a mixture of 3 parts nitric acid with 4 of hydrochloric, evaporating nearly to dryness, and diluting with water.

Read paragraph 252 for further tests. For the purple of Cassius test see paragraph 258.

4. In the solution in the fourth tube immerse a piece of tin-foil. Purple of Cassius is formed and deposits.

N. Compounds of Platinum:—

Dissolve 1 gramme of pure platinic chloride in 20 c.c. of water. Into each of four test-tubes pour 5 c.c. of the solution and test as follows:—

1. To the first tube add hydrochloric acid. No precipitate is formed.

2. To the second tube add 5 c.c. of a solution of sodium chloride, and a strong solution of sulphuretted hydrogen plentifully. A dark-brown precipitate, platinic sulphide, PtS_2, is formed. Filter, wash, add ammonium sulphide, and the precipitate is dissolved.

3. To the fourth tube add excess of sodium carbonate and sugar. Boil. A black precipitate (metallic platinum) is formed.

4. To the fifth tube add solution of ammonium chlo-

ride: a yellow, granular precipitate, double chloride of ammonium and platinum, $PtCl_4.2NH_4Cl$, is formed. Let settle, decant, collect on a filter, wash, dry, and heat in a small crucible. The precipitate is decomposed, and the metal remains as a finely divided gray powder (spongy platinum):—

$$3(PtCl_4.2NH_4Cl)=Pt_3+2NH_4Cl+16HCl+2N_2$$

548. O. Ferrous Compounds.

Dissolve 5 grammes of ferrous sulphate in 100 c.c. of water. Pour 5 c.c. of this solution into each of five test-tubes and test as follows:—

1. Add hydrochloric acid to the first test-tube: no precipitate is formed.

2. To the second test-tube add a few drops of hydrochloric acid, and strong solution of sulphuretted hydrogen plentifully. No precipitate is formed.

3. To the third test-tube add a few drops of ammonium sulphide. A black precipitate, FeS, is formed:

$$FeSO_4+2NH_4HS=FeS+(NH_4)_2SO_4+H_2S$$

Further add a little hydrochloric acid, and the black precipitate dissolves, with effervescence and separation of sulphur.

4. To the fourth tube add solution of potassium ferrocyanide: a whitish precipitate is formed, soon turning blue, $K_2FeFeCy_6$.

5. To the fifth tube add solution of potassium ferricyanide; a blue precipitate, ferrous ferrocyanide, is formed $Fe_3Fe_2Cy_{12}$.

P. Ferric Chloride.

Dissolve 5 grammes of ferric chloride in 100 c.c. of water. Pour 5 c. c. into each of five test-tubes and test as follows:—

1. To the first tube add hydrochloric acid; no precipitate is formed.

2. To the second tube add a few drops of hydrochloric acid and plenty of strong solution of sulphuretted hydrogen: a turbid liquid results with deposition of sulphur, and reduction of the ferric salt:—

$$Fe_2Cl_6+H_2S=2FeCl_2+2HCl+S$$

3. To the third tube add ammonium sulphide (half a dozen drops): black ferrous sulphide, FeS, is precipitated.

4. To the fourth tube add solution of potassium ferrocyanide. A dark blue precipitate is formed, ferric ferrocyanide, Prussian blue:

$$2Fe_2Cl_6+3(K_4FeCy_6)=12KCl+Fe_43(FeCy_6)$$

5. To the fifth tube add solution of potassium sulphocyanate; a blood-red precipitate is formed, ferric sulphocyanate.

Q. Compounds of Manganese:—

Dissolve 5 grammes of manganese sulphate, $MnSO_4$, in 100 c.c. of water. Pour 5 c.c. of this solution into each of three test-tubes and test as follows:—

1. To the first add hydrochloric acid; no precipitate is formed.

2. To the second add a few drops of hydrochloric acid, and strong solution of sulphuretted hydrogen, plentifully: no precipitate is formed.

3. To the third tube add a few drops of ammonium sulphide: a yellowish-pink, or flesh colored precipitate of hydrous manganese sulphide, $MnS.H_2O$, is formed:—

$$MnSO_4+(NH_4)_2S \quad (NH_4)_2SO_4+MnS$$

Let the precipitate settle, decant, treat the precipitate with acid, and it is dissolved.

R. Compounds of Chromium.

Dissolve 5 grammes of chromic chloride in 100 c.c. of water. Pour 5 c.c. of this solution into each of four test-tubes and test as follows:—

1. To the first tube add hydrochloric acid. No precipitate is formed.

2. To the second tube add a few drops of hydrochloric acid, and plenty of strong solution of sulphuretted hydrogen. No precipitate is formed.

3. To the third tube add ammonium sulphide; a gray-green precipitate is formed, chromic hydrate, $Cr_2(HO)_6$:

$$Cr_2Cl_6+3[(NH_4)_2S]+6H_2O=6NH_4Cl+3H_2S+Cr_2(HO)_6$$

4. To the fourth tube add a few drops of sodium hydroxide solution: the green hydroxide is precipitated, and is soluble with green color in excess of the hydroxide. Boil and there is reprecipitation.

S. Compounds of Zinc:—

Dissolve 5 grammes of zinc sulphate in 100 c.c. of water. Pour 5 c.c. of this solution into each of five test-tubes and test as follows:—

1. To the first tube add hydrochloric acid. No precipitate is formed.

2. To the second tube add hydrochloric acid and solution of sulphuretted hydrogen plentifully; no precipitate is formed.

3. To the third tube add half a dozen drops of ammonium sulphide; a white precipitate is formed, zinc sulphide, ZnS:—

$$ZnSO_4+(NH_4)_2S\quad(NH_4)_2SO_4+ZnS.$$

The sulphide is greenish or dark colored, if the zinc sulphate contains iron or lead as impurities. Let the precipitate settle, decant, and treat precipitate with hydrochloric acid, and it dissolves, a turbid liquid resulting (separation of sulphur).

4. To the fourth test-tube add ammonia-water cautiously, letting it trickle down the side of the tube; a white precipitate is formed, zinc hydrate, Zn2HO. Add the ammonium hydroxide solution freely, and the precipitate is dissolved.

5. To the fifth tube add solution of potassium ferrocyanide; a whitish precipitate, zinc ferrocyanide, Zn_2FeCy_6 is formed.

T. Compounds of Aluminium.

Dissolve 5 grammes of aluminium chloride or sulphate in 100 c.c. of water. Pour 5 c.c. of this solution into each of six test-tubes and test as follows:—

1. To the first tube add hydrochloric acid; no precipitate is formed.

2. To the second tube add a few drops of hydrochloric acid, and plenty of strong solution of sulphuretted hydrogen: no precipitate is formed.

3. To the third tube add ammonium sulphide; a gelatinous, white precipitate is formed, aluminium hydroxide, $Al_2(HO)_6$:

$$Al_2Cl_6+3(NH_4)_2S+6H_2O=Al_2(HO)_6+6NH_4Cl+3H_2S$$

4. To the fourth tube add ammonia-water freely: a white precipitate of the same hydroxide is formed, insoluble in excess of the ammonium hydroxide.

5. To the fifth tube cautiously add solution of sodium hydroxide:—the same precipitate is formed soluble in excess.

6. To the sixth tube add potassium ferrocyanide solution: no precipitate is formed.

U. Compounds of Nickel and Cobalt.

Make solutions of the respective sulphates, 5 grammes in 100 c.c. of water, and apply first three tests for iron, which are similar. Then (4) further add ammonia-water to each, and obtain in case of nickel a blue precipitate, cobalt a green, both soluble in excess. Sodium or potassium hydroxides give the same, but insoluble in excess.

V. Compounds of Barium.

Make a solution of 5 grammes of barium chloride in 100 c.c. of water. Pour 5 c.c. of this solution into each of seven test-tubes and test as follows:-

1. Hydrochloric acid: no precipitate.

2. Hydrochloric acid and sulphuretted hydrogen: no precipitate.

3. Ammonium sulphide: no precipitate.

4. Ammonium hydroxide (ammonia-water) together with solution of ammonium chloride and carbonate: a white precipitate, barium carbonate, $BaCO_3$, is formed.

5. To the fifth tube add yellow potassium chromate, K_2CrO_4: a pale yellow precipitate, barium chromate, $BaCrO_4$ is formed. Pour into two test-tubes, and add acetic acid to one and hydrochloric to the other. The latter only is dissolved.

6. To the sixth tube add sulphuric acid: white barium sulphate, $BaSO_4$, is immediately formed. Let settle, decant, and treat precipitate with boiling nitric acid. It is not dissolved.

7. To the seventh tube add solution of calcium sulphate plentifully: a white precipitate forms *at once*.

W. Compounds of Calcium.

Dissolve 5 grammes of calcium chloride in 100 c.c. of water. Pour 5 c.c. of this solution into each of seven test-tubes and test as follows:—

1. Hydrochloric acid: no precipitate.

2. Hydrochloric acid and sulphuretted hydrogen: no precipitate.

3. Ammonium sulphide: no precipitate.

4. Ammonium hydroxide, chloride, and carbonate: a white precipitate is formed, calcium carbonate, $CaCO_3$:—

$$CaCl_2+(NH_4)_2CO_3=CaCO_3+2(NH_4)Cl$$

5. To the fifth tube add sulphuric acid: no precipitate.

6. To the sixth tube add potassium chromate solution: no precipitate is formed.

7. To the seventh tube add ammonium oxalate solution: white precipitate, calcium oxalate, CaC_2O_4; pour the precipitate into two test-tubes; to one add acetic acid, to the other hydrochloric. The latter only is dissolved.

Show the presence of calcium in teeth by dissolving in hydrochloric acid. Filter, expel acid by evaporation, dissolve residue in water; add excess of ammonia, dissolve precipitate with the smallest quantity possible of acetic acid, and add solution of ammonium oxalate.

X. Compounds of Strontium.

Dissolve 5 grammes of strontium nitrate in 100 c.c. of water. Pour the solution into each of seven test-tubes and test as for barium.

The reactions are the same except that calcium sulphate gives a white precipitate forming slowly.

Y. Compounds of Magnesium.

Make a solution of 5 grammes of magnesium sulphate in 100 c.c. of water. Pour 5 c.c. of this solution into each of five test-tubes and test as follows:—

1. Hydrochloric acid: no precipitate.

2. Hydrochloric acid and sulphuretted hydrogen: no precipitate.

3. Ammonium sulphide: no precipitate.

4. Ammonium chloride, hydrate, and carbonate: no precipitate.

5. To the fifth tube add ammonia-water and solution of sodium hydro-phosphate:—a crystalline precipitate of ammonium-magnesium phosphate, $Mg(NH_4)PO_4+6Aq.$, is produced, insoluble in ammonia-water but soluble in acids, even in acetic acid.

Z. Compounds of Ammonium, Sodium, and Potassium:—

Dissolve 5 grammes of ammonium chloride in 100 c.c. of water, and pour into nine test-tubes. Test as follows:— no precipitate with any of the reagents used up to Z.

6. Into the sixth tube pour a little of solution of sodium hydroxide and boil: odor of ammonia is distinctly recognized.

7. Test with platinic chloride as in case of Potassium, which see.

8. Test with sodium cobaltic nitrite as with Potassium, which see.

9. To the ninth tube add water, till it is nearly full, then a little Nessler's solution (potassio-mercuric iodide) and a reddish-brown precipitate is formed.

10. Finally heat some of the dry compound on platinum foil: it volatilizes at low red heat.

Make a solution of sodium chloride, 5 grammes to 100 c.c. of water. Pour 5 c.c. into each of five test-tubes, and test as follows.

1. No precipitate with hydrochloric acid, sulphuretted

hydrogen, ammonium sulphide, ammonium chloride, hydroxide, and carbonate, or sodium hydro-phosphate.

2. Sodium compounds are white.

3. Heat the dry salt on platinum foil. It is not volatilized below red heat.

4. Dip the looped end of a platinum wire into the solution, made as first directed, and introduce the loop into the lower part of an alcohol-lamp flame, or other colorless flame. An intense, brilliant, luminous, yellow color is imparted to the flame.

Potassium.

Dissolve 5 grammes of potassium nitrate in 100 c.c. of water, pour 5 c.c. of the solution into each of eight test-tubes and test as follows:—

1. No precipitate with the usual group reagents.

2. To 5 c.c. of a potassium chloride or nitrate solution in a test-tube add a few drops of hydrochloric acid, then solution of platinic chloride and alcohol. Stir the mixture with a glass rod: a yellow granular or slightly crystalline, precipitate slowly forms, $PtCl_4(KCl)_2$:

$$2KCl+PtCl_4=PtCl_4(KCl)_2;$$

or

$$2KNO_3+2HCl+PtCl_4=PtCl_4(KCl)_2+2HNO_3$$

3. To 5 c.c. of solution of a compound of potassium add solution of sodium cobaltic nitrite: a yellow precipitate, potassium cobaltic nitrite $(KNO_2)_6.Co_2(NO_2)_6+H_2O$ is formed, in neutral or slightly acid solutions.

4. Make a saturated solution of any potassium compound, take the reaction and neutralize, if necessary. Then add freshly prepared, strong solution of tartaric acid; a white precipitate, potassium acid tartrate, $KHC_4H_4O_6$, is slowly formed. Add alcohol and the precipitate forms more rapidly.

5. Perform the flame test as with sodium, and look at

the flame through a thin vessel filled with indigo solution. A violet color appears.

6. Compounds of potassium are white, except the chromate, dichromate, permanganate, etc., are soluble, and not volatile at low red heat.

CHAPTER X.

APPLICATION OF CHEMISTRY TO DENTISTRY.

549. **Short scheme for qualitative analysis of ordinary metals.**—

I. Add hydrochloric acid: a precipitate may be:

Silver chloride,
Mercurous chloride, } White.
Lead chloride,

Add ammonia abundantly to all three precipitates and shake well: *silver* is dissolved, a *mercurous compound* blackened, *lead* not dissolved nor blackened.

II. If nothing with HCl, add hydric sulphide: a precipitate may be:

Insoluble in ammonium sulphide.		Soluble in ammonium sulphide.
Mercuric sulphide.	Black.	Arsenous sulphide, yellow.
Bismuth sulphide.		Antimonous sulphide, orange.
Cupric sulphide.		Stannous sulphide, brown.
Cadmium sulphide, yellow.		Stannic sulphide, yellow.
		Auric sulphide, brown.
		Platinic sulphide, brown.

A. In order to ascertain whether the precipitate is soluble or not in ammonium sulphide, throw on a filter, wash well, wash off precipitate from filter, by means of wash bottle, into a porcelain dish, let settle, pour off supernatant liquid, then add ammonium sulphide and stir well. If insoluble in ammonium sulphide, the original solution contained either lead, mercury(-ic), bismuth, copper, or cadmium. Cadmium is easily told by its yellow color, a mercuric salt by the change of color, on addition of hydric sulphide (reddish-yellow to black, with a mottled appearance). If neither of these be found, take a fresh amount of the original solution, and add ammonium hydrate: if it is copper, a beautiful blue color is seen at once. If none of the above tests are successful, it is probably bismuth, or a dilute solution of lead. To a fresh amount of the original solution, add potassium chromate: a bright yellow precipitate indicates lead. (*Dilute* solutions of lead may not be precipitated by hydrochloric acid, but yet may yield a slight precipitate of a dark color with hydric sulphide, verified by potassium chromate). If no lead be found, take a fresh amount of the original solution, and add hydric sulphide. A black precipitate, insoluble in dilute hydrochloric acid, indicates *bismuth.*

B. If the precipitate is soluble in ammonium sulphide, the color of the precipitate produced by addition of hydric sulphide will serve to distinguish *antimony*, which yields an orange precipitate in an acid solution. Arsenic and tin (stannic) yield yellow precipitates with hydric sulphide, but the arsenic in acid solutions is distinctly *lemon-yellow.* If there is any doubt, take some of the original solution and pour it into an apparatus from which hydrogen is being evolved and is burning at the mouth of the delivery tube. If arsenic is present, the flame will now deposit a stain on cold porcelain, soluble in sodium hypochlorite. Tin (stannous), gold, and platinum form brown precipitates, when hydric sulphide is added to solutions of their salts. To a fresh amount of the original solution, add stannous chloride: if *gold* is present, a purple color will be seen; if platinum, a brown; if tin, no change.

III. If there has been no precipitate with hydrochloric acid and none with hydric sulphide, take a fresh amount of the original solution, add ammonium hydrate, ammonium chloride, and ammonium sulphide:

Ammonium hydrate and **sulphide** precipitate
Iron group and **earths:**
Ferrous sulphide, black.
Cobaltous sulphide, black.
Nickelous sulphide, black.
Manganous sulphide, flesh colored.
Zinc sulphide, white.
Chromic hydrate, green.
Aluminium hydrate, white.

If the precipitate produced by the ammonium sulphide is *black*, to a fresh amount of the original solution add potassium ferrocyanide: a blue precipitate indicates presence of salt of *iron*.

If the precipitate with ammonium sulphide is white or greenish-white, zinc or aluminium is the metal. Take a fresh amount of the original solution, and cautiously add a small quantity of ammonium hydrate, causing it to trickle down the side of the tube: if the precipitate formed is cleared, on addition of plenty of ammonium hydrate, it is *zinc*, if not, *aluminium*.

IV. If no precipitate has occurred in I, II, or III, take a fresh sample of the original solution, and add ammonium hydrate, ammonium chloride, and ammonium carbonate:

Ammonium carbonate precipitates **Alkaline earths:**

Calcium carbonate,
Barium carbonate, } White.
Strontium carbonate.

If ammonium carbonate produce a white precipitate, add to the original solution potassium chromate: a precipitate of yellow color indicates *barium*, rather than calcium. If there is no precipitate with potassium chromate, but a white one with ammonium oxalate insoluble in acetic acid, but soluble in nitric, it is *calcium*, rather than barium. Calcium, barium, and strontium are readily identified by flame reactions.

In solution are left: **alkalies** and **magnesium**:

Magnesium.
Potassium.
Sodium.
Lithium.
Ammonium.

Magnesium salts are recognized by yielding a white precipitate with sodium phosphate, after addition of ammonium chloride and hydrate: the precipitate is ammonio-magnesium phosphate, readily soluble in acetic acid.

Ammonium salts do not answer to any of the preceding tests, but, if heated with potassium hydrate, the odor of ammonia is noticeable and fumes are seen, if a rod, moistened in hydrochloric acid, be held at the mouth of the tube.

Sodium and potassium are recognized by flame reaction. (See Section 544, III).

ANALYSIS OF AN AQUEOUS OR SLIGHTLY ACID SOLUTION OF ORDINARY COMPOUNDS OF THE METALS.

Suppose now that the solution is unknown. or contains compounds of several metals in solution. It is convenient to divide the metals into groups, for purposes of analysis, as follows: Group I: Pb,Hg(ous) and Ag. Group II (a):Pb, Hg(ic),Bi,Cu,Cd;(b) As, Sb,Sn,Au,Pt. Group III: Fe,Co,Ni,Mn,Zn,Cr,Al. Group IV:—Ca,Ba,Sr; Group V:—Mg,K,Na,NH_4.

Proceed with the analysis as follows:—

A. Group I. Pb,Ag,Hg(ous).

A. Test for metals of Group I by adding hydrochloric acid to the solution to be examined. The acid must be *chemically pure* and be added *plentifully*. If a precipitate is formed, filter, and save the filtrate (B) to examine for metals of Group II. Wash well and finally wash the precipitate off the filter into a beaker, boil with water, and filter again, saving this filtrate (1) to test for Pb. Collect the precipitate not dissolved by the boiling water on a filter, wash it well on the filter, till no longer acid, then add to it, while still on the filter, ammonia-water. Save the filtrate (2) to test for silver. If the precipitate on the filter turns black on addition of the ammonia-water, Hg (ous) is present. Go back now to filtrate (1), and add H_2SO_4 to it: a white precipitate indicates presence of Pb. Now take filtrate (2), and add nitric acid plentifully to it: a white precipitate indicates presence of Ag.

The beginner should mix the three solutions of silver, lead, and mercurous nitrates already made (Chapter IX, A, B, C.) and work out the separation as above outlined. The scheme is based on the solubility of lead chloride in boiling water, the precipitation of compounds of lead by sulphuric acid, the blackening of mercurous chloride by ammonium hydroxide, the solubility of silver chloride in ammonium hydroxide, and its reprecipitation from this solution by nitric acid. The beginner should be required to explain the *reason* for every step in the process.

B. Group II. Pb,Cd,Cu,Hg(ic)Bi,As,Sb,Sn:

If no precipitate with HCl, pass H_2S through the acidulated liquid for a long time; or if there has been a precipitate whith HCl, use the filtrate (B), obtained in A, and pass a current of H_2S for a long time into this.

If a precipitate forms, filter and save the filtrate (C) to examine for metals of Group III. The precipitate will contain one or all of the following:—Cd,Cu,Hg,(ic)Pb, (in small quantity not detected by HCl)Bi,As,Sb,Sn. Wash the precipitate well, wash it off the filter-paper into a dish, let settle, pour off supernatant liquid, and add it to filtrate (C), then add ammonium sulphide freely, stir well, and set it for a time in a warm place, at a temperature of about 100° F. The object of this proceeding is to separate the sulphides of Cd,Cu,Hg(ic) Pb,Bi from those of As, Sb,Sn, the latter being soluble in ammonium sulphide.

After the precipitate has thus been digested in ammonium sulphide, filter it, and save the filtrate (1). Wash the residue on the filter *thoroughly*, finally wash it off into a beaker, let settle, pour off supernatant liquid, add HNO_3, and boil. The object of this procedure is to separate mercuric sulphide from the sulphides of Cd,Cu,Pb, and Bi which are all soluble in strong boiling nitric acid. If after boiling in nitric acid an insoluble residue remains, presence of Hg(ic) is indicated, and the original solution will deposit mercury on a strip of copper. (It is often the case that a yellow half-fused globule of sulphur remains after boiling with nitric acid. The color and fusibility of this residue indicates its constitution. In case it is not yellow or if there is doubt, dissolve in aqua regia, concentrate by evaporation, dilute with water, and test for Hg(ic) with KI.). After boiling with nitric acid, filter, and filtrate (2) will contain, Cd,Cu,Pb, and Bi, if present. Add to this filtrate a few drops of dilute sulphuric acid. A white precipitate indicates presence of *lead*, now in form of sulphate. Filter, and save the filtrate (3). Wash the white precipitate on the filter till free from acid, finally wash from the filter into a test-tube or beaker, add solution of ammonium tartrate and excess of ammonium hydroxide, and the lead sulphate is dissolved.

Now take filtrate (3) and supersaturate it with strong ammonia-water. A white precipitate indicates presence of *bismuth*, now in form of hydroxide; filter, save filtrate (4), wash precipitate from the filter, let settle, decant, dissolve precipitate in HCl, and test for bismuth as in Chapter IX, F. Next take filtrate (4) and test it for Cu and Cd:—add solution of potassium cyanide and hydric sulphide. A yellow precipitate indicates Cd. Filter and the filtrate (5) will contain Cu. Render the solution acid, and test with potassium ferrocyanide, as in Chapter IX. E.

Now go back to filtrate (1) of this group which contains As, Sb, Sn, also perhaps Au and Pt. Add dilute sulphuric acid to it drop by drop as long as any precipitate is formed. The precipitate will consist of sulphides of As,Sb,Sn together with sulphur. Filter, save the filtrate (6), wash thoroughly, finally wash precipitate from filter into a beaker, let settle, decant, add strong HCl, boil. Dilute a little after boiling and filter. Residue on the filter, if yellow*, is to be tested for As by boiling in hydrochloric acid and a little potassium chlorate, and then using Fleitmann's test as in Chapter IX, I. Test the filtrate (6) for Sn and Sb by pouring into a Marsh apparatus. Sb escapes as H_3Sb and may be detected by the stain on the porcelain insoluble in hypochlorite. Sn remains in and with the zinc as a black metallic powder. Collect, wash, dissolve in HCl and test for tin as in Chapter IX, K.

C. Group III. Zn,Mn,Co,Ni,Al,Fe,Cr.

If no precipitate with either HCl or H_2S, add NH_4Cl,NH_4HO, and NH_4HS to the original solution or, if there has been a precipitate, add these reagents to the filtrate (C), obtained in B. A precipitate shows presence of Zn,Mn,Co,Ni,Al,Fe,Cr. Filter and save the filtrate (D) to test for metals of Group IV, wash the precipitate well, finally wash from filter into beaker, let settle, decant, add very little HCl and a few drops of HNO_3, warm, boil, add NH_4HO, to supersaturate, stir, and filter.

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*A dark colored residue suggests special tests for Au and Pt.

<table>
<tr><td colspan="3">Precipitate
Fe Al Cr.
Wash, dry, fuse on foil with Na_2CO_3 and KNO_3, boil in water and filter.</td><td colspan="3">Filtrate.
Zn Mn Co Ni.
Acidify with $HC_2H_3O_2$, pass H_2S. filter.</td></tr>
<tr><td rowspan="2">Residue
Fe_2O_3, brown. Test original solution for ferrous or ferric.</td><td colspan="2">Filtrate.
If yellow, Cr present. Divide in two parts.</td><td rowspan="2">Sol.
Mn.
Add NH_4HO and NH_4HS. Pink, turning brown.</td><td colspan="2">Precipitate.
Zn Co Ni.
Boil with HCl and a little HNO_2: add KHO, filter.</td></tr>
<tr><td>Sol.
Al.
Add NH_4Cl and warm. White ppt.</td><td>Sol.
Cr.
Add $HC_2H_3O_2$ and excess of $AgNO_3$; red ppt. Or boil with H_2SO_4 and spirit. Green solution.</td><td>Filt.
Zn.
Add NH_4HS. White ppt.</td><td>Precipitate.
Co Ni
Dissolve in HCl, and proceed as directed Chapter VIII, U</td></tr>
</table>

D. Group IV:—Ca,Ba,Sr.

This group is conveniently studied in connection with Group V.

E. Group V. Mg,K,Na,Li,NH_4:—

If metals of Group I—III are absent, add to the original solution NH_4Cl,NH_4HO, and $(NH_4)_2CO_3$. Or, if they are present, add these reagents to the filtrate (D) obtained in C. Warm and filter.

<table>
<tr><td colspan="3">Precipitate
Ba Sr Ca.
Collect, wash, dissolve in $HC_2H_3O_2$, add excess of K_2CrO_4, filter.</td><td colspan="3">Filtrate
Mg Li K Na NH_4.
Add $(NH_4)_2HAsO_4$, stir, filter.</td></tr>
<tr><td rowspan="2">Ppt.
Ba.
Yellow.</td><td colspan="2">Filtrate
Sr Ca.
Add dilute H_2SO_4, let stand, filter.</td><td rowspan="2">Ppt.
Mg.
White.</td><td colspan="2">Filtrate
Li K Na NH_4
Evaporate to small bulk. Add NH_4HO.</td></tr>
<tr><td>Ppt.
Sr.
White.</td><td>Filt.
Ca.
Add NH_4HO and $(NH_4)_2C_2O_4$. White ppt.</td><td>Ppt.
Li.</td><td>Filtrate.
K Na NH_4.
Evaporate, ignite, dissolve. K by $PtCl_4$. Na by flame. NH_4 in original solution.</td></tr>
</table>

CHAPTER XI.

REACTIONS OF ACIDS: (ACIDULOUS RADICALS).

After having demonstrated the presence of a compound of a metal in a given solution the next thing in order is to ascertain what *acidulous radical* is combined with it. Is the compound in question, for example, a nitrate, or a sulphate, or a chloride of the metal found? In order to answer this question become familiar with the following reactions.

A. Carbonates:--

1. Dissolve 5 grammes of sodium carbonate in 100 c.c. of water. Add any dilute acid to it, and effervescence takes place. Perform the experiment in a test-tube and pass the gas formed into lime-water:—a white precipitate is formed.

2. Prove the presence of carbonates in the teeth by acting on the latter with hydrochloric acid and passing the gas given off into lime-water.

B. Sulphides.

Place some sulphide of iron in small fragments in a dish and pour a little hydrochloric acid on it:—the characteristic odor of sulphuretted hydrogen is evolved. Soluble sulphides blacken metals, as silver.

C. Chlorides. (Hydrochloric acid).

Make a solution of 5 grammes of sodium chloride in 100 c.c. of water. To some of it in a test-tube add solution of silver nitrate. A precipitate of silver chloride is formed. Examine it as in Chapter IX, A. [Now go back to mercuric chloride Chapter IX, D. and notice that use of ammonia-water causes a precipitate].

D. Bromides. (Hydrobromic acid).

Make a solution of 5 grammes of bromide of potassium in 100 c.c. of water. 1. Test as for chlorides with silver nitrate: a yellowish-white precipitate is obtained, insoluble in nitric acid and only sparingly soluble in dilute ammonia. 2. Add strong sulphuric acid to the dry bromide on a plate:—yellowish-red vapors of bromine are liberated:

$$2KBr+H_2SO_4=2HBr+Na_2SO_4$$

and

$$2HBr+H_2SO_4=2Br+SO_2+H_2O$$

E. Iodides.(Hydriodic acid).

Dissolve 5 grammes of potassium iodide in 100 c.c. of water. Pour 5 c.c. into each of three test-tubes and test as follows:—

1. Pour into the first tube solution of silver nitrate and test further as for bromides.

2. To the second tube add a drop or two of nitric acid, and some mucilage of starch: a dark-blue color is formed.

3. To the third tube add solution of mercuric chloride; a red precipitate, HgI_2, is formed.

4. Treat the dry iodide with sulphuric acid; violet vapors of iodine are evolved.

F. Cyanides:—(Hydrocyanic acid).

Make a solution of 5 grammes of potassium cyanide in

100 c.c. of water. Pour 5 c.c of it into each of three test tubes, and test as follows:—

1. Add solution of silver nitrate plentifully to the first tube: a white precipitate, $AgCy_2$ or $AgCN$ is formed: let settle, decant, pour the precipitate into two test-tubes, add nitric acid to one and ammonia water to the other. The second is rather slowly dissolved.

2. To the second tube add a few drops of solution of ferrous sulphate and a drop or two of solution of ferric chloride; then add solution of potassium hydroxide and finally hydrochloric acid. Prussian blue is formed, thus:—

$$HCN+KHO=KCN+H_2O$$
$$2KCN+FeSO_4=Fe(CN)_2+K_2SO_4$$
$$4KCN+Fe(CN)_2=K_4Fe(CN)_6$$
$$3K_4Fe(CN)_6+2Fe_2Cl_6=12KCl+K_4(FeC_6N_6)_3$$

G. Nitrates:—(Nitric acid.)

Dissolve 5 grammes of potassium nitrate in 100 c.c. of water, and pour 5 c.c. of the solution into each of two test-tubes.—

Test as follows:—

1. To the first tube add a few small pieces of ferrous sulphate, shake gently, then cause strong sulphuric acid (8 or 10 drops only) to trickle down the side of the tube: a reddish purple or black coloration will appear between the acid and supernatant liquid, due to formation of $2FeSO_4.NO$.

2. To the second tube add crystals of pyrogallic acid, and test with sulphuric acid as above; a deep brown color is produced at the line of contact.

H. Chlorates.--

1. Heat dry chlorate of potassium and note liberation of oxygen.

2. To *a very little* dry chlorate add a little sugar, mix carefully, then add a *few* drops of sulphuric acid. Action takes place with explosive violence.

I. Chromates:—(Chromic acid.)

Chromates are easily recognized by the rich colors of the salts; thus potassium chromate is bright yellow, lead chromate is so called chrome yellow, potassium dichromate a rich red, etc.

Dissolve 5 grammes of potassium chromate in 100 c.c. of water. Pour 5 c.c. of the solution into each of five test-tubes and test as follows:

1. To the first tube add hydrochloric acid and hydrogen sulphide solution: sulphur is precipitated and the color turns green. The chromium is now in the form of base instead of acid, sulphate of chromium being formed.

2. Into the second, third, fourth, and fifth tubes pour solutions of compounds of lead, barium, silver, and mercury (mercurous) respectively, and look up the reactions which take place in Chapter IX.

J. Sulphites:—(Sulphurous acid).

1. Pour a drop or two of dilute hydrochloric acid on a little sodium sulphite contained in a plate, and note the suffocating odor of sulphur matches, due to formation of H_2SO_3.

2. Make a solution of sodium sulphite (5 : 100) and add to it solution of barium chloride: a white precipitate is formed soluble in dilute hydrochloric acid:—

$$Na_2SO_3+BaCl_2=BaSO_3+2NaCl$$

K. Sulphates. (Sulphuric Acid).

Dissolve 5 grammes of sodium sulphate in 100 cc. of water, and to 5 c.c. of the solution add solution of barium chloride. A white precipitate is formed, insoluble even in boiling nitric acid, thus:—

$$Na_2SO_4+BaCl_2=BaSO_4+2NaCl$$

Commercial samples of hydrochloric acid will give this precipitate with barium chloride, hence the necessity of using chemically pure hydrochloric acid in laboratory work.

L. Phosphates. (Phosphoric Acid .

Make a solution of 5 grammes of sodium phosphate, Na_2HPO_4, in 100 c.c. of water. Pour 5 c.c. of it into each of three test-tubes, and test as follows:—

1. To the first tube add plentifully solution of ammonium molybdate in dilute nitric acid. Warm. A yellow precipitate is formed, ammonium phospho-molybdate, $(NH4)_3PO_4.10MoO_3.2H_2O.$, soluble in ammonia water.

2. To the second tube add solution of barium chloride; a white precipitate of barium phosphate is formed, soluble in acids.

3. To the third tube add solution of ferric chloride: a yellowish-white precipitate of ferric phosphate, $Fe_2 (PO_4)_2$ is formed:—

$$2Na_2HPO_4+Fe_2Cl_6 \quad Fe_2(PO_4)_2+4NaCl+2HCl$$

In practice a little sodium acetate is first added, so that liberated HCl may unite with the sodium and not dissolve the precipitate.

Lastly dissolve teeth in hydrochloric acid, filter, precipitate with ammonium hydrate, filter again, wash precipitate from filter into a dish, dissolve in a little dilute nitric acid, add ammonium molybdate solution and heat. The presence of phosphates in the teeth is thus proved.

M. Borates. (Boric Acid).

Dissolve 5 grammes of borax in as little water as possible and pour into three test-tubes.

1. Dip into the first tube a piece of turmeric paper: it is colored brown-red as by alkalies. Next add a few drops of hydrochloric acid to the borate solution and dip a fresh slip of paper into it; remove, and dry over a flame. The brown color still appears.

2. Into the second tube pour solution of barium chloride: a white precipitate, barium metaborate, $Ba2BO_2$, is formed, soluble in acids and in alkaline salts.

3. To the third tube add solution of silver nitrate: a white precipitate is formed, soluble in both nitric acid and ammonia water.

Finally mix in a dish some dry borax with a few drops of sulphuric acid, and pour upon the mixture some alcohol. Ignite. The flame is tinged greenish at its edges.

For convenience a number of *organic* acidulous radicals will be included in this chapter.

N. Acetates. (Acetic Acid).

Dissolve 5 grammes of sodium acetate in about 20 c.c. of water. Pour 5 c.c. into each of three test-tubes. Test as follows:—

1. To the first tube add a few drops of sulphuric acid and heat: characteristic odor of vinegar (acetic acid) is evolved.

2. To the second tube add a little alcohol, then a few drops of sulphuric acid, and heat: a characteristic odor of acetic ether is evolved.

3. Take the reaction of the liquid in the third tube, neutralize carefully, if necessary, and then add a few drops of a neutral solution of ferric chloride: a deep red liquid results, owing to formation of ferric acetate, $Fe_2 6\, C_2H_3O_2$. Now boil and a red precipitate, iron oxyacetate, occurs leaving the liquid colorless.

O. Oxalates. (Oxalic Acid).

Make a solution of 5 grammes of oxalic acid or ammonium oxalate in 100 cc. of water. Pour 5 cc. into each of two test-tubes and test as follows:—

1. To the first tube add solution of calcium chloride; a white precipitate, calcium oxalate, CaC_2O_4, is formed. Let settle, decant, and pour precipitate into two tubes:

add acetic acid to one and hydrochloric to the other. The second only is dissolved.

2. To the second tube add silver nitrate: a white precipitate is formed. Lastly heat a fragment of dry potassium oxalate in a test tube; add water and acid: effervescence occurs. Decomposition has taken place, carbon monoxide is driven off, and potassium carbonate left:—

$$K_2C_2O_4=K_2CO_3+CO.$$

P. Tartrates. (Tartaric Acid).

Dissolve 5 grammes of potassium sodium tartrate in 100 cc. of water. Pour 5 cc. of this solution into each of three test-tubes and test as follows:—

1. To the first tube add solution of calcium chloride; a white precipitate, calcium tartrate, $CaC_4H_4O_6 4H_2O$, is formed. Collect precipitate quickly on a filter, wash, and treat with solution of potassium hydroxide. It is dissolved on stirring. Heat. Reprecipitation takes place.

2. To the second tube add acetic acid and solution of potassium acetate. Stir well. A crystalline precipitate, acid potassium tartrate, slowly separates.

3. To the third tube add solution of silver nitrate, first neutralizing if necessary; a white precipitate, silver tartrate, $Ag_2C_4H_4O_6$, is formed. Add a drop of ammonia-water and boil. It blackens, owing to reduction, and metallic silver forms as a mirror on the tube.

SHORT SCHEME FOR IDENTIFICATION OF ACIDS (ACIDULOUS RADICALS).

A. If the substance is in solid form, test for a carbonate, sulphide, bromide, iodide, chlorate, sulphite, and borate, using dry tests as described under the respective headings in Chapter XI. If the acid is not one of these seven, dissolve in water in the usual proportions and test for a chloride, cyanide, nitrate, chromate, sulphate, phosphate, acetate, oxalate, and tartrate. Confirm by performing all the tests under the heading of the acid found in Chapter IX.

B. If the substance is in liquid form, test for the commonest occurring acidulous radicals first: these are the chlorides, nitrates, and sulphates. If it is not one of these three, next test for carbonates, and phosphates. If still it is not found, test for bromides, iodides, cyanides, chromates, acetates, and oxalates. Finally for sulphides, chlorates, borates, and tartrates.

Hints on the above: if silver is the metal, and the substance is in solution, do not test for chlorides; it is likely to be a nitrate. If lead is the metal, test for nitrate and acetate. If a mercurous compound is found, first, test for a nitrate. If copper is the metal, test first for a chloride, nitrate, or sulphate. If a mercuric compound is found, test for a chloride (remembering the peculiarity of the action of ammonia-water) or for a nitrate, and cyanide. If bismuth is the metal, test for a chloride or a nitrate. If arsenic is the metal, test for a chloride; if found it is probably a solution of As_2O_3 in hydrochloric acid; if not found, test for arsenites and arsenates as in chapter IX. If antimony is found, test for a chloride and a tartrate. If tin is found, test for a chloride, so also if gold and platinum are found. If iron is found, test for a chloride, or nitrate, or sulphate. If manganese, nickel, or cobalt is found test for the same acids as in case of iron. If chromium is found, test for a chloride. If zinc is found, test for a chloride, or a bromide, nitrate, or sulphate. If aluminium is found, test for a chloride or sulphate. If barium is found, test for a chloride or nitrate. If calcium is found, test for a chloride, strontium for a chloride or nitrate, magnesium for a chloride, or sulphate. If sodium, potassium, or ammonium is found, test first for a chloride, or sulphate, or nitrate.

In the author's experience as a teacher, *oxalic acid* or *an oxalate* is commonly mistaken by the beginners for *potassium cyanide.* Oxalic acid turns litmus bright red while the cyanide solution turns red litmus blue.

CHAPTER XII.

REACTIONS OF ORGANIC SUBSTANCES OTHER THAN ACIDULOUS RADICALS.*

A. Phenol. (Carbolic Acid).

Read section 375.

1. Substance is either colorless crystals or a pink liquid having characteristic odor. Note greasy stain on paper and whitening of skin, with numbness.

2. To a few crystals or a little of the liquid in a test-tube add *very little* nitric acid: violent action takes place and the solution turns yellow, picric acid, $C_6H_2(NO_2)_3HO$ being formed.

3. Mix a few of the crystals or a little of the liquid with half a test-tube full of water and add a few drops of ferric chloride solution: a permanent violet-blue color is formed.

B. Chloroform.

Read section 412.

1. Note characteristic odor and hot sweetish taste.

2. Mix with equal parts water and note that it does not dissolve but sinks to the bottom of the tube in globules.

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*Organic acidulous radicals have been for convenience already considered in Chap. XI.

3. Mix with alcohol and note that it is soluble in this liquid.

4. Pour some of it into a dish and note that it does not inflame readily but burns with a dull smoky flame.

5. Dip a piece of filter paper into it and ignite: the paper burns with a greenish flame and gives off fumes of HCl, recognized by clouds when a rod moistened with ammonia water is brought near.

6. Heat 5 cc, of Haines's solution to boiling and add a few drops of chloroform. Note reduction as in test for Glucose which see in Chapter XIV.

C. Alcohol.

Read section 363.

1. Note odor, taste, inflammability, and solubility in water.

2. Dilute a little alcohol with 5 cc. of water then add to it a few drops of dilute KHO solution and a small crystal of iodine. A precipitate, iodoform, of characteristic odor is formed, according to the equation:—

$$C_2H_5HO+6KHO+I_8=CHI_3+CHO_2K+5KI+5H_2O$$

If too much alcohol is present, the precipitate is dissolved.

D. Glycerol. (Glycerin).

Read section 369.

1. Note the thick syrupy consistence, sweet taste, solubility in water and alcohol, and absence of inflammability.

2. Warm a solution of glycerol in water with a little sulphuric acid and note odor of acroleim.

3. Note no reduction of Haines's test liquid.

E. Ether. (Sulphuric Ether).

Read section 400.

1. Note odor, volatility, and great inflammability: the latter is well shown by pouring some ether into a dish

and approaching it with a long lighted taper. The ether takes fire before the flame touches it, owing to ignition of the vapor all about the dish.

F. Alkaloids:

For identification of alkaloids (section 449) as distinguished from other substances proceed as follows:—

1. Note (*very cautiously*) the taste by dissolving the substance in plenty of water and tasting but one drop; alkaloids have bitter taste.
2. Solubility in alcohol: most alkaloids and their salts are more or less soluble in alcohol even though insoluble in water.
3. Color: usually white.
4. Behavior with reagents:—aqueous solutions of alkaloids are precipitated by solutions of KHO and NaHO, and by solutions of alkaline carbonates, as Na_2CO_3; solutions of alkaloids as a class are precipitated by solutions of tannic acid, picric acid, phospho-molybdic acid, potassio-mercuric iodide, auric and platinic chlorides.

VOLATILE ALKALOIDS.

1. Nicotine. Recognized by liquid state, brownish color on exposure to air, strong odor of tobacco, solubility in ether, chloroform, turpentine, water, and alcohol Precipitated by picric acid, auric and platinic chlorides, and mercuric chloride. Precipitate by these reagents is amorphous, turning crystalline. An ethereal solution of iodine added to an ethereal solution of nicotine separates a brownish oil which slowly becomes crystalline.

Nicotine gives a violet color with HCl.

2. Coniine. Recognized by liquid state, odor of mice, and solubility like nicotine. Solutions are precipitated as above by general alkaloidal reagents. Evaporated with HCl, a greenish-blue, crystalline residue is obtained.

3. Sparteine. Resembles coniine and nicotine but ethereal iodine test separates dark greenish-brown crystal.

NON-VOLATILE ALKALOIDS.

Read section 449.

As distinguished from the volatile alkaloids they are usually white odorless solids, fused at a temperature of the boiling point of water, but decomposed at higher temperatures.

A. Morphine or its salts.*--

1. To a little of the powdered solid in a plate add a few drops of nitric acid: effervescence takes place and a red solution is formed which changes to yellow.

2. To a little of the dry substance in a dish add pure H_2SO_4: solution takes place. Pour half of the solution into another dish. Add a crystal of $K_2Cr_2O_7$ to solution in one dish, and a small drop of dilute nitric acid to the other: the first turns green, the second pink.

3. Neutralize a solution of ferric chloride with any convenient alkali at hand, stopping short of actual precipitation: add this to the substance and a blue color is developed, which changes to green on addition of excess of the reagent.

4. Dissolve the substance in water or other solvent and note absence of precipitation with solution of $HgCl_2$.

5. Note precipitation of solution by saturated auric and platinic chlorides, picric acid, and also solution of potassium dichromate.

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*Read section 459.

B. Codeine and its Salts.

1. Solution in nitric acid is yellow.

2. Solution in chlorine water is colorless, but reddened by ammonia water.

3. Solution in pure sulphuric acid is colorless, but turns blue when warmed with addition of trace of ferric chloride.

C. Quinine and its Salts.

Read section 464.

1. Note insolubility in water by shaking up a little of the dry substance in half a test-tube full of water. Next add just one drop of H_2SO_4 and note how quickly solution takes place. Hold below the window sill and note peculiar blue fluorescence.

2. To the solution thus made add a few c.c. of chlorine or bromine water then excess of ammonia water and note green color.

D. Caffeine. (Thein)

1. The solution in HNO_3 is yellow. Evaporate and warm with ammonia water, and it turns purple.

2, The solution in pure H_2SO_4 is colorless.

E. Strychnine and its Salts:—

Read section 467.

1. Add one crystal to a quart of water and note bitter taste.

2. Place a small crystal on a plate, add one or two drops pure H_2SO_4, and wait till it is dissolved. Solution is colorless. Now draw a small fragment of $K_2Cr_2O_7$ through the solution, A blue color is developed which rapidly changes to violet, cherry-red, and finally yellow.

F. Brucine.

1. The solution in HNO_3 is red turning yellow. Add

stannous chloride and the red changes to violet. (Differentiation from morphine).

G. Atropine:—

Read section 452.

1. The solution in HNO_3 is colorless and on addition of $K_2Cr_2O_7$ is only very slowly colored.

2. Add a little HNO_3 to the dry substance, dry on the water bath, cool, and add a few drops of solution of KHO in alcohol; a violet color is developed changing slowly to red.

3. Dissolve a fragment of $K_2Cr_2O_7$ in H_2SO_4, add a gramme of atropine and a few drops water, warm, and a pleasant orange blossom odor is perceived.

H. Veratrine:—

Read Section 468.

1. The solution in H_2SO_4 is first yellow, then orange, finally carmine red, and shows a partial green fluorescence.

2. The solution in HCl is colorless but turns dark red when warmed.

3. Addition of bromine water colors the substance violet.

I. Aconitine;

Read section 450.

1. The solution in H_2SO_4 is yellow brown.

2. The solution in aqueous phosphoric acid when evaporated shows a violet color.

J. Physostigmine:

1. The solution in H_2SO_4 is yellow turning olive green.

2. The above, if neutralized carefully with ammonia water and warmed, turns red then red-yellow, green, and blue.

3. Solution of bromine in potassium bromide turns the substance red.

K. Cocaine and its Salts.

Read section 457.

1. The solutions in H_2SO_4 and HNO_3 are colorless.

DEPORTMENT OF ALKALOIDS WITH GENERAL REAGENTS.

1. Picric acid:—Precipitates nicotine, coniine, sparteine, morphine, quinine, strychnine, brucine, atropine, and cocaine. Gives no precipitate with aconitine.

2. Auric and platinic chlorides:—Precipitate nicotine, coniine, sparteine, morphine, atropine, veratrine, cocaine.

3. Tannic acid:—Precipitates quinine, strychnine, brucine, aconitine.

4. Mercuric chloride:—Precipitates nicotine, coniine, sparteine, strychnine, cocaine; does not precipitate aconitine and morphine.

5. Sodium hydroxide:—Precipitates quinine, and aconitine.

6. Iodine in potassium iodide:—Precipitates strychnine (brown), veratrine (brown), aconitine; cocaine (brown), dilute solutions rose-colored.

CHAPTER VIII.

LABORATORY WORK CONTINUED—CHEMICAL WORK IN THE DENTAL LABORATORY: REFINING GOLD, TESTING AMALGAMS, MANIPULATION OF VULCANITE, COMPOUNDING RUBBER, ETC., ETC.

550. **Refining Gold:** the separation of foreign metals from gold is a matter of great importance to the dentist, as can be inferred from page 169, on which the effects of the different metals on gold are discussed. Metals may be separated from gold in two ways, by the "dry way" and the "wet way." The object of the "dry method," or *roasting*, is to convert the metals into oxides, chlorides, or sulphides.

1. Plate-scrap or clippings, and plate-filings; these need usually only to be remelted, if of suitable fineness originally.
2. Mixed filings, and fragments containing solder and platinum; these should be either roasted, or reduced to gold by the "wet way."
3. Sweepings: these should be first well washed, then either mixed with class second, or separately refined.

A good method is to fuse 8 parts of sweepings with 4 of common salt, 4 of impure potassium carbonate, 1 of potassium bitartrate, and one-half of potassium nitrate, in a crucible.

551. **Separation of foreign metals from gold:** the most troublesome constituents of gold alloys are tin, lead, zinc, iron, antimony, bismuth, etc., etc. Most of these are oxidizable, hence roasting with nitre is usually sufficient, but tin alloys may better be roasted with mercuric chloride, and if the alloy contain a number of the different metals, sulphide of antimony should be used.

Richardson recommends the following method:

1. Remove all traces of iron or steel by passing a magnet repeatedly through them.*
2. Place the fragments and filings in a clean crucible, lined on the inside with borax, and covered either with a piece of fire-clay slab, or broken crucible.
3. Place the crucible in a furnace, on a bed composed of mixed charcoal and coke.
4. Add small bits of borax and when the metallic mass is fluid, add the potassium nitrate (or whatever refining agent is used) in small quantities from time to time, and continue the roasting from half an hour to an hour, according to the coarseness of the alloy.

Roasting with nitre is usually sufficient, but

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* Gold scrap sometimes contains traces of steel that should be removed by treatment in the "wet way."

sometimes effects partial separation only. In such a case proceed as follows:

1. Remove crucible from the fire, after roasting with nitre, and let cool gradually.
2. Break the crucible, remove the button of gold, separate from slag by use of hammer, put into a new crucible, and melt again.
3. Add any particular agent capable of uniting with any particular base metal known to be present; or, try, first, one refining agent then another, until sufficient separation is effected.
4. Pour the melted metals into previously warmed and slightly oiled ingot moulds.
5. Hammer, anneal, and roll the ingot, and if still brittle, melt again with mercuric chloride.

Another method, of advantage in a greatly impoverished alloy, is the following:

1. Melt the alloy in a large crucible, adding small quantities of native antimony sulphide, until three or four times the weight of the alloy has been reached.
2. A lead-colored alloy of gold and antimony is formed; place it in a clean crucible, melt, and blow a current of air, by means of a bellows, over its surface.
3. Blow gently at first; a current strong enough to produce visible fumes is all that is necessary. When the fumes cease, increase

the heat, and before pouring out the gold throw a forcible current of air on the surface.

In case the alloy be found now malleable, but stiff or elastic and of dull color, *platinum* is probably present and must be removed by the "wet method," which, in general, must be used when it is desired to reduce the alloy to *pure* gold, as is the case when the gold to be refined consists of very coarse filings, fragments of plates containing large quantities of solder, linings with platinum pins attached, particles of base metals, etc., etc. Proceed as follows by the method of Watt:*

1. Dissolve the alloy in aqua regia, using four parts of hydrochloric to one of nitric, C. P. acids being used. The chloride of silver is found as a grayish-white powder at the bottom of the vessel. Let settle, and pour off supernatant liquid.

2. Add gradually to the liquid poured off a clear, filtered solution of ferrous sulphate in distilled water. Gold is precipitated as a brown powder.

3. Let settle, filter, wash off from the filter paper, digest in dilute sulphuric acid, filter again, wash well, and the result is pure gold.

552. **To determine the carat of an alloy.**—

Multiply 24 by the weight of gold in the alloyed mass, and divide product by weight of the mass. Take, for ex-

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* Quoted by Richardson.

ample, a solder composed of 6 parts gold, and 3 of other ingredients: the weight of the gold is represented by 6, the total weight 9 ∴ 24 × 6 ÷ 9 = 16. The alloy is, then, 16 carats fine. When now the gold is not pure, attention should be paid to the number of carats, and deduction made accordingly. Suppose a solder contain 48 parts of 22 carat gold, and 28 parts of other constituents; here the true weight of the gold is not 48, but 44. (22 carat gold is one-twelfth alloy; one-twelfth of 48 is 4 and 48—4 = 44).

553. **To reduce gold to a required carat:** multiply 24 by the weight of pure gold used, and divide the product by the required carat. The quotient is the weight of the mass when reduced, from which subtract the weight of the gold used, and the remainder is the weight of the alloy to be added. For example, reduce 10 ounces of pure gold to 18 carats: 24 × 10 ÷ 18 — 10 = 3.3 + ounces of alloy to be added. If the gold is not pure, allowance must, of course, be made by subtracting as in the previous rule.

554. **To raise gold from lower to higher carat:** Multiply the weight of the alloyed gold used, by the number representing the proportion of alloy in the given carat, and divide the product by that number representing the proportion of alloy in the required carat; the quotient is the weight of the mass, when reduced to the required carat by adding fine gold.

For example, suppose it is required to raise 16 carat gold to 18 carats: in 16 carat gold there is 24 — 16, or 8, alloy; in 18 carat gold there is 24 — 18, or 6, alloy. The example, therefore, becomes 1 × 8 ÷ 6 = 1⅓; that is, add ⅓ of a pennyweight of pure gold to the 1 pennyweight of 16 carat gold, in order to obtain 18 carat gold.

If, now, instead of adding pure gold it be desired to add gold of some particular carat, it is merely necessary to subtract the numbers, as 16 and 18 above, from the carat instead of from 24. The example above would then become, if 22 carat gold were to be added, 1 × 6 ÷ 4 = 1½, that is to each pennyweight of 16 carat gold, add ½ pennyweight of 22 carat gold.

555. **Methods of preparing dental amalgam alloys.**—Take a Hessian or sand crucible, fuse in it enough borax to fill the crucible at least one-third full, melt the tin in it over the usual dental or smelting forge-fire and, after it is melted, add the granulated silver, which, preferably, should have been heated to a low redness. The silver soon fuses in the molten tin and after thoroughly stirring with an iron rod or clay pipe-stem of small size, the copper, in form of small pieces of wire, should be added. After it has melted, and the mixture has been stirred, the gold is added, melted, and all is thoroughly stirred. After fusion and mixing is complete, quickly pour the fused mass into a broad, open, flat, shallow receptacle of iron or soap stone, and let cool. (Flagg).

According to Flagg, *very slow cooling* is to be avoided, as it gives rise to almost complete separation of the silver from the tin, or in other words, the cohesion of like molecules overcomes the adhesion of unlike ones. The end sought for is to fix the molecules, as much as possible, in the position into which they are driven by the heat. Prompt cooling secures the greatest uniformity of distribution to components. (Flagg).

Essig prefers to melt the platinum and silver together first, in case platinum is used, so that oxidation of the tin may not take place at the instant of union with the platinum. After the platinum and silver have been melted, the tin and gold are to be added. Borax is to be fused in the crucible first and, lastly, a layer of broken charcoal should be placed over the mass before the heating.

556. **Alloys and amalgams: tests:** the tests by which good amalgam alloys are recognized are partly chemical, partly mechanical. The latter will not be considered in this work. The chemical tests include the quality of the

mercury. Pure mercury, practically free from metallic admixtures, should be used.

557. Mercury may be freed from mechanical impurities by filtering it through a cone of paper, round the apex of which a few pinholes have been made. Lead may be removed from it by exposing the mercury in a thin layer to the action of nitric acid, diluted with two measures of water, which should cover its surface and be allowed to remain in contact with it for a day or two, with occasional stirring. Wash well with water, dry first with blotting paper, then by gently heating.

For effect of sulphuretted hydrogen on alloys, see Section 530, 31. Use a weak solution to note gradual discoloration.

558. **In testing an alloy** for constituent metals, first make a preliminary examination as follows: into a test tube drop some of the metal or alloy in form of clippings, or coarse powder, then pour in some C. P. nitric acid; convenient proportions are a few grains of the metal to a drachm or two of the acid; warm over an alcohol flame, being careful not to let the acid boil over out of the test-tube, as it is very corrosive and will burn hands, clothing, etc. Of the commoner metals, copper, silver, and zinc will be dissolved. If the copper is in any noticeable quantity, the solution may acquire a green or blue color. Tin, gold, antimony, and platinum are not dissolved, though traces of the last two may go into solution.

559. **Short method of qualitative analysis of amalgam alloys:** according to Eckfeldt and Dubois,* an idea

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* Quoted by Flagg.

may be had of the presence of gold and platinum from the action of the tin, which is not dissolved; but, after the action of the acid is over, shows itself as a whitish precipitate, colored from light to deep purple, if *gold* be present, or dirty-blackish color, if *platinum* be present with or without gold. After some idea is thus gained, take more of the metal or alloy, say 20 grains, and dissolve in half an ounce of acid, using a *beaker*. It is advisable to use what is sold as C. P. nitric acid, strong. The beaker should not be brought into contact with the naked flame in warming; it may be passed to and fro through the flame, or warmed by dipping into boiling water. After the action is over, evaporate to dryness in a porcelain dish over the *water bath*, a copper vessel filled with water under which is the alcohol flame. The whole should be under a "hood" for carrying off the vapors, or in a well-ventilated room. The fumes of the nitric acid are very irritating, and should not be breathed. (I.) After the nitric acid mixture has well evaporated, which will take some little time over the water-bath, add distilled water, stir well, and filter. [Previous work has revealed the presence or absence of gold, platinum, and tin; there remain silver, copper, cadmium, and zinc to be looked for].

(II.) After filtering, add some dilute hydrochloric acid—a few drops of acid in a test-tube half full of water will be enough—and, if *silver* is plenty, a white, *curdy* precipitate will be formed.

(III.) Filter again, and to a little of the filtrate (liquid which goes through the paper) apart from the rest, add a few drops of ammonia water (made by mixing one volume of *stronger* ammonia water with three volumes of distilled water); a blue color indicates *copper.*

(IV.) To the rest of the filtrate add sulphuretted hydrogen. After the sulphuretted hydrogen water has been added, a black precipitate of *copper sulphide* will result, unless modified in color by a large percentage of *cadmium.*

(V.) Filter, saving the filtrate, wash the precipitate off the filter paper into a porcelain dish, using the *wash bottle* (a flask with a perforated cork having two bent glass tubes passing down into the flask; blowing into one tube will force water out through the other in a fine stream). Boil the precipitate in the porcelain dish with sulphuric acid diluted with water (one part of acid, added very slowly and with constant stirring, to four parts of water, well mixed, allowed to stand 24 hours, and decanted).

(VI.) Filter, and add sulphuretted hydrogen water to the filtrate, and then a few drops of ammonia; a bright yellow precipitate will indicate *cadmium.* Suppose now that when testing for copper as above (III.), no blue color appeared with ammonia, then test directly for cadmium, as in (IV), which, if present, will appear as a yellowish precipitate, on addition of the sulphuretted hydrogen; (*brownish-yellow* indicates that silver has not been completely removed by precipitation with HCl).

(VII.) Go back now to the filtrate saved in (V) and boil it down until nearly dry to expel sulphuretted hydrogen, then add a little pure water, and solution of sodium carbonate until neutral (shown by dipping a piece of red and a piece of blue litmus paper into the mixture which, when neutral, will not change the color of either paper). A white precipitate indicates presence of *zinc.*

The above described process will enable the beginner to test the various dental amalgam alloys for the presence of those metals usually found in them. The detection of *gold*, *platinum*, *copper*, *cadmium*, and *zinc* is of importance, for all the alloys contain silver and tin. It is desirable to procure a sulphuretted hydrogen apparatus, such as a Kip generator, and some Woulfe bottles; pass the gas generated through a Woulfe bottle, containing a little water, so as to *wash* it, then directly into the solution to be tested.*

560. **Short method of quantitative analysis of the more common amalgam alloys.**

1. Estimate the **mercury**—of an old amalgam, for example—by weighing, heating to redness, weighing again. The loss in weight indicates the weight of mercury which was present.

2. Estimate the **tin** by weighing, heating to *bright redness* with borax, adding potassium nitrate in small quantity, cooling, collecting button and globules, weighing again. The loss in weight indicates the weight of the tin.

3. Estimate the **silver** by rolling out the button (obtained by procedure as in 2) into a thin ribbon, boil in a platinum or glass vessel with at least two or three times its weight of concentrated sulphuric acid. Continue boiling until the acid no longer attacks the metal, let settle, pour off supernatant liquid, **save the residue.** Precipitate silver from the poured-off liquid, by dipping plates of copper into it. Collect the silver, wash well, heat, weigh.

4. Go back to residue obtained in 3, wash well, dissolve in aqua regia, drive off acid by evaporation, dissolve in a large quantity of distilled water, add oxalic acid, the **gold** is thrown down, let settle, pour off supernatant liquid and save it. Collect gold, wash, dry, heat to redness, weigh.

5. To the supernatant liquid obtained in 4, add ammonium chloride as long as there is any precipitate. Let

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*To detect mercury in form of vapor given off from amalgam alloys, Haines and Talbot have used ammonio-silver nitrate, a drop or two of which, on *chemically pure filter-paper*, they find will detect, by discoloration, exceedingly small quantities of mercury. Whether fillings which respond to this test are hurtful to the patient or not, must be decided by clinical experience.

precipitate settle, filter, wash, dry, and weigh the precipitate. Every 100 parts contains 44.28 of platinum. (Essig).

6. Estimate the percentage of each metal present by dividing the weight of the metal found by the weight of the amalgam in the beginning, before anything was done to it.

561. **Tests for cements:** tests should be made both of the liquid and of the powder. The *oxyphosphate* cements consist usually of glacial phosphoric acid and oxide of zinc. Take the reaction of the liquid with blue litmus to show that it is acid. Pour a little of the liquid into a test tube, and holding the latter inclined, let an aqueous solution of a little egg-albumin gradually trickle down the side of the tube into the acid. If a zone of whitish turbidity is noticed at the juncture of the two liquids, it is glacial phosphoric acid, rather than the common acid. To prove that it is phosphoric acid rather than any other, as for example, lactic or hydrochloric, add to a little of it, solution of silver nitrate, and a *white precipitate* is produced; this does not tell it from hydrochloric, but further add *barium chloride* solution, and if glacial phosphoric acid is the one, a white precipitate will be produced. The tests, then, for glacial phosphoric acid are as follows:

1. Coagulation of albumin.
2. White precipitate with silver nitrate.
3. White precipitate with barium chloride.

[*All* these tests should be successful; hydrochloric acid gives two of them, (1 and 2) but not three if pure. Sulphuric acid is distinguished by the heat evolved on mixing it with water. Nitric acid coagulates albumin, but does not answer to tests 2 and 3. Common phosphoric acid, *when pure*, does not answer to test 1, nor when diluted to test 3, but if it contains sulphates as an impurity, will answer to test 3, and it may, if not pure, answer also to test 2. The "vegetable" acids like acetic, lactic, etc., etc., do not respond to test 1]. If the phosphoric acid is in form of crystals, dissolve in as little water as possible, or melt by *gentle* heat, and then apply the test as above. If the crystals are dry, drop one of them into a solution of egg albumin, and if a *cloudiness or turbidity* surrounds the crystal as it dissolves, test No. 1 is successful. At red heat the crystals should volatilize. As to the *purity* of the glacial acid: *commercial* glacial acid is a hard, glassy mass, but the pure is softer and wax-like.

The acid is deliquescent, and dissolves readily in water, and in alcohol.

To test the liquid of the *oxychloride of zinc* cements, it is necessary to show that it contains *zinc* and is a *chloride*. Take the reaction of the liquid, which should be acid. Pour a little of the liquid into a test tube, and add *hydrochloric acid;* no precipitate should be noticed. Next add *sulphuretted hydrogen*, either in gaseous form or in solution, and no precipitate should be noticed. Take a fresh amount, to which nothing thus far has been added, and add *ammonium hydrate* (Aqua Ammoniæ will do), *ammonium chloride*, and *ammonium sulphide*; a *white* precipitate should be noticed. N. B. The precipitate may be greenish white, if there is iron present as an impurity. Now take still another sample of the liquid, and cautiously add *ammonium hydrate*, letting it trickle down the side of the tube, and a delicate white zone of turbidity will be noticed. Shake it or add plenty of ammonia, and it will disappear. *All* these tests, if successfully obtained, show presence of zinc; confirm with blow-pipe. Next, to prove that it is a *chloride* of zinc. Take a fresh amount of the liquid, and add *silver nitrate* to it; a curdy, white precipitate becoming violet on exposure to light, and soluble in (plenty of) ammonium hydrate, shows the presence of a *chloride*.

In testing the *powder* used in both oxyphosphate and oxychloride cements, attention should be paid both to its ingredients and quality; first, prove that it contains zinc by dissolving in nitric acid, as dilute as possible, and testing as for zinc in the liquid, or by means of the blowpipe.

Next as to quality: its specific gravity should be 5.6,*it should turn yellow when heated in a test-tube, and become white again on cooling. Try to dissolve a little in water, and notice that it is insoluble; add to a mixture of it with water, a little nitric acid, and notice that it is dissolved completely. To the solution thus obtained in nitric acid, (1) add *silver nitrate:* no precipitate should appear; to a fresh amount of the nitric acid solution, (2) add *barium chloride:* no precipitate should appear. Now take a fresh amount of the powder, add water to it, and a few drops of *hydrochloric acid:* then add (3) *sulphuretted hydrogen:* there should be no discoloration; to a fresh amount of hydrochloric acid solution, add (4) *potassium ferrocyanide.* A precipitate appearing should not be colored green or blue. Test (1) is for chlorides, (2) for sulphates, (3) for lead, (4) for iron.

562. **Manipulation of vulcanite, etc.:** much in regard to this subject belongs properly to mechanical dentistry. When the rubber is ready for hardening or vulcanizing, the latter may be accomplished by submitting it for a time to the action of hot air, steam, or hot water. A strong boiler called a **Vulcanizer** is usually used, the metal of which should preferably be wrought.

563. **To improve the color of rubber,** Wildman advises exposing to action of alcohol in sunlight from six to twelve hours. **Bending** hard rubber may be accomplished after heating to the proper temperature as 240° to 280° F. Small pieces, *uniformly thick*, may be softened by oiling and holding over the flame of a spirit lamp. Large pieces or those of irregular thickness may be softened by immersing in oil in a vessel and raising to the required temperature.

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*Determine the specific gravity according to Chapter I.

564. **Parting the plaster:** an ounce of castile soap (cut into thin shavings) dissolved in a pint of water, by boiling, is used for parting the plaster.

565. **Coloring plaster:** to color plaster add a little vermilion or burnt umber to the dry plaster.

566. **Hardening the plaster:** the operation may be hastened by mixing thick, adding common salt,* or using hot water, or by combining the three methods.

567. **Compounding rubber:** caoutchouc may be mixed with sulphur and the coloring matter, either by passing repeatedly between steam-heated rollers or by reducing the caoutchouc in the first place to a pulpy or gelatinous state (by the action of some such substance as carbon disulphide) and then mixing the sulphur and coloring matter with it. [Wildman prefers to soften caoutchouc in oil of turpentine or in equal parts of coal naphtha, or benzine, and oil of turpentine]. From 5 to 50 per cent. of alcohol should be added to the solvent, in order that the latter may be at least partially recovered after the caoutchouc has softened. Wildman levigates the coloring matter and sulphur in spirits of turpentine, first grinding the coloring matter to a fine powder, then adding the sulphur and grinding thoroughly. He next adds a little of the pulpy caoutchouc, mixes thoroughly, and so on.

568. **Substances used to color rubbers:** the natural color of hard rubber, composed of caoutchouc and sulphur only, is a dark brown. Red oxide of iron and also vermilion are used to make red rubbers; cadmium sulphide to make a yellow, and with oxide of zinc to make a lighter yellow. Ivory black is used to produce a black rubber. Various modifications of the different colors may be made by combining the coloring materials in different proportions.

569. **Testing rubbers chemically:** to ascertain whether

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*Addition of salt is said to weaken the plaster.

metallic mercury is set free in the body of the rubber by the decomposition of the sulphide (vermilion) during vulcanization, a simple method is to digest the rubber in nitric acid, then test the solution for mercury in the usual way.* **Sulphuretted hydrogen** may be proved to be given off during vulcanization by heating a sample of the rubber to 320°F., for one hour and a quarter in a suitable receptacle, and collecting the gas in a solution of a lead salt. A black precipitate indicates formation of sulphuretted hydrogen.

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*Prof. Salisbury says that some of his students have used the copper test for mercury in rubbers: no response to the test has been obtained *before* vulcanizing, but *after* vulcanization evidence of abundance of mercury has been obtained, showing a change to have taken place to a more soluble compound or to metallic mercury.

CHAPTER XIV.

Laboratory Work in Physiological Chemistry.

This chapter will deal with carbohydrates, fats and oils, fatty acids, proteids, digestion of proteids, examination of the gastric juice, and the blood.

CARBOHYDRATES.

Read paragraphs 387 to 391 inclusive.

Exercise 1. Starch:—

A. Show that wheat flour contains starch by kneading flour in a thin calico bag under water. The starch passes out with the water, forming a milky liquid from which it deposits on standing.

(There remains in the bag a sticky, gray, tenacious mass composed of what is called *gluten*, a nitrogenous substance which soon decomposes, and smells badly. See Proteids).

B. Let the starch obtained in A settle, pour off the water, and let dry. Then take a little of it, and rub it up in a mortar with a little water. It first becomes sticky, but, if more water be added. mixes with it. Prove that it is a mixture and not a solution by letting it settle, and noting the bulk of the sediment. Decant off the supernatant liquid, filter, and add to the filtrate dilute tincture of iodine. No blue color appears, hence starch is absent from the solution.

C. Go back to the starch mixture made in B, and boil a little of it, so as to make a thin paste. Let cool. Add a few drops of the dilute tincture of iodine, or of an aqueous solution of iodine, and note deep blue color. Boil, and the color disappears.

These experiments show that starch is recognized by its reaction with iodine, and that it is not soluble in cold water.

D. Prepare starch from potatoes as follows: grate the potatoes to a pulp on a common tin grater, steep the pulp in water, and squeeze through coarse unbleached muslin.

Steep several times, and strain, collecting the liquid strained each time ; or rub the softened pulp in a sieve under a current of water, which washes out the starch In either case let the washings settle half an hour or so, and the starch will deposit slowly to the bottom of the glass. Pour off the supernatant liquid, add fresh water, stir well, and let settle again. This may be done several times, until the starch is clean and white, when it may be dried in a clean, shallow dish.

E. Examine starch from different plants under the microscope, using ¼-inch objective, and notice the concentric layers of the granules, and the differences in size, shape, general appearance, distinctness, and character of the rugæ, and position of the more or less central point called the hilum.

Exercise 2. Action of dilute acids on starch.

A. Mix a grain or two of starch with half a test-tube full of cold water. Add one drop of sulphuric acid, and boil about five minutes. No mucilage is formed. Remove some of the liquid, let cool, and test with the iodine solution. The deep blue color is not obtained, but, instead, a *blue-violet.* Continue the boiling, and notice that on testing the cooled liquid, from time to time, the color reaction with iodine grows less and less marked, and finally disappears.

Starch, when heated with dilute acids, is converted first into *dextrine*, and finally into *dextrose.*

Solutions of dext*rine*, containing unchanged starch, give a vinous-purple reaction with iodine, but solutions of dext*rose* give no reaction at all. Dext*rine* is a gum-like substance, dext*rose* is a sugar.

B. Boil for an hour the liquid described in A. Neutralize the acid by adding chalk in excess, pouring the liquid into a beaker, and warming. Filter, and evaporate filtrate nearly to dryness on water bath. Let cool, and notice sweet taste, (dextrose).

C. To one fluidrachm of Haines's solution (Ex. 8) add one or two drops of the sweet-tasting residue, and boil. A bright yellow color indicates presence of dextrose.

Exercise 3. Action of Strong Acids on Starch.

A. Add excess of strong sulphuric acid to starch, say 5 c.c. of acid to 1 gramme of starch, and heat to boiling in a large flask. Note that the experiment resembles a previous one, Chapter VII. A black mass is soon produced. Heat still further, and note fumes of sulphurous oxide, and that finally a colorless liquid results.

B. Pour a mixture of 15 c.c. strong nitric acid and 35 c.c. of water on 10 grammes of sugar in a 200 c.c. flask. Heat gently until the reaction begins (copious red fumes), Then withdraw heat.

When the red fumes no longer escape, transfer the liquid to an evaporating dish, and evaporate to one-half its volume. Let cool. Crystals separate on cooling, which, when tested, will be found to be *oxalic acid.*

Exercise 4. Action of heat on starch.

Heat 5 to 10 grammes of starch in a porcelain dish on a sand-bath, with constant stirring, not allowing it to burn. The starch turns yellowish-brown. Heat for ten minutes after the starch is uniformly yellowish brown, allow to cool, add water, and boil. Dilute and filter. Note that the filtrate is precipitated by alcohol.

The starch in this experiment is converted into *dextrine* or "British gum," the ingredient of mucilage of commerce. Farinaceous foods for infants are made by baking flour, in order to convert the starch into dextrine.

Exercise 5. Action of ferments on starch.

A. Note the action of malt on starch as follows: treat 50 grammes of pale, ground malt with 500 c.c. of cold water for an hour, with occasional stirring. Then heat the solution to 60°, C. keeping at that temperature for half an hour. Filter through a dry filter. Now make a thin starch paste, by boiling in each of three flasks 0.1 gramme of starch in 100 c.c. of water. When the starch is thoroughly gelatinised in each flask, add 10 c.c. of the malt infusion to one, 15 c.c. to another, and 20 c.c. to the third. Maintain the flasks at a temperature of 50° C for three hours. Then, on a porcelain plate, test a drop or two from each with solution of iodine. If no blue or brown coloration is obtained from any one of the flasks, it is plain that the starch has been converted. If a color is obtained from any one, it shows that the conversion is incomplete, more malt solution is to be added, and the heating repeated for three hours longer. Finally evaporate the solution to very small volume and note sweetish taste. Test it with Haines's solution as before.

B. Repeat experiment A heating the malt to boiling beforehand. No change to sugar takes place.

C. Repeat experiment A previously adding a little strong sulphuric acid to the malt. No change to sugar takes place.

D. Repeat experiment A previously adding a little strong potassium hydroxide solution to the malt, until the reaction is strongly alkaline. No change to sugar takes place.

These experiments show that malt contains a principle which has the property of converting starch into sugar, and that this property is destroyed by high heat, strong acids, and strong alkalies.

Exercise 6. Action of the saliva on starch.

A. Perform the test outlined in paragraph 571, A, 1 to 3.

B. Boil the saliva first, then add starch, and lay aside as in A, subsequently testing for sugar. No reaction is obtained, owing to the action of heat on the salivary ferment.

C. Add a little strong sulphuric acid to the saliva first, then add starch, and go on as in A. No reaction for sugar is obtained.

D. Repeat C, substituting concentrated solution of potassium hydroxide for the acid. No sugar reaction is obtained.

E. Perform experiment A with raw starch instead of the boiled paste. No sugar reaction is obtained.

These experiments show that the saliva contains a principle which has the property of converting starch into sugar; that this property is destroyed by heating above 35° to 40° (95° to 104°), by strong acids, and by alkalies. Moreover the ferment is without action on raw starch.

Exercise 7. Action of the pancreatic fluid on starch.

A. Repeat the experiment with starch, described in paragraph 571, A, 1 to 3, using, however, pancreatic extract instead of saliva.

Good Pancreatic extract for this purpose can be made according to Long by cutting a hog's pancreas into small pieces, and passing these through a small sausage mill. Take about 10 grammes of the finely divided matter, and cover with 50 c.c. of 25 per cent. alcohol. Let stand a week, filter, evaporate alcohol at low temperature, take up residue with 50 c.c. of water, and use this solution for the experiment.

B. Repeat the experiment, boiling the pancreatic solution first. No sugar reaction is obtained.

Exercise 8. The sugars in solution.

A. Make up solutions for testing sugars as follows:—

1. Haines's solution:—dissolve 30 grains of pure sulphate of copper in one half a fluidounce of pure water; make a perfect solution, and add to it one half a fluidounce of pure glycerine, mix thoroughly, and add five fluidounces of liquor potassæ. (See paragraph 163). This solution is used for qualitative work and is permanent, after being decanted from reddish precipitate which takes place after a time.

2. Fehling's solution:—dissolve 69.28 grammes of pure **recrystallized*** cupric sulphate in distilled water sufficient to make the solution measure just one liter. Keep in a well stoppered flask labelled I. Next dissolve 100 grammes of sodium hydroxide, precipitated by alcohol, in 500 c.c. of water, heat to boiling, and add gradually 350 grammes of pure recrystallized Rochelle salt. (See paragraph 445). Stir until all is dissolved. Let solution stand 24 hours in a covered

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*Necessary on account of presence of ferrous sulphate in most commercial samples.

vessel, filter through asbestos into a liter flask, and add pure water, enough to make the solution measure just one liter, keep in a well-stoppered bottle labelled II.

When about to use it, mix equal parts of the two solutions. The mixture will then contain 34.64 milligrammes cupric sulphate in each cubic centimeter of liquid.

This mixed solution is used both for qualitative and quantitative work. It is not permanent.

B. Make up solutions of sugars to be tested as follows: dissolve one gramme each of grape-sugar (dextrose), cane-sugar (saccharose), and milk-sugar (lactose) in 100 c.c. of distilled water. Note that the milk-sugar is dissolved less readily than the other two. Test as follows:—

1. Boil one fluidrachm of Haines's solution which, if properly made, should not change when boiled. Add to the boiling solution, drop by drop, 8 to 10 drops of each of the solutions of sugar above described. As each drop is added shake, and boil a few seconds. Finally when the whole 8 or 10 drops have been added, boil for 30 seconds.

Compare the reactions obtained with the different sugars, and it will be found that the grape-sugar (dextrose) makes the solution turbid on addition of the second drop, and, on adding further drops and boiling, a reddish violet tint appears; finally after 8 drops have been added, and the solution boiled 30 seconds, a brick-red precipitate (cuprous oxide) appears, which acquires a brighter tint as the tube cools, and soon settles to the bottom, leaving a clear liquid above. The grape-sugar (dextrose, glucose) is said to *reduce* the alkaline copper solution, cupr*ous* oxide, CuO, being thrown down. Milk-sugar (solution 1 to 100) acts in a similar way with Haines's solution yet if, after boiling, the solution be held up to reflected light, a distinctly bluish tint can be seen. *Milk-sugar reduces the copper solution more slowly than grape-sugar.* Cane-sugar does not affect the brilliant blue color of the solution at all.

2. Test the same three solutions with Fehling's solution, as follows:—Heat 10 c.c. of the solution to boiling, and when boiling, add 1 c.c.of each solution of sugar.

The principle of all the alkaline copper tests is the same namely the reduction of the cupric sulphate to cuprous oxide.

4. Boil a little of the solution of cane sugar with a few drops of hydrochloric acid, neutralize with sodium carbonate, and then apply the three tests as above. It will be found that the cane sugar now reduces the alkaline copper liquids, its molecule being split up into reducing sugars, dextrose and levulose.

3. Subject the sugar solutions to Trommer's test as follows:—

Add to 4 c. c. of each sugar solution enough cupric sulphate solution to impart to it a very faint greenish-blue tint, and considerable excess of strong potassium hydroxide solution. Warm the mixture, and continue the heat to boiling.

Note the difference in action of the different sugar solutions, dextrose giving a yellowish precipitate, which grows bright red on boiling.

Exercise 9. Fermentation of sugars.

A. Measure off 120 c.c., each of solutions of the three sugars, in strength 2 grammes of sugar to 500 c.c. of water. Next add to each sugar solution, a two-cent cake of compressed yeast in small fragments; shake up well, and take the specific gravity. Set aside in a warm place, not cooler than 20°C (68°F), for 24 hours. At the end of that time note that in the bottle containing solution of grape-sugar, there is escape of gas bubbles, and, if the flask is provided with a stopper and twice bent delivery tube, the latter dipping into lime water, a precipitate of calcium carbonate will be formed. The molecule of grape-sugar is split up, as follows:—

$$C_6H_{12}O_6=2C_2H_5HO+2CO_2$$

Note the alcoholic odor of the mixture.

Take the specific gravity, and it will be found to be much less than before fermentation.

On the other hand note absence of any fermentative change in the bottles containing cane sugar, and milk sugar.

B. Pour some of the mixture of grape-sugar solution and yeast, before fermentation, into a flask, and heat to boiling. Let stand for 24 hours, and note absence of fermentative change. The high heat has destroyed the activity of the yeast germ. To another portion of the grape-sugar solution and yeast, before fermentation, add strong alcohol, and note absence of fermentative change in 24 hours, the alcohol destroying the activity of the yeast cell. This explains why wines containing a large percentage of alcohol " keep " well.

C. Let the fermented solution of grape-sugar stand three or four days more in a *warm* place, and note disappearance of alcoholic odor, and the presence of a sour smell. This is due to *acetic acid fermentation*. (See paragraph 420).

D. Study lactic fermentation, paragraphs 436, and 438.

Exercise 10. Glycogen.

A. Glycogen is a white, tasteless, inodorous, and amorphous powder, obtained from the liver.

B. Test the solubility of glycogen in alcohol, ether, cold and boiling water.

C. To a solution of glycogen in water add a little iodine solution, and note the red color produced. Heat the mixture, and the color disappears.

D. Boil solution of glycogen for 10 minutes with dilute hydrochloric acid; nearly neutralize the acid, cool, and test with iodine solution. No color appears, the glycogen having been converted into sugar.

Exercise 11. Fats and Oils:—

A. Knead beef or mutton suet in a muslin bag in a basin of hot water; the fat melts, and passes out, leaving the membrane or tissue in the bag. Let the melted fat cool, when it will solidify and is then known as *tallow*. Obtained from hogs the fat is known as *lard*, and is much softer. These fats together with human fat are mixtures of *palmitin* and *stearin*, together with olein, the first two being solids but olein a liquid at ordinary temperatures, hence the solid or liquid condition of a fatty substance is determined by the relative quantity of the three fats just mentioned present in it. Tallow is hard because it contains a relatively large proportion of stearin and palmitin.

B. Take a piece of tallow or lard, and note that it stains paper permanently.

C. Weigh out six small samples of tallow, all of the same weight, place in six test-tubes, and pour into the tubes water, alcohol, hot alcohol, ether, carbon disulphide, and benzene (paragraph 319) respectively. Notice that the fat floats on water, and is insoluble in it, that it is less soluble in alcohol than in ether, or the remaining solvents, and that is more soluble in hot alcohol than in cold.

D. Obtain a little lanolin (wool-fat), and mix it with twice its weight of water. Notice that, unlike other fats, it mixes with the water.

Lanolin differs from other fats in that it does not contain glycerin, but two alcohols of the same formula (isomeric) $C_{26} H_{43} HO$, known as *cholesterin* and *iso-cholesterin.*

E. Keep samples of butter and of lanolin in a warm place for some days. Note that the butter becomes *rancid*, undergoing a kind of fermentation, resulting in liberation of *butyric acid.* The lanolin does not become rancid so readily.

Exercise 12. Saponification.

A. Prepare hard soap as follows:—Weigh out 50 grammes of olive oil, mix with 60 c.c. of a 15 per cent. solution of sodium hydroxide, and boil for at least an hour. Then add solution of 15 grammes sodium chloride in 40 c.c. of water, and boil again, but only for a short time. The soap formed by action of the alkali rises to the surface of the saline solution in which it is insoluble, and solidifies on cooling.

The equation is as follows:

$$\underset{\text{olive oil}}{C_3H_5(C_{18}H_{33}O_2)_3}+3NaHO=\underset{\text{hard soap}}{3NaC_{18}H_{33}O_2}+\underset{\text{glycerin}}{C_3H_5(HO)_3}$$

Olive oil is the oleate of tritenyl or glyceryl (paragraph 369); when acted on by sodium hydroxide, sodium oleate (hard soap) and glycerin are formed, the latter being a hydroxide of the radical glyceryl.

B. *Soft Soap.* Prepare soft soap as follows:—Boil 25 grammes of tallow with a solution of 10 grammes of potassium hydroxide in 25 c. c. of water. Stir until no more oil globules are seen floating on top of the water, and add water from time to time to make up for that lost by evaporation. Soft soap, excess of alkali, and glycerol are the products.

Exercise 13. Glycerol (Glycerin).

A. Prepare glycerin on a small scale by mixing a little fat with finely powdered litharge and water in a porcelain dish. Heat. Lead plaster is formed, and glycerin remains in solution in the water. Filter. Pass a current of sulphuretted hydrogen through the filtrate, evaporate to small bulk, and filter again. Note the sweetish taste of the filtrate.

In the above experiment it is convenient to take 50 c.c. of cottonseed oil, 25 grammes of litharge, and 100 c.c. of water, more of the latter being added from time to time as needed.

Glycerin of commerce is not made in this way, but by passing superheated steam into melted fats, which is decomposed into glycerin and fatty acid.

B. Examine the solvent power of glycerin (paragraph 369) as follows:—

1. Weigh out 20 grammes of tannic acid, and add it to 100 c. c. of glycerin.

2. Mix 20 c. c. of liquefied carbolic acid with 100 c. c. of glycerin.

3. Mix the same proportions of creasote and glycerin, and note that the creasote does not dissolve in the glycerin.

4. Mix 6 grammes of boracic acid with 9 grammes of glycerin. Heat in a porcelain dish on a sand-bath at 150° C. (302° F), stirring well, until no more aqueous vapors are given off. A homogeneous, transparent mass is formed which is *boroglyceride;* for equation and uses see paragraph 371.

5. Test any liquid supposed to contain glycerin by mixing with zinc carbonate, and drying at the temperature of the water bath. Extract the dried mass with absolute alcohol, evaporate, and obtain a sweetish residue.

Exercise 14. The Fatty Acids.

A. Dilute the soft soap mixture described in Exercise 12, with water, and to about 25 c.c. of the mixture add 10 c.c. of strong, commercial hydrochloric acid, and warm on the water bath. Liberated fatty acids collect on the surface. If more water now be added, and the whole allowed to cool, a semi-solid layer of fatty acids can be lifted from the surface of the liquid.

B. Add a little of the fatty acids obtained above to a solution of rosanilin hydrochloride, and warm:—note the dark-red or reddish-black color.

C. Make a saturated solution of the fatty acids (obtained in A) in alcohol by warming. Let cool, and obtain *crystalline scales.*

Exercise 15. Emulsions.

A. Shake up a little olive oil in a test-tube with some white of egg. Note that the liquids mix, forming a white mass known as an *emulsion.*

It is by emulsification in the small intestines that fatty substances are brought into a condition in which they can be absorbed by the lacteals. The process is brought about by the pancreatic juice and bile, as may be shown by rubbing up oil in a mortar with fresh, finely divided pancreas.

B. Examine a drop of the emulsion, obtained in A, under the microscope:—small globules are seen, varying in size and shape, which are maintained apart by their albuminous coatings.

C. To some oil add a little of the free fatty acids obtained in Exercise 14, and then a few drops of a strong solution of sodium carbonate. Shake well, and a stable emulsion is produced.

This experiment shows that the presence of free fatty acids is probably necessary in producing an emulsion. It is probable that the alkaline juices of the intestine act in this way by splitting up the fats into free acids and glycerin.

Exercise 16. Crystallization of Fats.

A. Examine a little tallow, without melting it, under the microscope and note the *granules.*

B. Melt the tallow, place a drop of it on a glass slide, press down a cover glass on it before it is hard, let cool, and then examine with the microscope. Note that crystals have now formed.*

These experiments show that fats in the tissues have no crystalline structure, but that, after being melted, they become crystalline on standing.

C. Dissolve tallow in chloroform, place a drop on a slide, let evaporate until film is seen on top of drop, put on cover glass, and let stand until crystallization is complete. The crystals formed are finer than those seen in B.

It is not, however, thought to be possible to identify the various fats by their crystalline forms, since from one and the same portion of fat, dissolved in chloroform, four or five different kinds of crystals may be obtained.

Exercise 17. General characters of the Proteids.

A. Take several eggs, and having made a small hole in each end, let the white only escape. Cut up the albuminous fluid, thus obtained, with scissors, so as to divide the network of membranes, stir up rapidly with twice its volume of water, and strain through a linen cloth.

White-of-egg belongs to the large number of substances to which the general term *proteid* is given. (Read paragraph 470. Note that the solution is incapable of *dialysis*, paragraph 72.)

B. Set a little of the proteid solution aside in a warm place for a few days. Note the odor and, on addition of a solution of lead acetate or nitrate, the *blackening*. *Putrefaction* has taken place.

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*Use a power of 200 to 300 diameters.

Read paragraphs 471 and 476 and distinguish between fermentation and putrefaction.

C. Fill a test-tube two-thirds full of the solution of white of egg obtained in A. Hold the closed end by the thumb and forefinger, and boil the upper third over a spirit lamp. Flocks appear, due to formation of *coagulated albumin.*

The soluble proteids (paragraph 472) are converted into insoluble modifications, by heating to 60° to 70° C. (140° to 158° F). When once thus coagulated, they will not return to their original soluble form without suffering some alteration.

D. Procure the dried albumin (coagulated blood albumin), of commerce and heat some of it in an ignition tube. Note that it is decomposed.

E. Perform the experiment as in D, but previously mix with equal bulk of soda-lime and heat strongly. Ammoniacal vapors are given off, which may be recognized by their odor or action on litmus paper. This experiment may be also tried with common wheat flour.

F. Lastly subject the solution made in A to the following;—

1. Tests by acids and salts of the heavy metals:—

Add to the solution, poured into seven test-tubes, solutions of the following compounds respectively:—tannin, carbolic acid, picric acid, acetic acid together with potassium ferrocyanide, lead acetate, mercuric chloride, and silver nitrate. Note that a precipitate is formed in each case.

The fact of the precipitation of egg albumin by salts of the heavy metals is taken into account in the treatment of poisoning by the latter. (Read paragraph 232, Toxicology).

2. *Xantho-proteic reaction:*—

Add strong nitric acid to some of the solution of albumin, boil, and a yellow precipitate is formed, or merely a yellow *color* if the albumin solution is dilute. Now further add ammonia-water, when the precipitate will assume a deep orange-red color. With very dilute solutions nothing may happen on addition of nitric acid, but the addition of ammonia produces a yellow color.

3. *Test with Millon's reagent:*—

Millon's reagent is made by dissolving 10 grammes of mercury in 20 grammes of nitric acid (sp. gr. 1.42), and diluting with 20 c.c. of water.

(In dissolving the mercury use heat finally, but let cool before diluting with water.)

Add to some of the proteid solution half its volume of Millon's reagent, and heat. A yellowish precipitate is formed, which becomes red when boiled. If the solution is dilute, a red color, without precipitate appears.

4. *Biuret test:*—Add to the proteid solution excess of sodium or potassium hydroxide, so that the reaction is strongly alkaline. Then add two or three drops only of a dilute cupric sulphate solution. A violet color appears, which is deepened on heating.

5. *Precipitation by neutral salts:*—Strongly

acidify some of the albumin solution with acetic acid, add some sodium sulphate, and boil. A whitish precipitate takes place, except in case of peptones. This test is, therefore, of use in separating peptones from other albuminous substances. Moreover the filtrate, after boiling, is in condition to be tested for other substances, as sugar.

The term *peptone* is given to the products of the action of gastric and pancreatic juices upon proteids during digestion. (Paragraph 472.5).

Exercise 18. Characteristics of individual proteids.

A. Obtain a sample of albuminous urine from a patient with Bright's disease, and compare it with the solution of egg-albumin prepared in exercise 17.

Note that the reactions are the same. Now add ether to both the albuminous fluids, and it will be noticed that it does not coagulate the albumin in the urine, but does, on the other hand, coagulate that of the egg.

Egg-albumin differs from the albumin of the blood, in being coagulated by ether. Egg-albumin once coagulated by heat is less soluble in excess of strong nitric acid than is blood albumin. The albumin of the blood is chiefly a mixture of what is called serum-albumin and serum-globulin. The fluid of hydrocele also contains serum-albumin.

Egg albumin and serum albumin are known as *native albumins.* (Paragraph 472.1).

B. Obtain fresh blood from the slaughter-house, separate the fibrin* by whipping with twigs, strain through unsized muslin, rotate in a centrifugal machine, and pour the clarified liquid thus obtained into a beaker. Saturate

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*Keep the fibrin for F.

with ammonium sulphate, filter, redissolve precipitate in water, saturate again with ammonium sulphate, filter, wash with strong solution of ammonium sulphate, dissolve in a little water, and place in dialyzer. The salts pass through the membrane, and during dialysis a precipitate forms in the dialyzer, which is composed of a proteid called *serum globulin.* (Paragraph 472. 2.) Filter the liquid after dialysis. The filtrate is pure *serum albumin,* and the precipitate remaining in the filter is globulin. Wash it off with water from the wash-bottle, and note its insolubility in water. Then add a little salt, stir, and it dissolves. Add excess of salt, and it is reprecipitated.

If in the experiment above the globulin alone is desired, it can be prepared more quickly, after separation of fibrin and rotation in centrifuge (removing blood corpuscles) by saturating the clarified liquid with magnesium sulphate, instead of ammonium sulphate. The magnesium salt precipitates serum globulin, but not serum albumin.

The globulins are insoluble in pure water and strong saline solutions, but soluble in weak saline solutions.

The different globulins are enumerated in paragraph 472,2. *Myosin* is the globulin obtained by extracting muscle tissue in 10 per cent. solution of ammonium chloride (in which it is readily soluble) and precipitation by addition of large quantities of water. Myosin is a constituent of muscle-plasma, a yellowish opalescent fluid, which coagulates after death, giving rise to *rigor mortis.*

C. Treat white of egg, diluted with four times its volume of water, with one-fifth its volume of dilute hydrochloric acid (0.2 per cent.) for several hours at a temperature of 45 C. (113°F.). Carefully neutralize with solution of an alkaline hydroxide, and a precipitate forms.

It can be washed in water by decantation, and is no longer coagulated by boiling, when redissolved in hydrochloric acid.

This experiment shows that the egg-albumin (native albumin) which, as has already been shown, is soluble in water and in neutral salt solutions, has been changed into a form insoluble in these agents. This modified form is known as *acid-albumin*. It is readily soluble in either dilute acid or dilute alkaline solutions. (Read paragraph 472, 4. See also *Syntonin*, 472, 2.)

D. Remove the whites of two fresh eggs, divide freely with scissors, as before in Exercise 17, shake up well in a flask, and filter through linen: then add strong solution of potassium hydroxide until it becomes a firm jelly. Cut into bits, roll up in gauze, and wash well in distilled water. Dissolve in boiling water, filter, and carefully neutralize filtrate with acetic acid. A precipitate now takes place.

This experiment shows that the native albumin has been changed into a form insoluble in water by contact with the alkali. This modified form is known as *alkali-albumin*, and is soluble in both dilute acid and dilute alkaline solutions.

The jelly formed by action of the alkali is known as *Lieberkuehn's* jelly.

E. Dilute 100 c.c. of fresh milk with 400 c.c. of water, and add five cubic centimeters of acetic acid, so as to give it distinctly an acid reaction. A white precipitate takes place. Let settle, decant, and wash by decantation. Filter, let drain, wash with strong alcohol, then with ether, and let dry in the air. *Casein* is obtained.

Casein is the chief proteid of milk. It forms about 4 per cent. of cow's milk, but less than three of human milk. Chemically it resembles alkali-albumin, being soluble in weak alkaline solutions, but differs from alkali-albumin in being coagulated by rennet (an enzyme of gastric juice) and in yielding no ash on ignition.

F. Go back to B and wash with water the filamentous coagulum obtained, and then with alcohol and with ether. An impure *fibrin* is obtained holding blood corpuscles. Note that it is insoluble in water and in weak saline solutions. (Read 472, 3).

G. Boil a solution of white-of-egg in water. *Coagulated proteid* is obtained. Pour nearly equal parts of the mixture into several test-tubes. Add dilute nitric acid to one, strong nitric acid to another, dilute potassium hydroxide solution to a third, and strong potassium hydroxide to the fourth. It will be seen that the coagulated proteid is soluble in strong acids and alkalies but insoluble in weak. It is also insoluble in neutral saline solutions.

Exercise 19. Digestion of Proteids:—

A. Take some of the freshly prepared fibrin* of exercise 18, B., cut it up very fine in a dish, and cover it with 5 or 6 times its volume of weak hydrochloric acid (0.20 to 0.25 per cent.). As soon as the fibrin becomes transparent, add a little glycerin extract of pepsin, and warm the whole to 40°C (104°F) on the water bath. At the end of half an hour pour off half the liquid. After several hours the gelatinous mass will have disappeared, and an opalescent gray solution taken its place.

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*Small pieces of boiled egg albumin may also be used.

The process which has taken place is called *digestion*. The essential constituents of the gastric juice are hydrochloric acid, in strength about 0.25 per cent., and a soluble ferment (*enzyme*) called pepsin. Under the action of the gastric juice albuminous substances suffer a profound change, in virtue of which they become soluble and ready for absorption, preliminary to nutrition. The property of the gastric juice together also with the pancreatic juice, to be spoken of further on, is to convert other proteids into bodies known as peptones, the latter being exceedingly soluble, and more or less diffusible through animal membranes. Peptone is the name given to matter completely digested by the gastric and pancreatic juices. Albumose is a term given to substances in an intermediate stage between coagulated proteid and peptone. (Paragraph 472, 5).

So many peptic extracts are on the market that they can be obtained at every pharmacy, but, if the student has time, he may prepare one himself, by separating the mucous membrane of a hog's stomach, cutting it into small bits, placing in a bottle, and covering with twice its weight of good, strong glycerin. Let stand a week or ten days, shake often, and pour off the glycerin.

B. Test the digested mass for the products of digestion, namely albumose and peptone. Take the liquid poured off after half an hour of digestion, neutralize carefully with ammonia water, and saturate with ammonium sulphate. A precipitate is formed which is *albumose*, intermediate between acid albumin and peptone.

Filter off the albumose precipitate. The filtrate contains peptone.

C. Test the finally digested mass obtained in B as follows:—concentrate by evaporation at low temperature, then to the solution in four test-tubes add alcohol, and solutions of tannic acid, potassium-mercuric iodide, and mercuric chloride. A precipitate forms in each case.

To still another test-tube containing some of the peptone filtrate add solution of potassium or sodium hydroxide till strongly alkaline, then a drop or two of a very dilute solution of cupric sulphate. A pink color should be observed.

To still another portion in a test-tube add nitric acid : no coagulation takes place.

Exercise 20. Pancreatic Digestion:—

A. Add to 100 c.c. of water in a flask, 0.28 gramme of pancreatin and 1.5 gramme of sodium bicarbonate. Shake up till dissolved, and then add 400 c.c. of warmed fresh cow's milk of temperature 38°C (100°F). Keep the mixture at this temperature for half an hour. The milk becomes peptonized. To a little of it in a test-tube add nitric acid: no coagulation occurs.

It will be noticed from the above experiment that pancreatic digestion goes on in a solution which is *alkaline* in reaction, thus differing from gastric digestion, which requires an acid medium.

B. Final products of pancreatic digestion:—Go back to the freshly prepared fibrin of Exercise 18 and weigh out 25 grammes of it. To this add an equal weight of fresh minced pancreas, and 250 c.c. of water, to which a little thymol has been added.

Place all in a flask and the latter in a thermostat, and keep at a temperature of 40° C (104° F) for six hours.

At the expiration of this time pour off about one-third of the mixture, boil, and filter warm. Concentrate the filtrate to a small bulk, and examine drops under the microscope for leucin and tyrosin (paragraph 474. 10). Leucin forms spheres, tyrosin long needles.

The remaining two-thirds of the mixture is left for six hours longer in the thermostat at 40° C., when the characteristic odor of *indol* is developed.

Exercise 21. The Gastric Juice.

A. *Obtain the gastric juice for examination* by use of the stomach-tube* at a time when stomach is free from food, as before breakfast, or an hour or so after a test meal has been taken. The meal usually consists of bread and water taken on an empty stomach.

B. Take the reaction with litmus paper. Normal gastric juice reddens blue litmus.

C. *Determine presence of free acids* by the Congo-red test as follows:—

Soak filter paper in a 1 per cent. aqueous solution of Congo-red, and let dry. If a drop of the juice is placed upon the paper, and a blue color appears, the presence of free acids is indicated; intense **blue** indicates free hydrochloric acid.

D. *Determine the total acidity:* To 10 c.c. of the gastric filtrate add a few drops of phenolphtalein solution, and then run in slowly decinormal potassium hydroxide solution,† until the liquid assumes a slight reddish tint, which does not disappear with stirring. Express the percentage of acidity in terms of c.c. of hydrox-

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*For complete description see Ewald on "Diseases of the Stomach." D. Appleton & Co., New York.

†This solution can be obtained of any large dealer in chemicals.

ide used; thus, if 50 c.c. of deci-normal potassium hydroxide are necessary for neutralization, express the acidity as 50 per cent.

E. *Determine the presence of free hydrochloric acid:—*

1. Methyl-Violet test. Make an aqueous solution of methyl-violet, and dilute it until it has a reddish-violet color. Mix with the gastric filtrate, and a blue color results if free hydrochloric acid is present.

2. Phloroglucin and Vanillin test. Dissolve 2 grammes phloroglucin and 1 gramme vanillin in 30 c.c.* of absolute alcohol. Keep in a dark bottle. Mix 5 c.c. of this solution with an equal volume of the gastric juice, and concentrate on the water-bath. If free hydrochloric acid is present, the liquid, as it becomes concentrated, turns red.

3. OO-Tropäolin test. Soak filter paper in a saturated solution of OO-Tropäolin and let dry. Moisten the paper with a drop of the filtrate, then place the paper in a watch-glass, and heat. If there is free hydrochloric acid, the paper first becomes brown, then, as it dries, lilac.

Note:—It is said that none of these color tests give entirely reliable conclusions.

In cases where the reaction is positively obtained, free hydrochloric acid is undoubtedly present; but the reaction sometimes fails from presence of albumin, peptone,

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*Jaksch uses 100 c.c. of alcohol.

or salts, even when free hydrochloric acid is present also. The reactions with methyl-aniline, congo-red, and benzo-purpurin are thought by Von Jaksch to be most reliable. Ewald thinks well of the phloroglucin-vanillin test.

4. Benzo-purpurin test:—Soak strips of filter paper in a saturated solution of benzo-purpurin, 6. B. Let dry. Filter the gastric contents, and immerse the dried paper in the filtrate. If a brownish-black color results, organic acids (lactic or butyric) are present, with or without hydrochloric acid. If a blue color results, hydrochloric acid is present. Shake the brown or black paper in ether and, if the brown color changes to blue, hydrochloric acid is present. If it fades out without turning blue, organic acids are present.

F. *Determine presence of organic acids*, as lactic, by Uffelmann's reagent:—dissolve 1 gramme of pure carbolic acid in 75 c.c. of water. To this add 5 drops of a strong solution of ferric chloride, which produces a deep blue color. Of this solution, thus made, take 5 c.c. and add to it a few drops of the gastric filtrate. If lactic acid is present, the color changes from blue to yellow.

Dr. Long remarks that weak, almost colorless solution of ferric chloride alone serves as a test solution, as its color becomes much deeper on addition of a trace of lactic acid.

Professor Simon recommends in doubtful cases shaking 10 c. c. of gastric filtrate with 50 c. c. of ether, evaporating ethereal solution to dryness, dissolving the residue in a few drops of water, then adding Uffelmann's reagent as above.

G. *Estimate the amount of free hydrochloric acid,* approximately, by use of the phloroglucin-vanillin reagent:—the more or less intense red color gives us a rough idea of the larger or smaller amount of free acid present. More accurately dilute the gastric juice, giving the phloroglucin-vanillin reaction with water, and test repeatedly, noting at what stage of dilution the test fails. If the red color is just visible with the 20th dilution with equal parts water, then the juice contains 0.1 per cent. of free hydrochloric acid, since the limit of the reaction is known to be 1-20,000*

H. *Boas's cancer test.*

This test depends on absence of HCl *and* presence of lactic acid. Preliminary lavage and use of oat-meal gruel given after lavage are important.

According to Rosenheim in 12 to 15 per cent. of all cases of cancer of the stomach no diagnosis is possible.

Long thread-like bacilli, immobile, and often occuring in enormous numbers have been found in stagnating stomach contents, when HCl is absent and large quantities of lactic acid present. Sarcinæ are very rarely seen in the above-described stomach contents. Sulphuretted hydrogen is not found in cancer. Absence of pepsin as an important symptom is disputed. Tumors on the anterior wall have been recognized with the gastrodiaphone.

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*Ewald.

Exercise 22. The blood.

A. Obtain some fresh blood and take the specific gravity and the reaction. Note that the former lies between 1045 and 1075, and that the reaction is alkaline, shown by putting a few drops on plaster of Paris surface which has been soaked in neutral litmus.

B. Heat blood diluted with, say, 20 times its volume of water, and note that the red color is mostly destroyed near the boiling point, hemoglobin being resolved into brown hematin and albumin.

C. Evaporate a drop of blood on a glass slide, add a couple of drops of glacial acetic acid, and boil. Put on a cover glass, let cool, and examine with high power of microscope for the dark-brown, prisms or plates called Teichmann's crystals (hemin).

D. Obtain an old blood stain on linen, treat with a *very little* distilled water, then examine as in C, except that a small crystal of sodium chloride must be added to the glacial acetic acid in order to furnish hydrochloric acid, hemin being a chloride of hematin.

E. Mix old spirit of turpentine or ethereal solution of hydrogen dioxide and fresh tincture of guaiacum, equal parts, and let the blood solution of B trickle down into the mixture in quantity equal to that of the latter. A blue zone is seen at the juncture of the blood and mixture, due to oxidation of the guaiacum resin by the turpentine or dioxide in presence of the blood.

F. Pass a current of ordinary illuminating gas from the gas jet into a test-tube half full of defibrinated blood, for a short time. Cover the mouth of the tube with the thumb, shake thoroughly and then pass more gas into the blood. The color changes to cherry red, the arterial red having disappeared, owing to a compound formed by union of the carbon monoxide in the gas with the hemaglobin of the blood.

G. Shake the tube in contact with the air and note persistence of the darker red color.

These last two experiments show what happens in the blood when poisoning by illuminating gas takes place.

CHAPTER IX.

ANALYSIS OF SALIVA, TEETH, TARTAR, AND URINE.

570. A complete course in salivary analysis is as essential to the dental student as one in urinary analysis to the medical student.

I. Become familiar with the **physical characteristics** of the saliva: 1. Cause the patient to wash his mouth out thoroughly with a warm, dilute solution of sodium bicarbonate, and afterwards with cold spring water, if it can be obtained, or with cold distilled water. Brush the inside of the mouth lightly with a glass rod, moistened with a little dilute acid, when the mouth will be filled with a considerable amount of clear, viscid fluid. Cause the patient to expectorate into a cylindrical glass vessel, tapering at the bottom and provided with a lip, so that the sediment may be collected and examined with the microscope.

II. While it is settling, note the **color, odor, reaction, transparency, consistence, appearance of sediment, specific gravity:** color should be absent, so also odor; take the reaction with litmus paper, dipping both red and blue slips into the fluid at once; if neither change color, the reaction is *neutral;* if the blue is turned red, the reaction is *acid;* if the red is turned blue, the reaction is *alkaline.* A variety of litmus paper may now be obtained, which turns red in an acid liquid, and blue in an alkaline one. The transparency should not be great, for normal saliva is turbid; the consistence should be glairy, viscid, and there should be froth. Notice whether the sediment after standing some hours is opaque and whitish, or whether *stringy masses* are present in it. [The latter is not likely to be the case in saliva obtained as directed in (I) but is sometimes noticed in cases of chronic gastric catarrh].

N. B. In order to note the physical characters in detail, to collect and examine the sediment, and to ascertain the specific gravity, several specimens of saliva collected in separate beakers or cylinders should be conveniently procured, in order to save time. The first specimen may be set aside, in order that the sediment may settle in it; the second specimen may be used for observation of the color, odor, reaction, and also for the chemical tests; the third, in case of a scanty supply, may be set aside for dilution in order to ascertain the specific gravity by methods hereafter to be explained.

III. Next ascertain the specific gravity, which can be done by means of the urinometer:

The urinometer consists of a glass float weighted below with a bulb of mercury, and with a stem graduated from 0 to 60 at intervals of one or two degrees; the instrument should sink to zero when floated in distilled water in the beaker, which usually accompanies it. If there is plenty of saliva, the specific gravity can be obtained at once by floating the urinometer in the saliva, and reading off the number on the scale at the level of the liquid. It should average from 1002 to 1006, or possibly, 1008 or 9. If the amount of saliva is scanty, the specific gravity may be obtained by dilution: take *one* part of saliva by volume (bulk), and add one part of distilled water to it so as to make enough liquid to fill the cylinder, or beaker used, say two-thirds full; take the specific gravity as before and multiply the last figure of it by 2, and the result is the true specific gravity of the saliva.

IV. Next proceed with **chemical tests,** first for the **normal** constituents, next for possible **abnormal** ones.

571. **A. Qualitative tests for normal constituents.—**

1. Boil a little of the saliva in a slender, long test-tube, held between thumb and forefinger by the closed end; heat the *upper part*

only of the fluid. A turbidity noticed indicates presence of *albumin.*

2. To a fresh supply of the saliva, add a drop or two of *ferric chloride:* a blood-red color indicates presence of sulphocyanide. This test is sometimes performed by means of prepared test-paper: immerse strips of paper in an amber-colored solution of ferric chloride, to which a few drops of hydrochloric acid have been added. Let dry. A drop of saliva will give a red spot on such paper. The red color is removed by addition of a drop of mercuric chloride.

[The test may fail altogether, in which case the saliva must be distilled with phosphoric acid and the first of the distillate tested].

3. Collect a plentiful supply of the saliva by chewing rubber, or by inhaling ether vapor into the mouth: add four times its volume of water, stir well, let settle, pour off the supernatant liquid from the sediment. Prepare some starch mucilage by rubbing a little starch into a thin paste, with a little cold water, then pouring into about half a pint of boiling water. Boil for five or ten minutes and when cool, decant the clear liquid. Pour some of the starch mucilage into a small beaker, add a little of the diluted saliva, lay aside for ten minutes in a drying oven where the temperature is about 95° to 104°; in default of a hot chamber, place

the beaker some time in water of temperature of 104°, or warm the mixture very gently in a test-tube over a flame, taking care by cooling with the hand that the temperature does not rise much above 95°. Apply the tests for starch and for sugar, and it will be found that the starch has disappeared wholly or in part, and that sugar has been formed, showing presence of *diastatic ferment* (ptyalin) in saliva.

[The test for sugar should be made as follows: procure what is known as Fehling's test-liquid, essentially an alkaline solution of copper sulphate, boil a little of it diluted with four parts of water in a test-tube, and if it does not lose its blue color on cooling it is fit for use. Now add a drop or two of the starch mucilage on which the saliva has acted, and raise just to boiling point again; *reddish-yellow precipitate* indicates presence of grape-sugar. Compare now the action of a weak solution of *iodine* in alcohol on the original starch mucilage, and on that which has been acted on by the saliva; with the original it should form a deep indigo-blue compound].

4. Fill a tall beaker with dilute acetic acid —say one part of the ordinary acid to two or three of water—and let the saliva drop slowly into it; *stringy flakes* indicate presence of *mucin*.

5. To show the inorganic acids, evaporate the saliva to dryness in a porcelain crucible; do not withdraw the heat till the residue is well blackened or darkened from charring of the organic matter; when it is so, remove, let

cool, and add a little distilled water, stirring well, and adding a drop of acetic acid. Filter and divide the filtrate into three parts; to two add a few drops of nitric acid, and to one a solution of silver nitrate; a turbidity indicates presence of *chlorides*. The precipitate thus formed should be soluble in ammonia. To the other add ammonium molybdate solution and heat; a yellowish color, becoming possibly a precipitate, indicates presence of *phosphates*. To the third add a drop or two of hydrochloric acid and some barium chloride solution; a white precipitate shows presence of *sulphates*.

6. To show the presence of *lime* and *magnesia*, take a portion of the filtrate obtained in 5, and divide it into two parts; to the first add ammonium oxalate solution: a white precipitate indicates presence of *calcium* (lime); to the second part add ammonia and sodium phosphate solution: a white precipitate indicates presence of *magnesium*. The calcium precipitate should be insoluble in acetic acid but soluble in nitric; the magnesium precipitate should dissolve completely in acetic acid on shaking.

572. B. **Quantitative analysis.**—

Ptyalin may be separated nearly pure by precipitating fresh saliva with dilute normal phosphoric acid and then adding lime-water; filter off precipitate and dissolve it in distilled water, from which it is to be precipitated by alcohol, collected on a filter, washed repeatedly with a mixture of alcohol and water, dried, and weighed.*

Mucin, obtained as in the qualitative method, can be collected on a filter, washed with alcohol, dried, and weighed. The weight of the saliva being known, the percentage of ptyalin, or of mucin, can be readily calculated by dividing each weight by the weight of the entire saliva used.

Fatty matters can be estimated as follows: a definite quantity of saliva being evaporated to dryness over the water-bath, triturate the residue carefully, scraping off any that may adhere, and exhaust thoroughly with boiling ether. Evaporate in a weighed platinum capsule † and the increase in weight of the capsule represents the amount of fatty matter present. The operation should be repeated often enough to obtain a reasonably constant result.

Potassium Sulphocyanide. Dissolve perfectly dry potassic sulphocyanide, 0.05 gram in water (100 C. c.), and add to it ferric chloride till no more intensity of color is produced; then measure the volume of liquid. This is the test solution *a*.

Now take a definite volume of the saliva, and place it in a small, graduated, cylindrical glass vessel; add to it a drop or two of hydrochloric acid and ferric chloride, with brisk stirring, until its maximum of intensity of color is obtained; call this *b*.

Having carefully noted the intensity of the tint *b*, place three or four cylinders similar to that holding the saliva beside it on a piece of white paper in a good light; then add to one of these by means of a graduated pipette a few C. c. of the ferric sulphocyanide solution (*a*); make it up

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* In order to dry properly there is need of a *drying oven;* filters are conveniently dried and weighed by placing them between two watch glasses held together by a clamp. For weighing there is need of a delicate *chemical balance.*

† A nickel crucible may be used for this operation.

to the same volume as the saliva (*b*) using distilled water. After stirring well note the intensity of color by looking vertically downwards through the column of liquid, and compare it with that of the saliva. If not so deep a red tint, a fresh experiment must be made in the same way, but using more of the sulphocyanide test solution. We thus proceed till an equal intensity of color is obtained in the two columns of liquid. From the amount of the test solution *a* required, we can easily calculate the percentage of sulphocyanide in the saliva. (Charles).

Each C. c. of the test solution (*a*) contains .0005 grams sulphocyanide. If, therefore, 10 C. c. of the test solution are required, the amount of sulphocyanide in the saliva is .0005 × 10 or .005, and so on. Divide the amount of sulphocyanide found by the weight of the saliva, and the quotient is the percentage of sulphocyanide.

The **chlorides** may be estimated *volumetrically*,* that is by use of standard solutions, directly from the saliva after the removal of the organic constituents. Fifty cubic centimetres of saliva should be boiled and filtered. To the filtrate add an equal volume of saturated baryta solution (1 volume barium nitrate, 2 volumes barium hydrate, each a saturated solution); this precipitates the organic constituents and phosphates. Filter, and to the filtrate add, drop by drop, a standard solution of mercuric nitrate, of which 1 C.c. precipitates .01 gram of sodium chloride. The number of C.c. used shows the number of $\frac{1}{100}$ths of a gram of sodium chloride present. The filtrate from the baryta precipitate should be acidulated with a few drops of nitric acid, before the mercuric nitrate is added.

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*In *volumetric* analysis the determination is in general brought about by adding to a weighed quantity of the substance to be examined a solution of some reagent of known strength, until the reaction is exactly completed. The operation is termed *titration*, and requires skill and practice. The student is referred to "Sutton's Volumetric Analysis."

573. **Special tests for constituents of oral secretions:** T. Storer How has arranged a series of **litmus tests of oral fluids** together with a system of nomenclature as follows: first take with the foil-pliers a piece of blue litmus, wet it with parotid saliva and put the wet piece on a leaf from a foil book. In like manner treat the sub-max. saliva, placing the wet piece on the leaf below the other. Thus also test between the teeth, in carious cavities, pulp cavities, roots, sulci, pus-pockets, under calculi, plates, bridges, etc. Make the same tests in the same order with red litmus. Fill up the blank with the other statistics, and then note and record either the unchanged color of both the blue and the red by the symbol **N**, neutral, or the change of the blue to red by the symbol **A** acid; or the change of the red to blue by the symbol **AL** alkaline, as the case may be.

As abbreviations for the different reactions, How suggests the following:

AL —Alkaline.
A —Acid.
N —Neutral.
I —Slightly, alkaline or acid.
L —Obviously, alkaline or acid.
U —Decidedly, alkaline or acid.
O —Excessively, alkaline or acid.

[Dr. Oliver, of England, has prepared for use in urinary analysis, litmus paper charged with a definite quantity of alkali so as to distinguish several grades of acidity in reaction, such as *sub-acid*, *acid*, *hyper-acid*, etc. It would seem as if these papers under certain circumstances might be of use in salivary analysis].

Detection of mercury in saliva: collect all the saliva possible in 24 hours, and acidulate it with dilute hydrochloric acid (1 part acid to 9 of water). The mixture is heated for two hours on a water bath, filtered, and filtrate marked (*a*), and concentrated to half its bulk over the water bath. Go back to the precipitate on the filter, place it in a beaker filled three parts full with dilute hydrochloric acid (1 part acid to 6 parts water), and heat the whole over a water bath, adding from time to time small quantities of potassium chlorate, and constantly stirring to dissolve the organic residue. When this is completely dissolved, filter, and add filtrate to the previous filtrate marked *a*. Concentrate the mixed filtrates to one-fourth their bulk. The solution contains as dichloride, any mercury that may be present. To prove the presence of mercury, (1) place a drop of the solution on a gold or copper coin, and touch with blade of knife; a bright, silvery stain will appear. (2) Place a few strips of *pure* copper-foil in a test-tube, and add a little of the solution, and boil; the mercury will be deposited on the surface of the copper-foil. Remove the strips and wash them with very dilute solution of ammonia, and dry them between blotting-paper. Then place them at the bottom of a narrow glass tube (German glass), and apply heat; the mercury will be volatilized, and deposited as a ring of minute globules at the upper end of the tube. The character of these globules can generally be recognized by the eye. If, however, they are too small, remove the strips of copper from the tube, and dissolve the ring by the addition of a drop or so of dilute nitro-muriatic acid, and gently evaporate the solution. Dissolve the residue in a little water, and divide into two equal portions: (*a*) tested with a drop of dilute solution of potassium iodide, it gives a red precipitate of mercuric iodide, soluble in excess of potassium iodide solution; (*b*) a drop added to solution of caustic potash gives a yellow precipitate of hydrated mercuric oxide, insoluble in excess of liquor potassæ. (Ralfe).

Microscopic examination of the sediment: let the saliva settle in a conical vessel as directed, and examine the sediment with a power of 400 to 500 diameters; note the salivary corpuscles, various kinds of epithelial cells. With higher powers bacteria, fungi, etc., may be studied.

574. **Morphology of the human sputum:** E. Cutter has made a partial list of the forms and substances found in the human sputum.

1. Mucous corpuscles.
2. Mucous cells swarming with the moving spores, probably of the leptothrix buccalis; not found in the mouths of healthy infants.
3. Mucous corpuscles distended with crystalline and other bodies.
4. Epithelia, ciliate and non-ciliate.
5. Spirillum.
6. Vibriones.
7. Micrococcus spores.
8. Bacilli.
9. Spirulina splendens.
10. Gemiasma verdans and rubra.
11. Alcoholic and lactic acid alcoholic yeast.
12. Vinegar yeast and lactic acid vinegar yeast.
13. Mycelial filaments of vinegar and lactic acid yeasts.
14. Leptothrix buccalis spores and filaments.
15. Papillæ of tongue, usually infiltrated with spores of 14.
16. Mucor malignans.
17. Hairs of plants and animals.
18. Vegetations found in croupal membranes.
19. Pus corpuscles.
20. Blood corpuscles, white and red.
21. Clots of blood.
22. Granular tubercular masses.
23. Elastic lung-fibres.
24. Inelastic lung-fibres.
25. Lumen of veins and arteries.
26. Carbonized tissue from lungs.
27. Partially carbonized vegetable tissues from smoke.
28. Oxalate of lime.
29. Uric acid crystals.
30. Cystine.
31. Phosphate of lime.
32. Triple phosphate.
33. Cholesterine.
34. Calculi, made up of one or more of 28, 29, 30, 31, 32, 33. These may all come under the appellation of "gravel of the lungs."
35. Other crystals whose names have not been made out.
36. Amorphous, organic, and inorganic matters, including dust and dirt inhaled from the atmosphere.
37. Portions of feathers of animals and insects.
38. Potato starch.
39. Wheatstarch.
40. Elements of animal food eaten, cooked and uncooked.
41. Elements of vegetable food eaten,cooked and uncooked.
42. Cotton fibre.
43. Silk fibre.
44. Linen fibre.
45. Wool fibre.
46. Woody fibres,pitted ducts,etc.
47. Asthmatos ciliaris.

575. **Analysis of teeth and tartar:**—

I. Qualitative analysis of the teeth.

1. **To show the presence of organic matter, ossein, etc.** Digest the teeth for a day or two in dilute hydrochloric acid (10 per cent). The earthy salts will be dissolved out, and what remains will be *soft* and *elastic*.

2. **To show the earthy salts:** place a few teeth in a clear fire and let them remain there until perfectly white. Powder, and dissolve in hydrochloric acid; dilute and add plenty of ammonia; a white, gelatinous precipitate occurs of *phosphates of lime and magnesia*. Filter, and to the filtrate add oxalate of ammonium: a precipitate of *oxalate of calcium* shows itself, indicating presence of lime not as phosphate; prove that there is *carbonate* by digesting powdered, uncalcined teeth in dilute hydrochloric acid, when an effervescence due to carbonic anhydride takes place.

II. Quantitative analysis of teeth: the teeth should be cleaned and reduced to powder in a mortar; weigh out 5 to 10 grams of powdered teeth, dry at 212° and then at 248°, until it ceases to lose weight. 1. The loss gives the **water**. 2. Take the mass thus obtained and calcine in a porcelain crucible at as low a temperature as possible; the loss in weight gives the **organic matter**, and the residue the **ash.** It is desirable to saturate the calcined residue with ammonium carbonate before weighing, and then to heat again to an elevated temperature. 3. Dissolve with the aid of gentle heat the ash obtained in 2, in as little moderately dilute hydrochloric acid as possible; add ammonia in excess to the solution; a precipitate is thrown down, chiefly of calcium phosphate, with a little magnesium phosphate and calcium fluoride. Filter, and wash the precipitate with water containing ammonia. 4. To the filtrate add ammonium oxalate to complete precipitation, boil, filter, dry the precipitated oxalate of calcium, ignite, and weigh; the result is the amount of **calcium carbonate**. 5. Go back to the precipitate obtained in 3, dissolve in strong acetic acid with the aid of heat (calcine any remaining undissolved, and estimate as pyrophosphate), and to the solution add ammonium oxalate; boil and lay aside for 12 to 24 hours; collect the precipitated calcium oxalate on a filter, wash, dry, and ignite both precipitate and filter. Care must be taken not to heat too strongly, and it is always advisable to moisten the precipitate with ammonium carbonate before drying at a moderate heat and weighing. The result is calcium carbonate. Calculate the total amount of lime by adding the figures obtained in 4 and 5, and making the following proportion:

$$\underset{CaCO_3}{100} : \underset{Ca.}{40} = \text{weight obtained} : x$$

6. Evaporate the filtrate of 5 to small bulk, and also the washings of 5, mix with excess of ammonia, stir well, boil, lay aside for 12 hours; collect on a filter, wash with water containing ammonia, dry, ignite to redness, weigh. Calculate the magnesia by the following:

$$\underset{\substack{\text{Pyrophosphate}\\ \text{of}\\ \text{magnesium.}}}{174} : \underset{\substack{\text{Magnesia.}\\ \\ \text{(2 molecules).}}}{80} = \text{weight obtained} : x.$$

7. To the washings and filtrate obtained in 6, add a mixture of magnesium sulphate, ammonium chloride, and ammonia, lay aside for 24 hours, filter, wash with water

containing ammonia, dry, ignite to redness, weigh. Calculate the phosphoric acid by the following:

$$1 : 0.216 = \text{weight obtained} : x.$$

576. III. Qualitative and quantitative analysis of tartar:

A. 1. Take a gram of tartar, calcine in air, dissolve residue in nitric acid; the part remaining undissolved is **silica.** 2. Boil the nitric acid solution for two hours with great excess of pure sodium carbonate, filter, and the bases, lime, magnesia, etc., remain on the filter as carbonate or oxide. 3. Wash the precipitate well, add ammonium chloride in excess, then ammonia. A precipitate shows presence of **iron.** Now precipitate the **calcium** by adding excess of ammonium carbonate. Filter. 4. To the filtrate add sodium phosphate, and a slight precipitate of ammonio-**magnesium** phosphate is obtained, which after 24 hours is complete. Calcination gives very slight residue, so that the magnesia may be reckoned as a **trace.**

B. 1. Now take a fresh supply of tartar, reduce to fine powder, weigh, treat with boiling water, which removes soluble alkaline salts and a part of the organic matter. Filter, evaporate filtrate to dryness, calcine, and the residue consists in the main of chlorides and sulphates and should be weighed.

2. Take the precipitate obtained in 1, dry, weigh, calcine in an open porcelain crucible, weigh. Loss is **animal matter.**

3. Take residue obtained in 2, boil in concentrated solution of ammonium chloride, which converts all the calcium carbonate into calcium chloride, filter, treat filtrate with calcium oxalate, wash the precipitate, dry, calcine, weigh, and the result is the **carbonate of calcium.**

4. Take precipitate obtained in 3, wash it off from the filter paper, dissolve in nitric acid; all is dissolved except a slight residue (silica): which should be washed, calcined, and weighed. The result is the amount of **silica.**

5. Add to the nitric acid solution obtained in 4, some ammonia—enough to overcome the acidity. The **phosphates** are precipitated. Now add acetic acid in excess; part of the precipitate is dissolved, part is not. Filter. Collect the precipitate on the filter, wash it off, calcine, and weigh. The result is **phosphate of iron.**

6. The filtrate contains the calcium phosphate: neutralize with ammonia, then add ammonium oxalate, filter, collect precipitate on filter, wash, calcine, weigh, and the result is calcium carbonate. Calculate the **lime** from this.

7. To the filtrate obtained in 6, add ammoniacal magnesium nitrate, and in 24 hours triple phosphate is completely precipitated; collect on filter, calcine, weigh, and calculate the **phosphoric acid** from the weight as pyrophosphate.

ANALYSIS OF URINE.

577. A. Note the *quantity* of urine voided in 24 hours, the *color*, *odor*, *specific gravity* (using urinometer, section 563), *reaction*, (using litmus, section 563, 11), *transparency*, and *consistence*. Normal urine is excreted in quantity about three pints in 24 hours, of straw-yellow color, aromatic, characteristic odor, 1015 to 1025 in specific gravity, clear, with slight mucous "cloud" settling as the urine stands; normal urine is an easily dropping fluid like water.

B. Get the urine perfectly clear by filtering, if necessary, through a number of filter-papers folded together, then test for *albumin*. Place clear, filtered urine to depth of an inch in a test-tube; hold latter inclined, and allow pure, colorless nitric acid to flow down side of test-tube into the urine. Use a nipple-pipette for delivering the acid. A clear-cut whitish band of coagulated albumin will be seen at the juncture of urine and acid, if the urine contains albumin. Confirm by taking fresh amount of clear, filtered urine and pouring into test-tube until two-thirds full; add a drop or two of acetic acid and heat upper part of column of urine, holding test-tube at the bottom between thumb and fore-finger. A turbidity seen in the heated portion indicates albumin.

C. Test for *sugar*, first removing albumin, if any is present, by boiling the urine to which a drop of acetic acid has been added, and filtering. Test the filtered urine for sugar as in section 569, A.3. Or boil the filtered urine with an equal bulk of Liquor Potassæ and a decided yellow coloration becoming darker indicates sugar. Pay no attention to "flocks" seen in the liquid, as these are merely precipitated phosphates.

D. Test for *bile* precisely as for albumin, test 1, using, however, nitrous acid instead of nitric. [Nitrous acid may be made by boiling nitric acid with a bit of wood as end of tooth-pick]. A set of colors will be seen at the juncture, if bile is present. Of the colors, *green* is the most constant and the first in order from above downward.

E. Let four fluidounces of the urine settle in a conical glass vessel covered over to keep out dust. After the sediment has well settled, pour off supernatant urine and test sediment chemically or examine with microscope. [Use of the latter is to be preferred, but will not be considered here]. Test for *urates* by warming a little of the sediment in a test-tube. If gentle heat dissolves the sediment, it is composed of urates. If not, add acetic acid, shake well and warm; if now it clears, *phosphates* are in the sediment. If no results thus far, take fresh amount of the sediment and add a drop or two of Liquor Potassæ; if the sediment become stringy, *pus* is present.

Blood may be recognized by the color imparted to the sediment, which does not clear on being heated. *Uric acid* is often recognized by the naked eye, as it occurs in the form of reddish grains on the side or bottom of the glass.

F. Estimate *urea* the chief normal constituent of urine, (quantity 20 to 40 grammes daily). Use any of the convenient instruments, as Marshall's, Greene's, Doremus's, Squibb's, some of which may be obtained with full directions for use from the various dealers.*

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*For further information on this subject, the reader is referred to the author's work on " Diseases of the Kidneys."

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