NAMING THE ELEMENTS

Every element has been given a definite name and for covenience a nick name which in chemical language is called a symbol. When a new element is discovered, the discoverer usually gets the opportunity to suggest a name for the ele ment, which is then approved by The International Union of Pure and Applied Chemistry-IUPAC.

Symbols have been derived either by taking the first alphabet of the name of the element or by taking the first alphabet and one more alphabet from the name of the element (for example, C for carbon; N for nitrogen; O for oxygen; Ca for calcium; Al for aluminium, etc.) but there are quite number of elements for which the derivation of the symbol is not quite so obvious: for example, Na for sodium; Pb for lead; Ag for silver; Fe for iron, etc. Such anomalies occur because of the way, the elements were originally named. Some of the elements were given names in other languages such as Latin, German, etc.

Of all the elements on the periodic table, C,S, Fe, Cu, As, Ag, Sn, Sb, Au, Hg, Pb and Bi were known to ancient civilisations so the date of their 'discovery' is not known. Of these, Fe, Cu, Ag, Sn, Sb, Au, Hg and Pb are the abbreviations for the Latin names ferrum, cuprum, argentum, stannum, stibium, aurum, hydragyrum and plumbum. The earliest known discovery of an element was that of phosphorus, P. It was isolated in 1669 by Hennig Brand from the distillation of urine (he was appar ently trying to make silver or gold-unsuccessfully, of course!) and was named after the Greek word phosphoros, meaning 'bringer of light', as the element glows in the dark.

Scientist/Persons After Whom Elements Have Been Named

Name	Brief biography	Element named
1. Vasilii Yefrafovich von Samarski-Bykhovets (1803-1870)	Chief of staff of the Russian Corps of Mining. Engineers	samarium, Sm (element 62)
2. Johan Gadolin (1760-1852)	Finnish chemist; first person to isolate a lanthanide element	gadolinium, Gd (element 64)
3. Pierre Curie (1859-1906) and Marie Curie (1867-1934)	Husband and wife scientific team; Pierre French and Marie Polish by birth; jointly won the Nobel Prize in physics in 1903	curium, Cm (element 96) einsteinium, Es(element 99)
4. Albert Einstein (1879-1955)	Most famous scientist of the wentieth century; German by birth; won the Nobel Prize in physics in 1921	
5. Enrico Fermi (1901-1954)	Italian physicist; made great advances in the study of nuclearreactions; won the Nobel Prize in physics in 1938	fermium, Fm.(element 100)
6. Dmitri Mendeleev (1834-1907)	Russian chemist; renowned for the development of the periodic table	mendelevium, Md (element 101)
7. Alfred Nobel (1833-1896)	Swedish inventor of dynamite an patron of the Nobel Prizes	nobelium, No (element 102)

8. Ernest Lawrence (1901-1958)	American inventor of the cyclotron; won the Nobel Prize in physics in 1939	lawrencium, Lr (element 103)
9. Ernest Rutherford. (1871-1937)	New Zealand physicist/chemist; made seminal contributions to understanding the structure of the atom; won the Nobel Prize in chemistry in 1908	rutherfordium, Rf (element 104)
10. Glenn Seaborg (1912-1999)	American chemist; first prepared many of the elements beyond ranium in the periodic table; won the Nobel Prize in chemistry in 1951	seaborgium, Sg (element 106)
11. Niels Bohr (1885-1962)	Danish physicist; studied electronic energy levels within atoms, which help our understanding of the atom; won the Nobel Prize in physics in 1922	bohrium, Bh(element 107)
12. Lise Meitner (1878-1968)	Austrian physicist; made discoveries concerning nuclear fission; controversially never awarded a Nobel Prize	meitnerium, Mt (element 109)
13.Wihelm Rontgen (1845-1923	German physicist; discoverer of X-rays; won the Nobel Prize in physics in 1901	röntgenium, Rg (element 111)

Elements have been named after countries (germanium, francium, am ericium, polonium) and even after the places they were first discovered; the Swedish town of Ytterby has the distinction of having four elements (erbium, Er; ytterbium, Yb; yttrium, Y; and terbium, Tb) named after it, as these were found in depos its close to the town. Surprisingly few elements have been named after people; at present, only 14 people have been immortalised on the periodic table, and they are listed in table given above.

Nomenclature of Elements with Atomic Numbers > 100

The elements coming after uranium which do not exist naturally, are named **transuranic or transuranium** elements. The elements with Z = 104 - 116 and 118 have been reported recently and are called **transactinides or super-heavy** elements. These are synthetic, i.e., man-made elements. The production of synthetic elements requires binuclear reactions between two positive nuclei that must be fused together against the force of electrical repulsion. Nuclear accelerators are used for this purpose. There are currently two major groups working on producing super-heavy elements, one in California, USA and the other at Dubna near Moscow, Russia. By convention, the workers who discover a new element have the right to name it. However, in recent years, on account of competitive spirit disputes have arisen over the names of the newly discovered elements. For example, both American and Russian scientists claimed credit for the discovery of the element 104. The Americans named it **Rutherfordium** whereas Russians named it **Kurchatovium**. To avoid such problems, the IUPAC suggested that until the discovery of the new element is proved and its name is officially recognised, a systematic nomenclature based on the atomic number of the element be followed. The following are the points of the nomenclature of the element having atomic umbers > 100

1. The names are derived by using the numerical roots for three digits in the atomic number of the element and adding the ending -ium. The roots for the numbers are:

Digit	Name	Abbreviation
0	nil	n
1	un	u
2	bi	b
3	tri	t
4	quad	q
5	pent	p
6	hex	h
7	sept	s
8	oct	o
9	enn	e

2. In certain cases the names are shortened. For example, biium' and 'triium' are shortened to 'bium' and 'trium' and 'ennnil' is shortened to 'ennil'.

3. The symbol for the element is made up from the first letters from the roots which make up the names. The mixture of Latin and Greek roots has been chosen to ensure that the symbols are all different.

IUPAC Nomenclature for the Super Heavy-Elements

Atomic number	Name of the element		Symbol
101	Unnilunium	Un (1) – nil (0) – un (1) – ium	(Unu)
102	Unnilbium	Un (1) – nil (0) – bi (2) – um	(Unb)
103	Unniltrium	Un (1) – nil (0) – tri (3) – um	(Unt)
104	Unnilquadium	Un (1) – nil (0) – quad (4) – ium	(Unq)
105	Unnilpentium		(Unp)
106	Unnilhexium		(Unh)
107	Unnilseptium		(Uns)
108	Unniloctium		(Uno)
109	Unnilennium		(Une)
110	Ununnilium		(Uun)
111	Unununium	Un (1) – un (1) – nu (1) – ium	(Uuu)
112	Ununbium	Un (1) – un (1) – bi (2) – um	(Uub)
113	Ununtrium	Un (1) – un (1) – tri (3) – um	(Uut)
114	Ununquadium	Un (1) – un (1) – quad (4) – ium	(Uuq)
115	Ununpentium	Un (1) – un (1) – pent (5) – ium	(Uup)
116	Ununhexium	Un (1) – un (1) – hex (6) – ium	(Uuh)
118	Ununoctium	Un (1) – un (1) – oct (8) – ium	(Uuo)
120	Unbinilium	Un (1) – bi (2) – nil (0) – ium	(Ubn)

At present 117 elements have been discovered .These are the elements with atomic number upto 116 and 118 .Element with atomic number 117 is yet to be discovered. Official IUPAC names for the elements upto 111 have been approved by the Commission on Nomenclature of Inorganic Chemistry (CNIC).

Thus, the newly discovered element is first given a temporary name on the basis of atomic number and later on a permanent name with symbol is alloted by the consent of IUPAC representatives.

Nomenclature of Elements with Atomic Number above 100

Atomic number	Name on the basis of atomic number (Temporary)	Official IUPAC name (Permanent)	Symbol
101	Unnilunium	Mendelevium	Md
102	Unnilbium	Nobelium	No
103	Unniltrium	Lawrencium	Lr
104	Unnilquadium	Rutherfordium	Rf
105	Unnilpentium	Dubnium	Db
106	Unnilhexium	Seaborgium	Sg
107	Unnilseptium	Bohrium	Bh
108	Unniloctium	Hassium	Hs
109	Unnilennium	Meitnerium	Mt
110	Ununnilium	Darmstadtium	Ds
111	Unununium	Rontgenium	Rg
112	Ununbium*	—	—
113	Ununtrium*	—	—
114	Ununquadium*	—	—
115	Ununpentium*	—	—
116	Ununhexium*	—	—
118	Ununoctium*	—	—

*Official IUPAC name yet to be announced.

ELECTRONIC CONFIGURATIONS AND THE PERIODIC TABLE

The aufbau principle and electronic configuration of the atoms of elements provide a theoretical foundation for the classification of elements. It is now recognised that the periodic table is essentially the consequence of the periodic variation in electronic configuration of the atoms of the elements which determine the physical and chemical properties of the elements and their compounds. The elements in a vertical column, i.e., in a group of the periodic table exhibit similar chemical behaviour. This is due to the fact that these elements have same number and same distribution of electrons in their outermost orbitals, i.e., in the valency shell. For example, the group IA elements (alkali metals) which show same chemical behaviour possess same valence shell configuration, i.e., ns^1. Similarly, the group VIIA elements (halogens) which are similar in chemical properties possess same valence shell configuration, ns^2np^5.

In the periodic table, the elements have been arranged in order of increasing atomic number, i.e., increased number of orbital electrons. Thus, each element contains one more orbital electron than the preceeding element. Each period starts with ns^1 configuration and ends with a noble gas (He, $1s^2$, in the first period and ns'np configuration with rest of the elements). The sequence in which the various energy levels are filled determines the number of elements.

1st period	1s				2 elements in this period
2nd period	2s			2p	8 elements in this period
3rd period	3s			3p	8 elements in this period
4th period	4s		3d	4p	18 elements in this period
5th period	5s		4d	5p	18 elements in this period
6th period	6s	4f	5d	6p	32 elements in this period
7th period	7s	5f	6d	7p	32 elements in this period

The ground state electronic configurations of the elements are given in the following table. For the sake of simplicity, condensed electronic configurations of the elements are given. In writing condensed electronic configuration of an element, the electronic configuration of the nearest noble gas of lower atomic number is represented by its chemical symbol in square bracket. For example, the condensed electronic configuration of sodium can be written as: $[Ne]3s^1$

Classification of Elements on the Basis of Electronic Configurations

1. Bohr's Classification

The classification proposed by Bohr is based on complete and incomplete energy shells. The elements have been grouped into four types:

(i) Inert gases: In the atoms of these elements, the s-and p-subshells of the outermost shell are completely filled. With the exception of helium which has 1s configuration, all other have ns^2np^6 configuration. Because of stable configuration, these elements do not show chemical activity under normal conditions. These are all gases under normal conditions and thus, termed as inert gases. Under special conditions, the higher members do form some compounds with other elements and hence, the name has been changed to noble gases. Seven elements He, Ne, Ar, Kr, Xe, Rn and Uuo belong to this group. This group was unknown at the time when Mendeleev presented the periodic table. These elements are the end members of the respective periods of the periodic table, respectively.

(ii) Representative or Normal elements: In these elements atoms have all shells complete except outermost shell which is incomplete. The number of electrons in the outermost shell varies from 1 to 7, i.e., the configuration of the outermost shell varies from ns^1 to ns^2 np. These elements comprise of some metals, all non-metals and metalloids. These are the elements which are found in nature in abundance and active in nature. On account of this, these elements are called representative elements. All the three types of valencies are observed in the case of these elements. These elements have one of the following configurations in their outermost shell:

$$ns^1, ns^2, ns^2\,np^1, ns^2\,np^2, ns^2\,np^3, ns^2\,np^4, ns^2\,mp^5$$

1 2 3 4 5 6 7

The number of electrons present in the outerniost shell signify the group to which these elements belong

(iii) Transition elements: In the atoms of these elements the outermost shell and the penultimate shell (next to the outermost) are incomplete. These elements have the general configuration (n-112 either in the ground state or in excited state. These elements are present in fourth, fifth, sixth and seventh periods of periodic table and are called transition elements. The elements showing horizontal relationship as well as vertical relationship are termed transition elements. There are four transition series, every series consists of 9 elements each. Each series starts with a member of third group and ends with a member of first group.

1st series	Sc 21 to Cu 29	$3d^{1-9}4s^2$
2nd series	Y 39 to Ag 47	$4d^{1-9}5s^2$
3rd series	La 57 to Au 79	$5d^{1-9}6s^2$ [The elements from Ce (58) to Lu (71) are not included]
4th series	Ac 89, Rf (104), Db (105) and 106 to 111	[The elements from Th (90) to Lr (103) are not included]

The elements belonging to this group are all metals.

(iv) Inner-transition elements: Atoms of these ele ments have three outermost shells incomplete. The general configuration is $(n-2)f^{1-14}$ $(n-1)d^{0 \text{ or } 1}$ ns^2 . There are two series of elements,

(a) Lanthanides or rare-earths from Ce (58) to Lu (71)

(b) Actinides from Th (90) to Lr (103).

Each series consists of 14 elements, L.e., in the lanthanides, 4f is gradually filled up while in actinides, 5f is gradually filled up. The properties of these elements are similar to transition elements. The members of actinide series are radioactive and majority of them are not found in nature. The elements from atomic number 93 onwards are called transuranic elements and have been discovered by artificial means.

In this classification, the elements Zn, Cd and Hg have not been included in any of the four groups of elements. The elements Lu and Lr of the inner-transition group have *(1-2)f* shell complete consisting of 14 electrons, hence their inclusion in this group is not justified.

2. Differentiating Electron Classifications

(Division of elements into *s*-, *p*-, *d*-, *f*-Blocks)

This classification divides the elements into four types, i.e., *s*-, *p*-, *d*- and *f*-block elements depending on the nature of the atomic shell into which the last electron enters. The last electron is called as differentiating electron. This classification is most rational and is now commonly in use. The energy shell into which the last electron enters is of highest energy. This may not always belong to the outermost energy shell. In general, it can be said that aufbau principle is follow ed in filling of various energy shells with few exceptions.

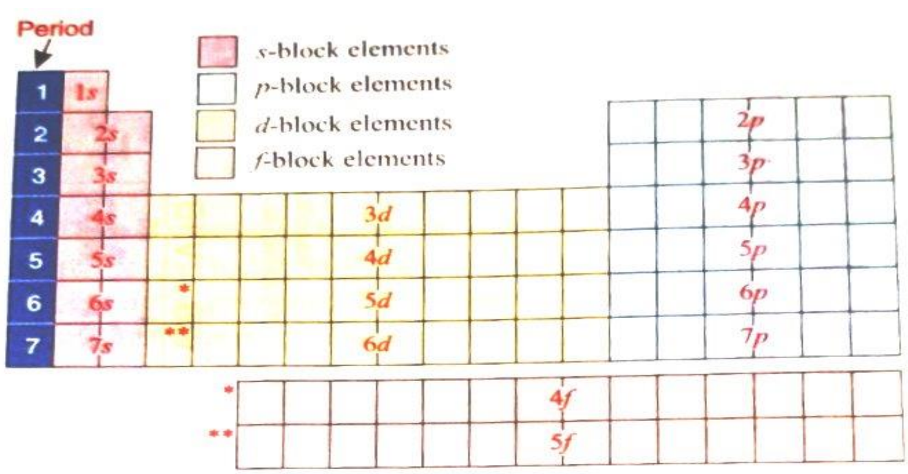


Fig. Periodic table, illustrating division of elements into s-, p-, d-, f- Blocks

(i) s-Block Elements

In these elements, the last electron enters the ns energy shell. The maximum capacity of ns energy shell is of two electrons, thus, these elements have valency shell confi guration either ns^1 or ns^2. The members of this block lie on the extreme left of the periodic table. The elements having ns^1 configuration are called alkali metals (Group IA elements) while those having ns^2 configuration are called alkaline earth metals (Group IIA elements). The elements of s-block are also called as Reactive metals.

Group IA

ns^1	Elements	Group IA		Alkali metals
H	1	$1s^1$	or	$1s^1$
Li	3	$1s^2, 2s^1$	or	[He] $2s^1$
Na	11	$1s^2, 2s^2 2p^6, 3s^1$	or	[Ne] $3s^1$
K	19	2, 8, 8, $4s^1$	or	[Ar] $4s^1$
Rb	37	2, 8, 18, 8, $5s^1$	or	[Kr] $5s^1$
Cs	55	2, 8, 18, 18, 8, $6s^1$	or	[Xe] $6s^1$
Fr	87	2, 8, 18, 32, 18, 8, $7s^1$	or	[Rn] $7s^1$

Group IIA

ns^2	Elements	Group IIA		Alkaline earth metals
He	2	$1s^2$ (Actually belongs to zero group)	or	$1s^2$
Be	4	$1s^2, 2s^2$	or	[He] $2s^2$
Mg	12	$1s^2, 2s^2 2p^6, 3s^2$	or	[Ne] $3s^2$
Ca	20	2, 8, 8, $4s^2$	or	[Ar] $4s^2$
Sr	38	2, 8, 18, 8, $5s^2$	or	[Kr] $5s^2$
Ba	56	2, 8, 18, 18, 8, $6s^2$	or	[Xe] $6s^2$
Ra	88	2, 8, 18, 32, 18, 8, $7s^2$	or	[Rn] $7s^2$

General Characteristics of s-Block Elements :

The general characteristics of alkali metals (Li, Na, K, Rb, Cs and Fr) and alkaline earth metals (Be, Mg, Ca, Sr, Ba and Ra), i.e., s-block elements are the following:

(i) They are soft metals, possess low melting and boiling points, have the largest atomic radii in their corresponding periods and are good conductors of heat and electricity.

(ii) They have low values of ionisation energies and hence highly electropositive.

(iii) They are very reactive and readily form ionic compounds. They show a fixed valency which depends on the number of electrons present in the outermost shell. The alkali metals show monovalency while alkaline earth metals show divalency. They are never found in free state in nature due to their reactive nature.

(iv) On account of low ionisation energies and highly negative electrode potentials, they act as strong reducing agents. The alkali and alkaline earth metals cannot be prepared by doing electrolysis of aqueous solutions of their salts.
(v) Except Be and Mg, they impart a characteristic colour to the flame.
(vi) The compounds of s-block elements are predomi nently ionic and colourless. However, lithium and beryllium compounds are covalent in nature.
(vii) They have great affinity for oxygen and nonmetals. The oxides are basic. The hydroxides are strong alkalies.
(viii) They displace hydrogen from acids and form corresponding salts.
(ix) With exception of Be and Mg, they decompose water and readily evolve hydrogen.

(ii) p-Block Elements

In the atoms of these elements, the last electron enters the p-subshell of the outermost shell. In these elements np subshell is gradually filled up. The valency shell configuration varies from $ns^2\ np^1$ to $ns^2\ np^6$.

Order of the period	$ns^2\ np^1$ (IIIrd group)	$ns^2\ np^2$ (IVth group)	$ns^2\ np^3$ (Vth group)	$ns^2\ np^4$ (VIth group)	$ns^2\ np^5$ (VIIth group)	$ns^2\ np^6$ (Zero group)
	A	A	A	A	A	
$n = 2$	B	C	N	O	F	Ne
	$2s^2\ 2p^1$	$2s^2\ 2p^2$	$2s^2\ 2p^3$	$2s^2\ 2p^4$	$2s^2\ 2p^5$	$2s^2\ 2p^6$
$n = 3$	Al	Si	P	S	Cl	Ar
	$3s^2\ 3p^1$	$3s^2\ 3p^2$	$3s^2\ 3p^3$	$3s^2\ 3p^4$	$3s^2\ 3p^5$	$3s^2\ 3p^6$
$n = 4$	Ga	Ge	As	Se	Br	Kr
	$4s^2\ 4p^1$	$4s^2\ 4p^2$	$4s^2\ 4p^3$	$4s^2\ 4p^4$	$4s^2\ 4p^5$	$4s^2\ 4p^6$
$n = 5$	In	Sn	Sb	Te	I	Xe
	$5s^2\ 5p^1$	$5s^2\ 5p^2$	$5s^2\ 5p^3$	$5s^2\ 5p^4$	$5s^2\ 5p^5$	$5s^2\ 5p^6$
$n = 6$	Tl	Pb	Bi	Po	At	Rn
	$6s^2\ 6p^1$	$6s^2\ 6p^2$	$6s^2\ 6p^3$	$6s^2\ 6p^4$	$6s^2\ 6p^5$	$6s^2\ 6p^6$
$n = 7$	Uut	Uuq	Uup	Uuh	—	Uuo
	$7s^2\ 7p^1$	$7s^2\ 7p^2$	$7s^2\ 7p^3$	$7s^2\ 7p^4$		$7s^2\ 7p^6$
	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18

[These elements belong to subgroup A in the extended form of periodic table except zero group in which no subgroup is present.] These elements include some metals, all non-metals and metalloids. s-block and p-block elements are collectively called normal or representative elements (except zero group elements). Each period ends with a member of zero group (18th group), i.e., a noble gas with a closed shell $ns^2\ np^6$ configuration. Prior to noble gas group, there are two chemically important groups of non-metals. These are halogens (group 17) and chalcogens (group 16).

General Characteristics of p-Block Elements

(i) p-block consists of the elements of six groups, viz., IIIA,IVA, VA, VIA, VIIA and zero group. The number of electrons in the outermost shell varies from 3 to 8, i.e., they have general configuration, ns^2np^{1-6}. The number of electrons in the penultimate shell is either 2 or 8 or 18.
(ii) Except F and inert gases, *p*-block elements show a number of oxidation states from +n to (n - 8) where n is the number of electrons present in the outermost shell.

Group	ΠIA	IVA	VA	VIA	VIIA
Oxid. States	+3	+4 to -4	+5 to -3	+6 to -2	+7 to -1

[Oxygen is an exception. However, it can show -2, -1,-1/2(KO_2), -1/3(KO_3) and +1/2(O_2PtF_6) oxidation states.]
(iii) The *p*-block elements generally show covalency but higher members can show electrovalency. The highly electronegative elements like halogens, O, S, N, etc., show electrovalency by accepting electrons and forming anions. Some of the elements show coordinate valency also.
(iv) In the period from left to right, there is regular increase in nonmetallic character. However, nonmetallic character decreases in the groups from top to bottom.
(v) Ionisation energies increase from left to right in a period while decrease in a group from top to bottom. The members of V group and zero group have exceptionally high values of ionisation energies on account of half filled and fully filled orbitals in the valency shell.
(vi) In every period, reducing nature decreases from left to right while oxidising nature increases. Reducing nature increases in a group from top to bottom. Halogens are strong oxidising agents.
(vii) Most of them are highly electronegative. The electronegativity increases in a period from left to right and decreases in a group from top to bottom.
(viii) Most of them form acidic oxides.
(ix) No member of p-block series or the salts imparts = characteristic colour to the flame.
(x) Chemical properties change from group to group. It is difficult to summarise them.
(xi) A number of elements of p-block series show the phenomenon of allotropy. Carbon, silicon, phosphorus sulphur, boron, germanium, tin, arsenic, etc., show thi property.
(xii) Catenation property is shown by many elements C p-block series such as carbon, silicon, germanium, nitroger oxygen, sulphur, etc.

(iii) d-Block Elements (Transition Elements)
The d-block elements are also called transition metals. In these elements, the last electron enters (n-1)d-subshell (d orbitals of the penultimate orbit), i.e., (n-1) d-subshell is gradually filled up. The configuration varies from $(n-1)d^1\ ns^2$ to $(n-1)d^{10}\ ns^2$. At certain places, the configurations are

different than expected. The general configuration of these elements can be represented as $(n-1)d^{1-10}\ ns^{0\ or\ 1\ or\ 2}$. The elements of IIIB, IVB, VB, VIB, VIIB, VIII, IB and IIB belong to this block. These elements are also called transition elements as their properties are intermediate between s- and p-block elements. Transition elements must have incomplete penultimate d-subshell, either in the neutral atom or in any one of its stable oxidation states. All the transition elements are metals. These elements are classified into four series, i.e.,
3d, 4d, 5d and 6d series corresponding to the filling of orbitals of 3d, 4d, 5d and 6d subshells of third, fourth, fifth and sixth energy shells, respectively. Each series starts with a member of third group. Every series consists 10 elements each. The end members of 3d, 4d, 5d and 6d series are the members of second group.

	3rd group		2nd group
3d series (1st transition series)	Sc (21) [Ar] $3d^1\ 4s^2$	to	Zn (30) [Ar] $3d^{10}4s^2$
4d series (2nd transition series)	Y (39) [Kr] $4d^1 5s^2$	to	Cd (48) [Kr] $4d^{10}5s^2$
*5d series (3rd transition series)	La (57) [Xe] $5d^1 6s^2$	to	Hg (80) [Xe] $4f^{14}5d^{10}6s^2$
†6d series (4th transition series)	Ac (89) [Rn] $6d^1 7s^2$	to	Unb (112) [Rn] $5f^{14}6d^{10}7s^2$

*The elements from Ce (580) to Lu (71) are not included
†The elements from Th (90) to Lr (103) are not included.

Group number of d-block elements can be determined with the help of value of Φ.

Φ = Number of electrons in ultimate shell + Number of electrons in penultimate shell -8

Φ = 3	IIIrd group
Φ = 4	IVth group
Φ = 5	Vth group
Φ =6	VIth group
Φ =7	VIIth group
Φ = 8, Φ = 9, Φ = 10	VIIIth group
Φ = 11	Ist group
Φ = 12	Ind group

General Characteristics of d-Block Elements

The general characteristics of d-block elements are :

(i) They are all metals having high melting and boiling points. They are hard in nature and good conductors of heat and electricity. They are malleable, ductile and possess high tensile strength. They have high densities.

(ii) The ionisation energies of most of d-block elements lie in between those of s and p-block elements. They are less electropositive than s-block elements and more electro positive than p-block elements. The members of 5d series such as Pt, Au, Hg, etc., are inert under ordinary conditions. They are called noble metals.

(iii) -block elements show variable valency. However, members of IIB group (Zn, Cd and Hg) do not show variable valency.

(iv) Most of the compounds formed by d-block elements are coloured in the solid state or in solution.

(v) Paramagnetism is common in d-block elements. This is due to the presence of unpaired electrons in (n-1)d orbitals.

(vi) Most of the transition elements and their compounds act as good catalysts.

(vii) They have high tendency to form complex compounds.

(viii) They have high tendency to form alloys with other metals.

(ix) They form both ionic and covalent compounds.

(iv) f-Block Elements (Inner-Transition Elements)

In these elements the last electron enters the *(n - 2)f* energy shell [*f*-orbitals of the *(n-2)* main shell], i.e., *(n-2)f* subshell is gradually filled up. The configuration varies from $(n-2)f^1\ (n-1)d^1\ ns^2$ to $(n-2)f^{14}\ (n-1)d^1\ ns^2$. At some places the actual configurations are somewhat different than the expected configurations. Thus, the general configuration can be represented as $(n-2)f^{0\text{-}14}\ (n-1)d^{0\ 1\ or\ 2}\ ns^2$. All *f-block* elements belong to 3rd group. The *f-block* elements are of two types:

(a) 4f-series (Lanthanides): This series has 14 elements from Ce (58) to Lu (71). In these elements 4f-energy shell is gradually filled up.

(b) 5f-series (Actinides): This series also has 14elements from Th (90) to Lr (103). In these elements 5f-energy shell is gradually filled up. These elements are also called inner transition elements. All the elements are accommodated in 3rd group but separately written in two horizontal rows below periodic table.

4*f*-elements	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
5*f*-elements	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

Note: Lanthanum ($_{57}La$) and actinium ($_{89}Ac$) are d-block elements. They are very similar in properties with lanthanides and actinides respectively and are usually studied along with them.

General Characteristics of f-Block Elements

The characteristics of f-block elements are similar to transition metals, i.e., d-block elements. The important characteristics are given below:

(i) All are metals.

(ii) They show variable valency. +3 is the most important oxidation state. Few elements show +2 and +4 oxidation stales.

(iii) They are paramagnetic in nature.

(iv) They form coloured compounds.

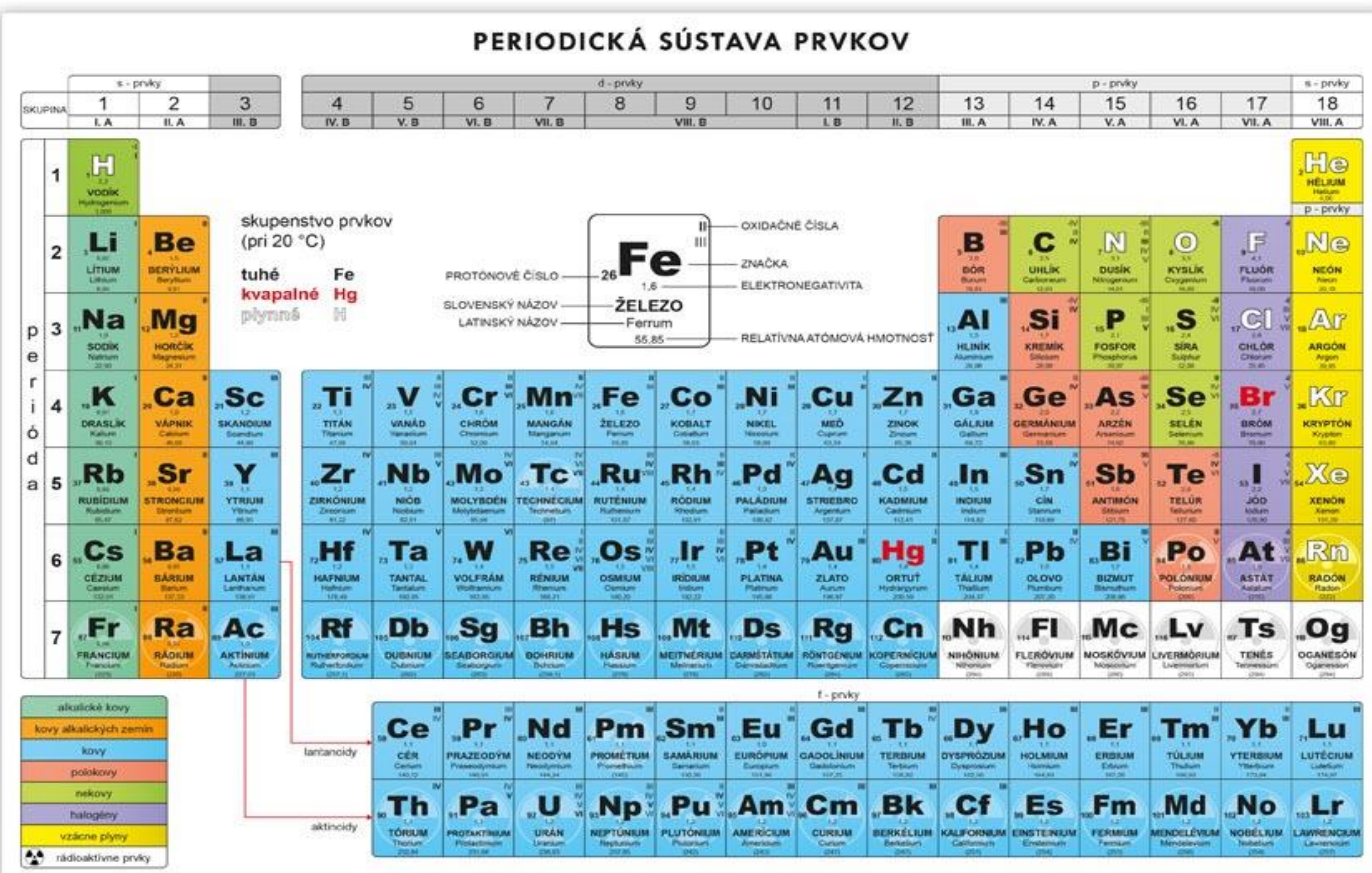
(v) They have tendency to form complexes.

(vi) Chemically lanthanides are very similar. It is difficult to separate them from a mixture by application of a chemical property. The members of the actinide series are also similar in chemical properties.

(vii) The members of actinide series are radioactive in nature. Elements above atomic number 92 are not found in nature. These are man-made elements. These are called transuranic elements.

EXTENDED OR LONG FORM OF PERIODIC TABLE

In order to remove the defects of Mendeleev's periodic table, a number of tables have been presented for the classification of elements. The best table out of these is the extended or long form of periodic table which has been shown in Fig. below.



The credit for this table cannot be given to any single person but it incorporates the modifications suggested by many scientists, especially Rang, Werner, Bohr, Bury, etc. The table is most widely used these days and is also referred to as Bohr's table, since it follows the Bohr scheme of the arrangement of elements into four types based on electronic configuration of the elements. This table is just a graphical representation of the aufbau principle.

Structural Features of the Long Form of the Periodic Table

Like Mendeleev's periodic table, the long form of the periodic table consists of horizontal rows called periods and vertical columns called groups. These are described below:

PERIODS :

Periods are numbered as 1, 2, 3, 4, 5, 6, and 7 from top to bottom. The period number corresponds to the value of n, i.e., principal quantum number for the outermost or valence shell of the atoms of the elements belonging to that period.. Number of elements in each period is twice of the atomic orbitals available in the energy level that are being filled.

1st Period: In the first period, the first main energy shell (K shell i.e., n=1) is filled. As it has only one orbital which can accommodate only two electrons, i.e., only two elements are present. The first period consists of hydrogen ($1s^1$) and helium ($1s^2$).

2nd Period: In the second period, the second energy shell (L-shell i.e., n = 2) is completed. This energy shell has four orbitals, one 2s and three 2p orbitals, which can accommodate eight electrons and therefore, second period has eight elements from Li ($2s^1$) to Ne ($2s^2 2p^6$).

3rd period: This period corresponds to the filling of third energy shell, ix, n = 3 There are nine orbitals, one 3s, three 3p and five 3d-orbitals in this shell. However, on the basis of aufbau principle, the 3d orbitals are higher in energy than 4s orbital. Thus, 3d orbitals are filled after filling of 4s orbital. Hence, only four orbitals, one 3s and three 3p orbitals are filled in this period. Consequently, this period, contains 8 elements from Na ($3s^1$) to Ar ($3s^2 3p^6$).

4th period: The fourth period corresponds to the filling of fourth energy shell, i.e., n = 4 Out of 4s, 4p, 4d and 4f-orbitals, the energies of 4d and 4f orbitals are higher than 5s orbital. Thus, 4s and 4p-orbitals are filled. However in between 4s and 4p-orbitals, five 3d-orbitals are also filled as their energies lie in between those orbitals. Hence, nine orbitals, one 4s, five 3d and three 4p-orbitals are filled. The fourth period contains 18 elements from potassium ($4s^1$) to krypton ($3d^{10} 4s^2 4p^6$). This period, therefore, includes first d-block series from scandium (Z = 21, $3d^1 4s^2$) to Zinc (Z = 30,$3d^1 04s^2$). Two s-block elements, ten d-block elements and six p-block elements are present.

5th period: Like fourth period, it also accommodates 18 elements as nine orbitals, one 5s, five 4d and three 5p orbitals are filled. It includes elements from rubidium ($5s^1$) to xenon ($4d^{10}\ 5s^2\ 5p^6$). This period, therefore, contains second d-block series from yttrium (Z = 39, $4d^{10}\ 5s^2$) to cadmium (Z = 48, $4d^{10} 5s^2$). Two s-block, ten d-block and six p-block elements are present in this period.

6th period: The 65, 4f, 5d and 6p-orbitals (i.e., sixteen orbitals) are filled accommodating 32 elements from caesium ($6s^1$) to radon ($4f^{14}\,5d^{10}\,6s^2\,6p^6$). This period includes third d-block series from lanthanum (Z = 57, $5d^1 6s^2$---Here aufbau principle is violated) to mercury ($4f^{14}\,5d^{10}\,6s^2$). The filling of 4f-orbitals begins from cerium (Z = 58, $4f^1\,5d^1\,65^2$) and ends up at lutetium (Z = 71, $4f^{14}$ $5d^1\,6s^2$). These fourteen elements 14 constitute 4f-series (Lanthanides). As the period can accommodate to the maximum of 18 elements, these 14 elements of 4f-series are separately placed in a horizontal row below the periodic table.

7th period: Like sixth period, seventh period is also expected to accommodate 32 elements corresponding to filling of sixteen orbitals, i.e., one 7s, seven 5f, five 6d and three 7p orbitals. However, at present this period is incomplete consisting 31 elements. One element of p-block bearing atomic numbers 117 is to be discovered to complete this period. The period includes two s-block elements, 10d-block elements, 14f-block elements and five p-block elements at present. 14 members of 5f-series (actinides) are also separately accommodated in a horizontal row below the periodic table like 4f-series.

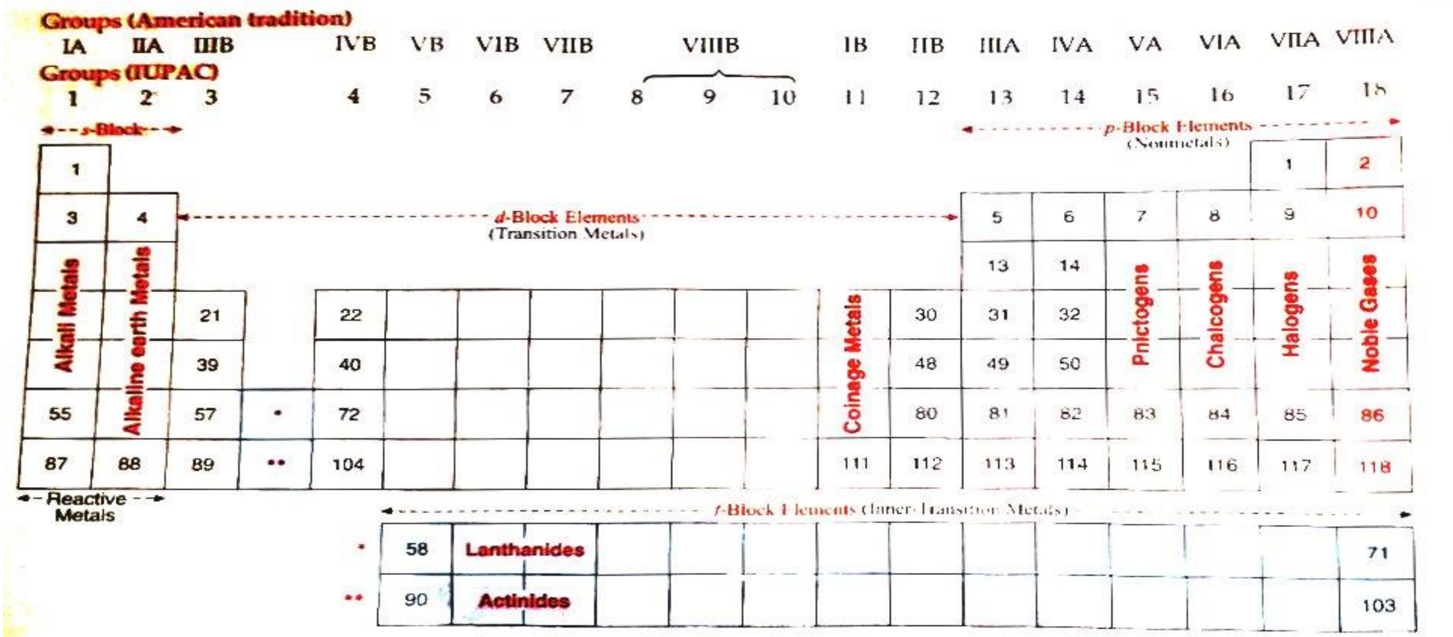
From the above discussion, it is clear that except first period which starts with hydrogen, all other periods start with a member of alkali group and ends with a member of zero group, i.e., the first member has configuration ns and last member has configuration ns^2mp'' where n is the order of the period. This provides a theoretical justification for periodicity in properties occurring at regular intervals of 2, 8, 8, 18, 18 and 32.

The first three periods having 2, 8 and 8 elements respectively are termed short periods while rest of the periods are called long periods. The majority of the elements of last period are man-made, i.e., synthetic. The elements from atomic numbers 104 to 112 (6d-elements) and elements with atomic numbers 113 to 116 and 118 have been reported in recent years. These are called transactinides and are all radioactive and have very short half life periods.

GROUPS:

There are 18 vertical columns in the extended or long form of the periodic table. Every column contains a series of elements whose atoms have same outermost electronic configurations, thereby similar chemical properties. The elements in a column are separated by magic numbers of either 2 or 8 or 18 or 32. The physical properties of elements follow a systematic pattern. The International Union of Pure and Applied Chemistry (IUPAC) have designated these columns as 1 to 18 groups. Previously there were sixteen groups as VIIIB consisted of three vertical columns. The groups were designated as IA, IIA, IIIB, IVB, VB, VIB, VIIB, VIIIB, IB, IIB, IIIA, IVA, VA, VIA, VIIA and VIIIA (zero group). Both the systems are still followed. These systems have been represented in the following diagram

Individual groups within the periodic table are also known by specific names, although this practice is less prevelant today than in the past. Group 1 elements are called alkali metals, group 2 elements called alkaline earth metals, and jointly both of these groups are called reactive metals. Group 11 elements are called coinage metals, group 15 elements are called pnictogens, group 16 elements are called chalcogens, group 17 elements are called halogens and group 18 elements are called noble gases. Of these only the terms halogens and noble gases are in common usage. The periodic table can be divided into four portions, i.e., into s-, p-, d- and f-blocks.



(i) The left portion (s-block elements):

This portion includes the elements of IA and IIA groups, i.e., s-block elements. These are highly reactive metals except hydrogen.

(ii) The right portion (p-block elements):

This portion consists of the elements of groups IIIA, IVA, VA, VIA, VIIA and zero, i.e., p-block elements. Zero group is present at the extreme right, i.e., last group of the periodic table. This portion includes all the nonmetals, metalloids and some metals. The higher members of IIIA, IVA, VA, VIA groups are metals. A clear demarcation line can be drawn to separate nonmetals from metals. The elements shown in zig zag lines between metals and nonmetals possess charac teristics of both metals and nonmetals. These elements are called semimetals or metalloids (Fig. below). Thus, B, Si, Ge, As, Sb, Te, Po and At are considered metalloids.

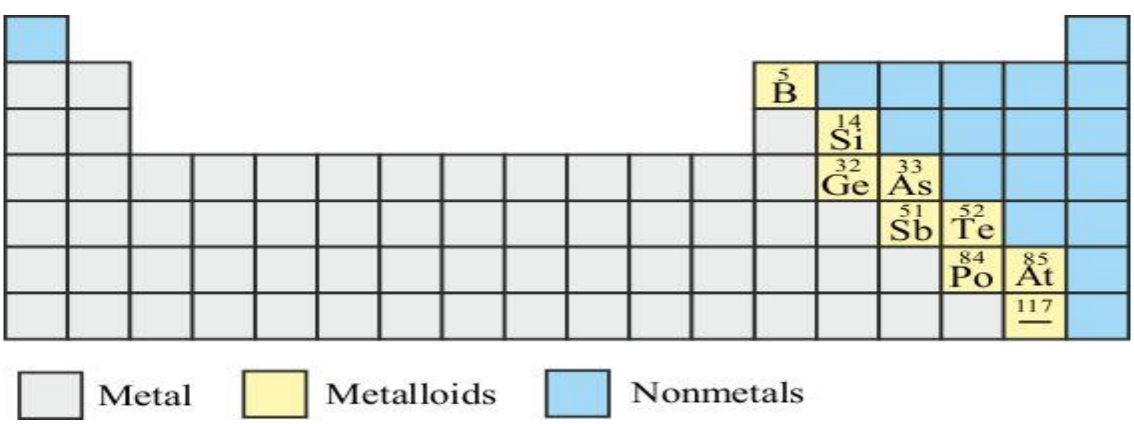


Fig. Periodic table: The elements shown in zig-zag lines between metals and nonmetals possess characteristics of both metals and nonmetals and are called metalloids

The first two groups on the extreme left and last six groups on the extreme right involve the filling of s and p-orbitals. These are the main groups of the periodic table and are numbered as 1, 2, 13, 14, 15, 16, 17 and 18 corresponding to configurations, ns^1, ns^2, ns^2np^1, ns^2np^2, ns^2 mp^3, ns^2np^4 , ns^2np^5, ns^2np^6 respectively. In the old system 115 these were denoted as IA, IIA, IIIA, IVA, VA, VIA, VIIA and VIIIA (zero) respectively. These elements (except zero group elements) are collectively called normal or representative or main group elements.

(iii) The middle portion (d-block elements):

This portion consists of the elements of IIIB, IVB, VB, VIB, VIIB, VIII, IB and IIB groups, i.e., d-block elements. In this portion, fourth, fifth, sixth and seventh periods of Mendeleev's periodic table have been stretched up. This portion accommodates the elements of *3d, 4d, 5d* and *6d* series. These elements are all metals.

(iv) The bottom portion (*f*-block elements):

These elements are also called inner transition elements. This portion consists of two horizontal rows, each having fourteen boxes. These boxes accommodate 14 elements of lanthanide series (4*f* elements) and 14 elements of actinide series (5*f* elements). These elements are metals.

Classification of Elements as Metals, Nonmetals and Metalloids

All the known elements can be broadly divided into metals, non-metals and metalloids on the basis of their properties.

Metals:

More than 78% of the known elements are metals. They occupy left hand side and central portion of the long form of the periodic table. Alkali metals, alkaline earth metals, d-block elements, *f*-block elements and higher members of *p*-block elements are all metals. The following are the general characteristics of metals:

(i) They are generally solids at ordinary conditions. Mercury is an exception which is a liquid at room tempera ture (m.pt. 234K). They possess high melting and boiling points. However, alkali metals have comparatively low melting points. The metals caesium (302 K), francium (300 K) and gallium (303 K) possess low melting points. Tungsten has the highest melting point (3653 K).

(ii) They are good conductors of heat and electricity.

(iii) They possess high density. The two elements osmium and iridium have highest densities 22.59 g mL and 22.61 g ml respectively. Lithium, sodium and potassium have low densities and float on water.

(iv) They are malleable (can be beaten into a thin sheet) and ductile (can be drawn out into a wire) and have usual metallic bright lustre.

(v) They react with mineral acids liberating hydrogen. However, less reactive metals such as Ag, Au, Pt, etc., do not liberate hydrogen.

(vi) Normal oxides of the metals are basic in nature. However, zinc oxide and aluminium oxide are amphoteric in nature.

(vii) Zinc, cadmium and mercury in group 12 (IIB), are not usually considered to be transition metals.

(viii) The higher members of p-block elements of groups IIIA, IVA, VA and VIA, the elements Al , Ga , In , Tl , Sn , Pb , Bi and recently discovered Uut , Uuq and Uuh are also referred as poor metals

Nonmetals :

Nonmetals are present on right side of the periodic table. They are p-block elements and their number is quite low. Six of the nonmetals carbon, boron, phosphorus, sulphur, selenium and iodine are solids. Bromine is the only liquid nonmetal at room temperature. The remaining nonmetals nitrogen, oxygen, fluorine, chlorine, hydrogen and noble gases are gases. Nonmetals are generally (i) brittle (ii) nonlustrous (iii) have low melting and boiling points (carbon and boron are exceptions) (iv) nonconductors of heat (v) capable of forming acidic oxides (vi) do not evolve hydrogen from acids.

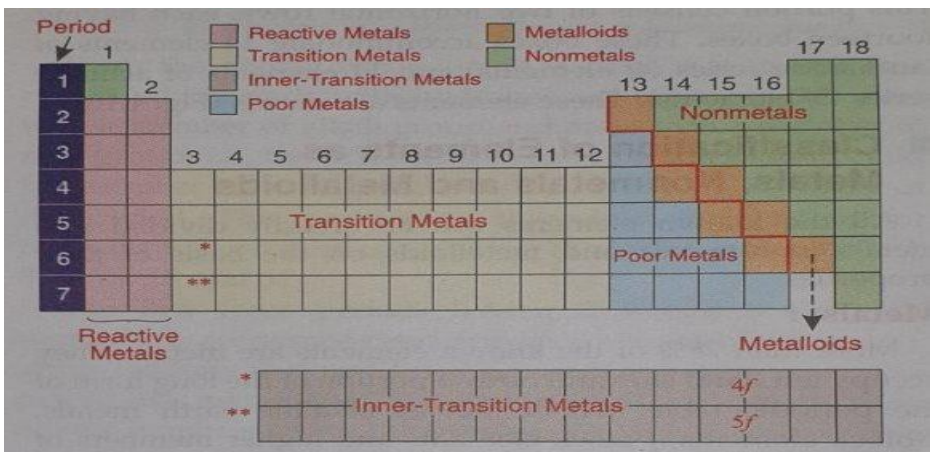


Fig. Blocks of elements representing similar properties in the periodic table

Metalloids :

There are some elements which do not fit completely into either metal or nonmetal class. Elements which have mixed properties of metals and nonmetals both are called semi metals or metalloids. Silicon, germanium, arsenic, antimony and tellurium are metalloids. But some scientists include boron, polonium and astatine also in the list of metalloids.

In most respects, metalloids behave as non-metals, both chemically and physically. However, in their most important physical property, the electrical conductivity, they somewhat resemble metals. Metalloids tend to be semiconductors; they conduct electricity, but not nearly so well as metals. This property, particularly found in silicon and germanium, is responsible for the remarkable progress made during the last fifty years in the field of solid-state electronics. The operations of every computer, audio system, TV receiver, DVD or CD player relies on transistors made from semiconductors.

In periodic table, the metallic character increases from top to bottom in a group while metallic character decreases from left to right along a period.

Superiority of the Long Form of the Table over Mendeleev's Periodic Table

(i) This table is based on a more fundamental property, i.e., atomic number.

(ii) It correlates the position of the element with its electronic configuration more clearly.

(iii) The completion of each period is more logical. In a period as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached. It eliminates the even and odd series of IV, V and VI periods of Mendeleev's periodic table.

(iv) The position of VIII group is appropriate in this table. All the transition elements have been brought in the middle as the properties of transition elements are intermediate between s- and p-block elements.

(v) Due to separation of two subgroups, dissimilar elements do not fall together. One vertical column accommodates elements with same electronic configuration thereby showing same properties.

(vi) In this table a complete separation between metals and nonmetals has been achieved. The nonmetals are present in upper right corner of the periodic table.

(vii) There is a gradual change in properties of the elements with increase in their atomic numbers, i.e., periodicity of properties can be easily visualised. The same properties of recurrence in properties occur after the intervals of 2, 8, 8, 18, 18 and 32 elements which indicates the capacity of various periods of the table.

(viii) This arrangement of elements is easy to remember and reproduce.

Defects of Long Form of Periodic Table

The long form of periodic table has following defects:

(i) Position of hydrogen: The position of hydrogen is not fixed in this table also. It is placed either in IA or in VIIA group.

(ii) Position of lanthanides and actinides : No individual places have been assigned to these 28 elements in the periodic table.

(iii) This table does not reflect the exact distribution of electrons among all the orbitals of the atoms of all the elements.

POSITION OF AN ELEMENT ON THE BASIS OF ELECTRONIC CONFIGURATION

The block, period and group of an element can be easily decided from its electronic configuration of the element

(i) The block of the element is decided on the basis of the type of the orbital on which the last electron is accommodated. If the last electron enters into *s*-subshell or *p*-subshell or *d*-subshell or *f*-subshell, then the element belongs to s-block or *p*-block or *d*-block or *f*-block respectively.

(ii) The period to which an element belongs depends on the total number of orbits (shells) on which electrons are present.

or

The serial number of the period corresponds to the principal quantum number (p.q.no.) of the outermost shell on which the electrons are present.

Cl	17	2, 8, 7 Three orbits	[Ne] $3s^2 3p^5$ p.q.no. 3	belongs to 3rd period
Pb	82	2, 8, 18, 32, 18, 4, Six orbits	[Xe] $4f^{14} 5d^{10} 6s^2 6p^2$ p.q.no. 6	belongs to 6th period

(iii) To decide about the group number (IUPAC), the number of electrons present on the outermost shell or/and penultimate shell [next to the outermost, i.e., (n-1) shell] are counted.

(a) If the last orbit contains 1 or 2 electrons, the group number is 1 or 2 respectively (Helium is an exception which belongs to group 18). There should not be any *d*-orbital in the penultimate shell, i.e., in the penultimate shell either 2 electrons [$(n-1)s^2$] or 8 electrons [$(n-1)s^2p^6$] electrons are present.

$ns^1 \longrightarrow$ 1st group $\qquad ns^2 \longrightarrow$ 2nd group

K	19	2, 8, 8, [1]	[Ar] $4s^1$	Group 1
Sr	38	2, 8, 18, 8, [2]	[Kr] $5s^2$	Group 2
Be	4	2, [2]	[He] $2s^2$	Group 2
Li	3	2, [1]	[He] $2s^1$	Group 1

(b) If the last orbit has 3 or more electrons, then the group number is the sum of electrons in the last orbit plus 10. Such an element belongs to *p*-block.

S	16	2, 8, 6	[Ne] $3s^2 3p^4$	6 + 10 = 16 *i.e.*, 16th group
Ge	32	2, 8, 18, 4	[Ar] $3d^{10} 4s^2 4p^2$	4 + 10 = 14 *i.e.*, 14th group
Xe	54	2, 8, 18, 18, 8	[Kr] $4d^{10} 5s^2 5p^6$	10 + 8 = 18 *i.e.*, 18th group
At	85	2, 8, 18, 32, 18, 7	[Xe] $4f^{14} 5d^{10} 6s^2 6p^5$	10 + 7 = 17 *i.e.*, 17th group

(c) If the last orbit contains 1 or 2 electrons and (n-1)*d*-orbitals where electrons are present, then group number is equal to the sum of electrons in the last orbit and (n-1)*d*-orbitals. Such an element belongs to *d*-block.

Cr 24	2, 8, 8 + **5, 1**	[Ar] $3d^5 4s^1$	5 + 1 = 6 *i.e.,* 6th group
Cu 29	2, 8, 8 + **10, 1**	[Ar] $3d^{10} 4s^1$	10 + 1 = 11 *i.e.,* 11th group
Ru 44	2, 8, 18, 8 + **7, 1**	[Kr] $4d^7 5s^1$	7 + 1 = 8 *i.e.,* 8th group
Hf 72	2, 8, 18, 32, 8 + **2, 2**	[Xe] $4f^{14} 5d^2 6s^2$	2 + 2 = 4 *i.e.,* 4th group