The Origins of the Conception of Isotopes.[1]

By Prof. Frederick Soddy, F.R.S.

ONE of the most important consequences of the study of the chemistry of the products of radioactive change has been the discovery of isotopes and the interpretation, in consequence, of the Periodic Law in terms of modern views of atomic structure. It is one of the few fields in the vast borderland between physics and chemistry, overrun of recent years by an advancing swarm of mathematicians and physicists, armed with all sorts of new-fangled weapons, in which the invaders have found the chemist already in possession. The broad highways they have hewn thereto are already dusty with the feet of pilgrims and are being watered by the tears of candidates for " Honours." But the somewhat intricate bye-ways through which the chemist first found his way into this virgin territory, and the views on the road before it was in sight, may still preserve something of their pristine interest.

The word *isotope* signifies " the same place," in allusion to isotopes occupying the same place in the Periodic Table. Before this word of theoretical meaning was coined, isotopes were experimentally well known as elements non-separable by chemical methods and completely identical in their whole chemical character. The analysis of the constituents of matter, to which we were born and brought up to regard as the most searching and fundamental, is an analysis by means of its chemical properties. Although, later, a new and even more powerful method—spectroscopic analysis—was developed, it merely dotted the *i*'s and crossed the *t*'s of chemical analysis, filled in a few vacant places in the Periodic Law, and handed over the newcomers to the chemist to classify along with the rest of the eighty or so " foundation stones " of which he supposed the material universe to be built up.

With the close of last century another new method—radioactive analysis—was developed, which is applicable, of course, only to the radio-elements; that is, to the elements uranium and thorium and the 34, as we now know, successive unstable products of their spontaneous disintegration. Each of these possesses a definite radioactive character; it is produced from one and changes into another element, and, in both changes, rays characteristic of the two substances are expelled, which are as fine a hall-mark of their identity as any of the " tests " of chemical analysis. But radioactive character, unlike spectroscopic character, is completely independent of chemical character. The latter might be called " existence properties," whereas the radioactive character is that attending the explosion of the atom which terminates the existence of the element as such. It provided the necessary independent method of analysis capable, for the first time, of distinguishing between elements identical chemically and occupying the same place in the Periodic Table, *i.e.* between isotopes.

The Earlier Chapter of Radio-chemistry.

Not a hint of this, however, was afforded by the earlier chapter of radio-chemistry. On the contrary, no development could appear more normal. Just as

rubidium, thallium, etc., were detected by the spectroscope before anything of their chemistry was known, so radium was detected in pitchblende by its radioactivity in concentration thousands of times less than is necessary to show a single line of its spectrum. But with more concentrated preparations a new spectrum *was* discovered, and then a new element, which was found to possess a chemical character entirely new and sufficing for its separation in the pure state from all other elements. As in the case of the elements discovered by the spectroscope, radium was found to occupy a place, hitherto vacant, in the Periodic Table. But, as it happened, radium is exceptional in this. Its chemical character was quite normal, and indeed could have been largely predicted beforehand for the missing element occupying this place. The development of the subject showed it to be but one of some 34 radio-elements formed from uranium and thorium. But there are not 34 vacant places in the Periodic Table to accommodate them.

Meta-elements.

So far as I am aware, there is no anticipation, prior to the systematic study of the chemistry of the radio-elements, of the idea that there may exist different elements with absolutely identical chemical character. Sir William Crookes, it is true, once thought, though the idea has not survived more extended examination, that the properties of the elements, as we know them, might be a mean value, and that the individual atoms composing the element might differ in weight and chemical character continuously on either side of this mean. If so, more refined methods might serve to resolve the element into a collection of what he termed " Meta-elements," possessing the main character of the original, but differing from one another to a slight extent. Misled by the phosphorescence spectra, which are now known to be characteristic of mixtures rather than chemically homogeneous substances, he thought at one time that he had been successful in so resolving yttrium. But the present idea, that elements may exist absolutely the same in chemical nature and yet absolutely different in other properties, such as radioactivity and atomic weight, is totally distinct from this.

The Experimental Method that first revealed Isotopes.

I venture to think that no more elegant extension of our methods of gaining new knowledge has ever been obtained than that which, in due course, was to reveal the existence of isotopes. The original observations, upon which the theory of atomic disintegration was first founded, were that thorium is continuously producing a new radioactive substance, thorium X, separable from it by precipitation with ammonia but not with other precipitants, and, after separation, continuously re-forming again. The thorium X was short-lived and changed again into a gas, the thorium emanation, for which the name *thoron* has recently been proposed, which was even shorter-lived and changed again to a solid—the " excited activity " now known

as the active deposit—which again went through further changes. The rays resulted from these successive changes, α-rays in the first and α-, β-, and γ-rays in the last changes. Below is the first part of the thorium disintegration series as it appeared to Sir Ernest Rutherford and myself in 1903 :

$$\text{THORIUM} \xrightarrow{\alpha} \text{THORIUM X} \xrightarrow{\alpha} \text{THORON} \xrightarrow{\alpha}, \text{ etc.}$$
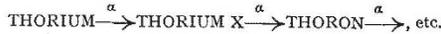
In 1905 Sir William Ramsay and O. Hahn were engaged in extracting radium from thorianite, a new Ceylon mineral containing both uranium and thorium in important quantity. The radium was separated with the barium, and the chlorides fractionated in the usual way. They found a new radio-element to be present and to be separated from the radium with the barium. It proved to be the direct parent of thorium X, and intermediate in the series between the latter and thorium, and they called it radiothorium. In spite of this easy and apparently straightforward separation, the experience of a number of chemists showed that something remained to be explained, for it was found to be difficult to the verge of impossibility to separate radiothorium from thorium. Ramsay and Hahn had in fact " separated " isotopes in 1905, for radiothorium and thorium are isotopes. Yet further work has shown the two to be so alike that no separation by chemical means is possible !

Then in 1907, along with the radium which had been separated from thorianite, Hahn discovered another new radio-element, mesothorium, the direct parent of radiothorium and intermediate between it and thorium. In the next year he showed that mesothorium consists of two successive products—the first, the direct product of thorium, mesothorium 1, being practically rayless and generating a short-lived product, mesothorium 2, giving powerful β- and γ-rays.

This resolved the mystery, and one cannot do better than to quote the words of McCoy and Ross (J. Amer. Chem. Soc., 1907, 29, 1709).

> " Our experiments strongly indicate that radiothorium is entirely inseparable from thorium by chemical processes. . . . The isolation of radiothorium from thorianite and from pure thorium nitrate . . . may have been accomplished by the separation of mesothorium which in time changed spontaneously into radiothorium."

Thus the radiothorium separated from the mineral thorianite by Ramsay and Hahn was not the radiothorium *in the mineral*, but that subsequently produced from the easily separated mesothorium, after it had been removed from the thorium. If they had fractionated the radium-mesothorium-barium mixture at once they would not have discovered radiothorium. The lapse of time after the separation of the mesothorium is essential. Nowadays many non-separable radio-elements are, like radiothorium, " grown " from their separable parents. Thus radium D, an isotope of lead, is grown from the radium emanation (radon), although it cannot be separated from the mineral, which always contains lead in quantity.

The first part of the thorium series now runs [2]

$$\text{THORIUM} \xrightarrow{\alpha} \text{MESOTHORIUM 1} \xrightarrow{} \text{MESOTHORIUM 2}$$
$$\underset{2 \cdot 10^{10} \text{ years}}{} \qquad \underset{9 \cdot 67 \text{ years}}{} \qquad \underset{8 \cdot 9 \text{ hours}}{}$$
$$\xrightarrow{\beta} \text{RADIOTHORIUM} \xrightarrow{\alpha} \text{THORIUM X} \xrightarrow{\alpha} \text{THORON} \xrightarrow{\alpha}, \text{ etc.}$$
$$\underset{2 \cdot 91 \text{ years}}{} \qquad \underset{5 \cdot 25 \text{ days}}{} \qquad \underset{78 \text{ seconds}}{}$$
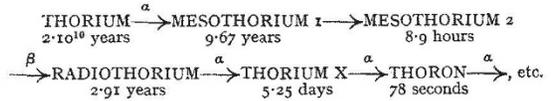
In this series thorium and radiothorium and mesothorium and thorium X are two pairs of isotopes. If we represent the successive products by balls of different colours to indicate their chemical character, isotopes being of the same colour, chemical analysis will sort the balls into their different colours, and the lapse of time will cause some of the colours to change. The ball representing mesothorium will in time turn into that representing radiothorium, so that the latter, before indistinguishable from thorium, becomes known as a separate individual.

THE ISOTOPES OF URANIUM.

It will be noted that the method of separating isotopes depends upon their being alternate rather than successive in the series. If radiothorium had been the direct product of thorium, the two would to this day never have been separated. The changes of chemical character are, as we shall later see, intimately connected with the electric charges on the α- and β-particles expelled. For successive products to have the same character, no rays, or at least no charged particles, must be expelled. It is always as well, and no subject illustrates the point better than that of isotopes, to reflect not only upon what our methods are able to reveal but also upon what they could not reveal.

At first it seemed that uranium itself was a case of successive isotopes. Boltwood in 1908 proved from his study of the relative activities of the successive products giving α-rays in minerals, that whereas all of them, except uranium, gave off only one α-particle per atom disintegrating, uranium gave off two. By direct observation with the scintillation method it was proved that the two α-particles from uranium are *not* simultaneously expelled, and later it was shown that they possess different velocities. If the slower comes from uranium itself (uranium I), the period of which is known to be $6 \cdot 10^9$ years, the swifter must come from the isotope (uranium II), and its period must be some three million years. This is an example of isotopes being revealed by difference of radioactive nature simply, though no other evidence of their separate existences is available. Owing to the long periods of the α-ray-giving members of the early part of the uranium series, it has been much more difficult to unravel than the thorium series. As a result of researches too numerous to detail, it has been concluded that the main series is almost entirely analogous to the thorium series and runs

$$\text{URANIUM I} \xrightarrow{\alpha} \text{URANIUM X}_1 \xrightarrow{\beta} \text{URANIUM X}_2 \xrightarrow{\beta} \text{URANIUM II}$$
$$\underset{6 \cdot 10^9 \text{ years}}{} \quad \underset{35 \cdot 5 \text{ days}}{} \quad \underset{1 \cdot 65 \text{ minutes}}{} \quad \underset{3 \cdot 10^6 \text{ years}}{}$$
$$\xrightarrow{\alpha} \text{IONIUM} \xrightarrow{\alpha} \text{RADIUM} \xrightarrow{\alpha} \text{RADON} \xrightarrow{\alpha}, \text{ etc.}$$
$$\underset{10^5 \text{ years}}{} \quad \underset{2 \cdot 440 \text{ years}}{} \quad \underset{5 \cdot 55 \text{ days}}{}$$
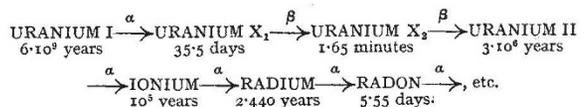
Though two short-lived products probably intervene between the two uraniums, analogous to the two mesothoriums between thorium and radiothorium, the relation of their period to that of their product, uranium II, is so hopelessly unfavourable that there is no hope of ever being able to put the separate existence of uranium II into evidence in the same way as was done

for radiothorium. For all *practical* purposes the two uranium are as non-separable by this method as if they were actually successive products. I spent many years, before this part of the series was at all well known, looking for the product of uranium X, and separated this constituent from 50 kilograms of uranium nitrate repeatedly in the attempt. I was looking for a growth of α-rays concomitantly with the decay of the β-rays of the uranium X. If the product had been ionium, as at first thought $(UI \xrightarrow{\alpha} UII \xrightarrow{\alpha} UX \xrightarrow{\beta} Io \xrightarrow{\alpha})$, it should have been just possible to detect it; but since it is the 30 times longer-lived uranium II, the attempt is hopeless, especially as uranium X and ionium are isotopes, and therefore the uranium X separated must always possess a certain initial α-activity due to ionium.

THE ABSOLUTE CHEMICAL IDENTITY OF ISOTOPES AND ITS IMPLICATIONS.

The years 1908–10 were productive of many prolonged and serious efforts to separate isotopes by chemical means. In 1908 Boltwood discovered ionium and showed that it resembled thorium. Keetman, who with Marckwald discovered ionium independently, tried twelve good methods all known to be effective in the purification of thorium in the attempt to separate the ionium from thorium, completely without success. Auer von Welsbach, on a technical scale, separated the ionium and thorium from 30 tons of pitchblende and tried fresh methods in the hope of separating them, but failed. It was with this preparation that Exner and Haschek tried without success to find the ionium spectrum; and Russell and Rossi confirmed their result, that the spectrum of ionium was that of pure thorium. When later I had determined beyond doubt, from measurements of the rate of growth of radium from uranium, that the period of ionium was 100,000 years, and that Welsbach's preparation must have been approximately 30 per cent. ionium and 70 per cent. thorium by weight, it followed that the spectra of isotopes must, like their chemical character, also be identical. The difference, if any exists, is almost beyond the limit of detection by the most powerful methods.

Similarly, the chemical identity of radium D and lead was established as a consequence of very prolonged and refined chemical examination. Paneth and Hevesy established upon this their well-known method of using radioactive isotopes as indicators for elements in too small quantity to be dealt with except by such methods. On the principle that wherever the radioactive element is there will its inactive isotope be also, provided that they have once been properly mixed, many difficult or uncertain chemical analyses may be converted into simple radioactive ones.

In 1909 Strömholm and Svedberg made what was probably the first attempt to fit a part of the disintegration series into the Periodic Table, and although the effort in itself was in an important respect erroneous, in their paper is to be found the first anticipation that the chemical non-separability found for certain pairs and groups of radio-elements may also apply to the non-radioactive elements. Remarking on the fact that there are three parallel and independent radioactive series, they suppose this to proceed down through the Periodic Table, " but that always the three elements of the different genetic series, which thus together occupy one place in the Periodic System, are so alike that they always occur together and also have not been able to be appreciably separated in the laboratory." They point out also, this idea would explain the exceptions to the Periodic System " if the elements of the scheme were mixtures of several homogeneous elements of similar but not completely identical atomic weight."

In the next year I arrived independently, and without in the least postulating any continuance of the genetic series beyond the radio-elements, at a similar view. Marckwald and I found independently that mesothorium 1 was chemically similar to radium, a fact undoubtedly known to Hahn and those engaged in the technical extraction of mesothorium, but kept secret. It was known from some work of Boltwood that precipitating barium sulphate in a solution containing mesothorium removes it, but it was thought that the action of the barium sulphate was similar to that in removing uranium X, for which it had long been used, namely, a simple adsorption. I was surprised to find it absolutely different. The removal of the barium from the mesothorium, as from radium, could only be accomplished by the fractional crystallisation of the chlorides. In this fractionation the radium and mesothorium remained together and behaved as a single element. Within the limit of error of the most careful radioactive measurements, there was no change in the relative proportion of the two elements at the end of the process from that in which they exist in the original mineral.

Chemistry has many cases of elements similar in chemical character, but nothing approaching this. For we know, beforehand, that we are dealing with a mixture of two substances and can estimate accurately the proportion of each individual. Yet to all chemical operations they behave as a single substance. The differences of atomic weight are considerable, two units in the cases of mesothorium and radium, and of ionium and thorium, and four units in that of radiothorium and thorium. It was certain that if isotopes existed in the case of the ordinary chemical elements the absence of a second radioactive nature independent of the chemical nature would make it impossible for them to have been recognised. Hence the implication followed that any supposed element may be a mixture of several chemical identities of different atomic weight, and any atomic weight might be merely a mean number (Ann. Reports, Chem. Soc., 1910, 286). There is an element of tragedy in this. The lifetime labours of the chemists who, since the time of Stas, have devoted themselves to the exact determination of atomic weights appear to have as little theoretical interest now as if you sought to determine the average weight of a collection of beer bottles, all exactly alike but not all quite full.

THE RADIO-ELEMENTS AND THE PERIODIC LAW.

The years from 1911–13 were crowded with important advances, and to do the exact history justice would take an undue share of the available time. In 1911 the chemistry of most of the α-ray-giving members was sufficiently known for it to be seen

that the expulsion of the α-particle caused the element expelling it to move from the place it occupied in the Periodic Table to the next place but one to it in the direction of diminishing mass.

At this time the chemistry of the post-emanation members had scarcely been studied, though von Lerch, from electrochemical researches, had put forward the rule that the successive products are each electrochemically "nobler" than the last, a rule which describes well enough the electrochemical behaviour of the first three—the A to C members, as they are called. Then, as a result of the experiments of Schrader and Russell, it was found that their volatility was much affected by chemical treatment and by the atmosphere in which they were volatilised. Thus, in hydrogen, radium C volatilises at as low a temperature as 360° C., though, in air, a temperature of 1200° is necessary. This clearly indicated the possibility that even these excessively ephemeral elements have a definite chemical character. Hevesy showed, by electrochemical methods, that the three B-members are identical in properties among themselves, and also the three C-members.

But the work which, more than anything else, served to reveal, as in a flash, the simple and sweeping generalisation which covers the evolution of the radioactive elements was that of A. Fleck in my laboratory in Glasgow. He studied the chemistry of the various members, still uncharacterised, from the definite point of view of ascertaining to which element each most closely approximated in chemical character, and then whether it was separable from that element or not. In addition to confirming more rigorously many conclusions already reached, he proved that mesothorium 2 was non-separable from actinium, the three B-members from lead, like radium D, and the three C-members and radium E from bismuth.

Hevesy and Russell—the first with regard to the valency of the radio-elements and the second with regard to the positions they occupy in the Periodic Table—published early in 1913 statements of the full law underlying radioactive evolution, but only in part correct. Within a month K. Fajans, in Carlsruhe, published the scheme correct and complete, including the complicated branchings that occur at the C-members. In a paper, amplifying and amending Russell's scheme, I arrived independently at the same scheme as Fajans. Each α-ray expelled causes a shift of two places in the Periodic Table in the direction of diminishing mass, and each β-ray a shift of one place in the opposite direction. In its present form the scheme is shown in Fig. 1. The chief uncertainty remaining is whether the actinium branch starts from uranium II, as shown in the figure for convenience, or from uranium I, or even from a third independent isotope of uranium. So that the atomic weights shown for the actinium series are purely provisional.

By the consistent application of the two rules mentioned, the members found to be non-separable from one another fall in the same place in the Periodic Table. The chemical character has nothing to do with the radioactivity, nor with the series to which the element belongs, nor with its atomic weight. It depends upon a number, now called the atomic number, shown at the top of the place in the figure.

Before passing on to this, the chief practical consequences of the generalisation may be briefly enumerated.

(1) Of the members still uncharacterised, the A and C′ members must be the isotopes of polonium (radium F) and radium C_2 (now called radium C″), actinium D and thorium D must be isotopes of thallium. Fleck at once verified these predictions as regards radium A, actinium D, and thorium D.

(2) Uranium X, like mesothorium, must consist of two successive β-ray-giving products, intermediate between the two uraniums. Fajans and Gohring at once succeeded in separating from uranium X a very short-lived product, uranium X_2, giving the more penetrating of the two types of β-ray expelled, the uranium X_1 giving the less penetrating β-rays.

(3) The parent of actinium in the IIIrd family must be an isotope of radium, if actinium is formed in a β-ray change—a conclusion I at once experimentally disproved—or it must be an isotope of uranium X_2, in the Vth family, if actinium is formed in an α-ray change. This was proved by Cranston and myself, and the name "eka-tantalum" given to the new element, and by Hahn and Meitner, who named it protoactinium. It is linked to uranium through uranium Y, a branch member discovered by Antonoff in 1911, and suspected to be in the actinium series.

Protoactinium, to give it Hahn and Meitner's name, has been shown by them to give α-rays and to be chemically so like tantalum that hitherto it has not been separated from it. Its period is about 17,000 years, and from this it may be calculated that there is about one-fifth as much of it by weight in minerals as there is of radium. This may be sufficient to enable it to be isolated, and for its spectrum, atomic weight, and chemical character to be ascertained. The branch series runs

$$ \underset{\text{VI}}{\text{U}} \xrightarrow{\alpha} \underset{\text{IV}}{\text{UY}} \xrightarrow{\beta} \underset{\text{V}}{\text{Pa}} \xrightarrow{\alpha} \underset{\text{III}}{\text{Ac}} \xrightarrow{} \underset{\text{IV}}{\text{RaAc}} \xrightarrow{\alpha} \underset{\text{II}}{\text{AcX}} \xrightarrow{\alpha} \underset{0}{\text{An}} \xrightarrow{\alpha} , \text{etc.} $$
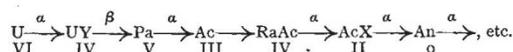
in which the figures in the second line refer to the family in the Periodic Table to which the element belongs.

(4) All the ultimate products in all branches are isotopes of lead. The atomic weight of the two products of thorium are both 208, and of the major branch of uranium 206. As is well known, this had only to be tested to be proved correct. The atomic weight of the lead from the purest thorium minerals is as high as 207·9, and of that from the purest uranium minerals 206·0. The spectra of these isotopes, but for the infinitesimal difference already alluded to, are identical. But the densities are proportional to their atomic weights. This was a very simple prediction I made, before testing it, from the theoretical views about to be dealt with.

THE THEORETICAL INTERPRETATION OF ISOTOPES.

The results on the theoretical side were no less definite and important, and isotopes found a ready explanation on the nuclear theory of atomic structure put forward in a tentative form by Rutherford in 1911. This theory accounted for the large angles through which occasional α-particles were deflected in their

passage through atoms, by the existence of a very minute highly charged nucleus at the centre of the atom, the rest of the atom being occupied by separate charges of opposite sign equal in number to the nuclear charge. For such an atom scattering should be


FIG. 1.—Radio-elements and the periodic law. All elements in the same vertical column are isotopes.

proportional to the square of the nuclear charge. Experiment showed that scattering was approximately proportional to the square of the atomic weight. So that it looked as if, as in the α-particle itself, there existed one unit of nuclear charge to each two units of atomic weight. This would make the nuclear charge of uranium of atomic weight about 240, 120+.

Since the α-particle carries two positive charges and the β-particle one negative, the obvious inference from the figure is that the successive places in the Periodic Table correspond with unit difference in the intra-atomic charge. This view, and also that each unit of charge corresponded to two units of mass, had been suggested independently by van der Broek in 1911. At first he tried to stretch the Periodic Table to make it accommodate 120 places. But in 1913 he pointed out that the experimental results for scattering were completely in accord with his own view (that the number of the place or atomic number is the same as the intra-atomic charge) *on the existing Periodic Table*, which accommodates some 90 elements. It would not be inconsistent with his other view (that the nuclei of the heavy elements are made up of helium nuclei) if there were electrons in the nucleus as well as in the outside shell. Thus uranium in the 90th place would have to have, in addition to the 60 helium nuclei in its nucleus, to account for its weight, 30 electrons, to account for its charge of 90+.

The existence of electrons as well as positive charges in the atomic nucleus was also postulated by Bohr to explain the emission of β-rays, for on his theory the electrons in the external shell form a stable configuration and could only be dislodged by the expenditure of work.

The Periodic Law generalisation practically settled this question. β-ray changes are no less transmutational than α-ray changes, and are sharply to be distinguished from the numerous processes, such as friction, chemical change, action of ultra-violet light, and incandescence, during which electrons are detached from atoms. The effect on the chemical character produced by the expulsion of one α-particle is exactly undone by the expulsion of two β-particles, and the product becomes isotopic with the original parent. This means that both α- and β-particles must be expelled from the nucleus and that isotopes are elements the atoms of which have the same *nett* nuclear charge; *i.e.* the same excess number of positive over negative charges in the nucleus, but different numbers of positives and negatives reckoned separately. For such systems the electronic shell would be identical, and so the identity of the chemical and spectroscopic character is explained. Also the atomic volume is the same; that is, the density must be proportional to the atomic weight.

We were able to get an interesting confirmation of this view. In the change of uranium X_1 to uranium II

two electrons are lost as β-rays. In the oxidation of a uranous salt to a uranic or uranyl salt two electrons are also lost,

$$U^{++++} = U^{++++++} + 2E.$$
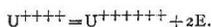
If these come from the same region of the atom as the β-particles, then uranous salts, so long as their valency does not change, should be like uranium X_1, chemically non-separable from thorium. Fleck, trying this, found great similarity in chemical properties between uranous salts and thorium, but not identity. He was able to separate them by chemical methods without changing the valency of the uranous salt.

The great merit of the nuclear atom from the chemist's point of view was that it afforded for the first time a clear picture of the difference between a chemical and a transmutational (or radioactive) change. The latter occur in the nucleus and are irreversible. The external shell accommodates itself instantly to the change of the nucleus. But any change suffered by the external shell (chemical change) has no effect on the nucleus, which always acts so as to make the external shell conform to one most stable configuration.

The atom is an *imperium in imperio*, and like most such systems is very conservative and resistant to change. The electrons in the shell, that govern almost all the atomic properties, except mass and radio-activity, are in turn but the bureaucratic instruments of the real government, which is the intensely charged central nucleus. The transmutation of atoms, as of social systems, is alike impossible because the apparent government is not the real government. Rutherford's experiments on the bombardment of atoms by α-particles show that only about one out of a hundred thousand of the latter, in passing through hydrogen, ever hits a hydrogen nucleus, and the proportion of hits to misses is something like one in a thousand millions. In politics, contrasting the number of missiles hurled with the results achieved, the shooting seems even worse. It is only when the atomic or social systems break up or break down that we learn even of the existence of their real internal constitution.

Current Topics and Events.

ON July 30 there was read a third time in the House of Lords the Wild Birds Protection Bill introduced by Viscount Grey of Fallodon. The Bill aims at the repeal of existing enactments on the subject, and at substituting new provisions on lines recommended in 1919 by a Departmental Committee. The measure appears to us to be a wise one which should be welcomed by ornithologists and other bird lovers and also on grounds of economic importance. More than this, it is a much stronger measure than any of its predecessors, and if it become law and be properly enforced it should give a much more effective protection than is at present possible. The important new powers are those which are to make it an offence to be in possession of any bird, part of a bird, nest, or egg which may be presumed to have been illegally taken, and those which are to place the onus of proof on the possessor. At present, on the other hand, the onus is on the prosecution, and the act of killing or taking is the material fact to be proved : as a result, the skins and eggs of protected birds can be offered for sale with impunity by taxidermists and dealers, and " plovers' eggs " are freely sold in shops and restaurants in the close season. The Bill has still to be passed by the House of Commons, but we hope that this may be successfully accomplished next session.

AUGUSTIN LE PRINCE has rarely been recognised as one of the pioneers in kinematography. Mr. E. Kilburn Scott, who knew him personally, recently lectured before the Royal Photographic Society on his work in this direction, and a report of the lecture is given in the current number of the Society's Journal. Mr. Scott considers it established that Le Prince was the first to make a successful camera to take photographs at more than 16 in a second, was the first to show moving pictures on a screen (at Leeds in 1889), was the first to appreciate the importance of using flexible film (he is stated to have used celluloid films before September 1890), and was the first to use perforations and sprocket wheels (patents dated 1888). Le Prince's career came to an extraordinary end. He was last seen on September 16, 1890, at Dijon, entering a train for Paris, but since then nothing whatever seems to be known of him. One suggestion was that he might have been kidnapped by agents of American inventors whom he had forestalled.

THE Royal Geographical Society of Australasia (Queensland) is contemplating the investigation of the problems of the Great Barrier Reef, and is inviting other scientific societies and the universities of Australia to co-operate. In the *Queensland Geographical Journal* for 1920–22 Prof. H. C. Richards indicates some of the problems that await solution, and shows by a sketch of previous work on the subject how divergent are the views expressed on some important points. For example, it is apparently not known if the Great Barrier Reef is rising or falling or is in a static condition. The suggested investigations would include complete charting, including making vertical sections, of at least three island points on the reef, one each in the northern, middle, and southern regions, and recharting at intervals of a decade ; charting of several of the more important troughs or valleys in the reef and the lagoon area, and recharting, also, at intervals of a decade ; complete survey of the fauna, flora, and economic resources ; and experiments on the growth of corals under varying conditions.

A COPY of a pamphlet has reached us on " Suggestions for the Prevention of the Decay of Building Stone," by Mr. J. E. Marsh (Basil Blackwell, Oxford, 1s. 6d. net). The author remarks in the preface : " In 1861 the Commission, appointed to stop the decay in the stone of Westminster Palace, decided to wait till a remedy had been discovered, and did not expect to have to wait long. We have waited sixty