The Periodic Table of the Chemical Elements

SYNOPSIS OF LECTURE BY PROFESSOR C. E. FAWSITT on January 20th, 1936.[1]

ALTHOUGH it is only a comparatively short time since the lecturer delivered an address on the chemical elements (in the post-graduate course held in January, 1932, under the Sydney University Extension Board), an immense amount of research work has been carried out in the interval.

There were at that time two blanks in the table, the then unknown elements Nos. 85 and 87. Both these elements have now been detected.

No. 85. Allison, Murphy, Bishop and Sommer(1) detected this element in monazite sand. They did not obtain it or its compounds pure (1932). It has been called "**Alabamine**".

No. 87. Allison and Murphy(2) showed that the existence of this element was extremely probable in certain ores containing lithium and caesium, and it was suggested that the new element be called **Virginium.**(3) The existence of this element has since been confirmed.(4) (5)

ISOTOPES.

A large number of new isotopes have been discovered in the last few years, so many that no one now takes very much notice of the discovery of a new isotope.

A new method of writing the symbol of an element has also been introduced. For example, the lithium which occurs most abundantly with an atomic weight 7 is written ${}_3Li^7$. The 3 below at the left indicates the nuclear **charge**, and the number 7 above the symbol on the right indicates the nuclear **mass**.

HEAVY HYDROGEN.

The fact that the atomic weight of hydrogen is greater than 1 was attributed in the past to the fact that there was "packing effect", and that this disappeared largely in other elements if we suppose that atoms of other elements have been formed by an evolutionary process from hydrogen.

It is now known that most of the discrepancy between the atomic weight 1·0078 and 1 in hydrogen is due to the presence of an isotope ${}_1H^2$ and to a much smaller extent ${}_1H^3$.

A great deal of interest has been taken by scientists in the isotope ${}_1H^2$. It is called Deuterium, and is now usually given a separate symbol, D or ${}_1D^2$, instead of ${}_1H^2$. The reason is that the chemical properties of deuterium are somewhat different from those of ${}_1H^1$. The chemical properties are not different in ordinary isotopes. If lead (${}_{82}Pb^{207}$) had an isotope of twice this atomic weight ${}_{82}Pb^{414}$, it is considered

[1] Given during a course on "Recent Advances in Science" arranged by the Sydney University Extension Board.

that such isotopes of lead would be chemically inseparable.[6] ${}_{1}H^{1}$ differs, however, from ${}_{1}H^{2}$ in that its reactivity in chemical compounds is distinctly greater.

NEUTRONS.

A new particle has been discovered, the "neutron". It may be considered as a hydrogen atom in which the electron, usually circulating far from the proton, has come so near to it as to have combined with it more closely. The neutron can penetrate matter more easily than a proton.

Neutrons can be produced by the bombardment of some of the elements with α-particles, and also by the bombardment with protons and deuterons.

POSITRONS.

Another discovery is that of the positron. The positron is a point electrified with positive electricity to the same extent as the point called the electron is electrified with negative electricity. The positron appears frequently in cases of induced or artificial radioactivity.

INDUCED OR ARTIFICIAL RADIOACTIVITY.

It is possible successfully to bombard the atom of a large number of elements by protons, deuterons, α-particles and neutrons so that an artificial radioactivity is produced. This artificial radioactivity can even be imposed on the naturally occurring radioactive elements.

The uranium atom, for example, is radioactive naturally, and yet by bombardment with neutrons it can be turned to a small extent into an isotope with a mass one unit greater. This new radioactive atom decomposes of itself into other radioactive substances by loss of an electron. Whereas in natural radioactivity the atom may lose an electron or an α-particle, the atom made radioactive by artificial means loses an electron or a positron.

An interesting summary of the work that is going on in artificial radioactivity was given by Mr. L. A. Buckley, one of our university research workers in chemistry, in the Sydney University Chemical Colloquium on November 7th, 1935, and he has kindly provided a synopsis of his lecture, which is now printed to follow.

TYPES OF ARTIFICIAL DISINTEGRATION.

1. By bombardment with α-**particles** one can obtain stable nuclei with emission of either protons or neutrons. Sometimes the residual nucleus is radioactive and emits electrons or positrons.

$$
\begin{aligned}
\text{e.g., } {}_{4}Be^{9} + {}_{2}He^{4} &\longrightarrow {}_{0}n^{1} + {}_{6}C^{12} \\
{}_{7}N^{14} + {}_{2}He^{4} &\longrightarrow {}_{1}H^{1} + {}_{8}O^{17} \\
{}_{13}Al^{27} + {}_{2}He^{4} &\longrightarrow {}_{1}H^{1} + {}_{14}Si^{30} \\
&\longrightarrow {}_{0}n^{1} + {}_{15}P^{30} \quad ({}_{15}P^{30} \longrightarrow e^{+} + {}_{14}Si^{30}) \\
{}_{12}Mg^{24} + {}_{2}He^{4} &\longrightarrow {}_{0}n^{1} + {}_{14}Si^{27} \quad ({}_{14}Si^{27} \longrightarrow e^{+} + {}_{13}Al^{27}) \\
{}_{12}Mg^{25} + {}_{2}He^{4} &\longrightarrow {}_{1}H^{1} + {}_{13}Al^{28} \quad ({}_{13}Al^{28} \longrightarrow e^{-} + {}_{14}Si^{28})
\end{aligned}
$$

2. Bombardment with other **positive particles.**

(*a*) **Protons** give rise to helium nuclei, and also to radioactive nuclei.

e.g., ${}_5B^{11} + {}_1H^1 \longrightarrow 3_2He^4$

${}_3Li^7 + {}_1H^1 \longrightarrow 2_2He^4$

and ${}_6C^{12} + {}_1H^1 \longrightarrow {}_7N^{13} \begin{cases} \longrightarrow e^+ \\ \longrightarrow {}_6C^{13} \end{cases}$

(*b*) **Deuterons** react similarly, and also react as α-particles, giving protons and stable nuclei.

$${}_3Li^6 + {}_1H^2 \longrightarrow 2_2He^4$$
$${}_3Li^7 + {}_1H^2 \longrightarrow 2_2He^4 + {}_0n^1$$
$${}_1H^2 + {}_1H^2 \longrightarrow {}_1H^1 + {}_1H^3$$
$${}_7N^{14} + {}_1H^2 \longrightarrow {}_6C^{12} + {}_2He^4$$
$${}_5B^{10} + {}_1H^2 \begin{cases} \longrightarrow {}_1H^1 + {}_5B^{11} \\ \longrightarrow {}_0n^1 + {}_6C^{11} \begin{cases} \longrightarrow e^+ \\ \longrightarrow {}_5B^{11} \end{cases} \end{cases}$$
$${}_{11}Na^{23} + {}_1H^2 \longrightarrow {}_1H^1 + {}_{11}Na^{24} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{12}Mg^{24} \end{cases}$$

3. **Neutrons** react in four different ways :

(*a*) Production of stable isotope.

$$zA^{\omega} + {}_0n^1 \longrightarrow zA^{\omega+1} + \gamma\text{-radiation}$$

(*b*) Disruption of nucleus gives stable products.

e.g., ${}_7N^{14} + {}_0n^1 \longrightarrow {}_2He^4 + {}_5B^{11}$

${}_3Li^6 + {}_0n^1 \longrightarrow {}_2He^4 + {}_1H^3$

(*c*) Formation of radioactive isotope.

$${}_{53}I^{127} + {}_0n^1 \longrightarrow {}_{53}I^{128} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{54}Xe^{128} \end{cases}$$
$${}_{92}U^{238} + {}_0n^1 \longrightarrow {}_{92}U^{239} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{93}U^{239} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{94}U^{239}, \text{ etc.} \end{cases} \end{cases}$$

(*d*) Expulsion of positive particle and formation of radioactive residue.

$${}_{13}Al^{27} + {}_0n^1 \longrightarrow {}_2He^4 + {}_{11}Na^{24} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{12}Mg^{24} \end{cases}$$
$${}_{12}Mg^{24} + {}_0n^1 \longrightarrow {}_1H^1 + {}_{11}Na^{24} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{12}Mg^{24} \end{cases}$$

N.B.—One stable nucleus can be made to yield a number of different radioactive nuclei.

(1) ${}_{13}Al^{27} + {}_0n^1 \longrightarrow {}_2He^4 + {}_{11}Na^{24} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{12}Mg^{24} \end{cases}$

(2) ${}_{13}Al^{27} + {}_0n^1 \longrightarrow {}_1H^1 + {}_{12}Mg^{27} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{13}Al^{27} \end{cases}$

(3) ${}_{13}Al^{27} + {}_0n^1 \text{ (slow)} \rightarrow {}_{13}Al^{28} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{14}Si^{28} \end{cases}$

(4) ${}_{13}Al^{27} + {}_2He^4 \longrightarrow {}_0n^1 + {}_{15}P^{30} \begin{cases} \longrightarrow e^+ \\ \longrightarrow {}_{14}Si^{30} \end{cases}$

Also one particular radioactive element can be produced in a number of different ways,

e.g., (1) ${}_{13}Al^{27} + {}_0n^1 \longrightarrow {}_{13}Al^{28} \begin{cases} \longrightarrow e^- \\ \longrightarrow {}_{14}Si^{28} \end{cases}$

(2) ${}_{13}Al^{27} + {}_1H^2 \longrightarrow {}_{13}Al^{28} + {}_1H^1$

(3) ${}_{14}Si^{28} + {}_0n^1 \longrightarrow {}_{13}Al^{28} + {}_1H^1$

(4) ${}_{15}P^{31} + {}_0n^1 \longrightarrow {}_{13}Al^{28} + {}_2He^4$

(5) ${}_{12}Mg^{25} + {}_2He^4 \longrightarrow {}_{13}Al^{28} + {}_1H^1$

Relationship of Neutrons to Protons.

The nucleus of an atom is supposed to consist of neutrons and protons. Radioactive emission of a positron or electron consists of a switch-over of one of these to the other, as follows :

$${}_1H^1 \longrightarrow {}_0n^1 + e^+$$
$${}_0n^1 \longrightarrow {}_1H^1 + e^-$$

Tables of Isotopes.*

In the following tables W–2Z is plotted against Z, where Z = atomic number (number of protons in nucleus) and W = atomic mass (number of protons + number of neutrons).

The following diagram, copied from *Science Progress*, No. 117, page 29, will serve to make this clear.

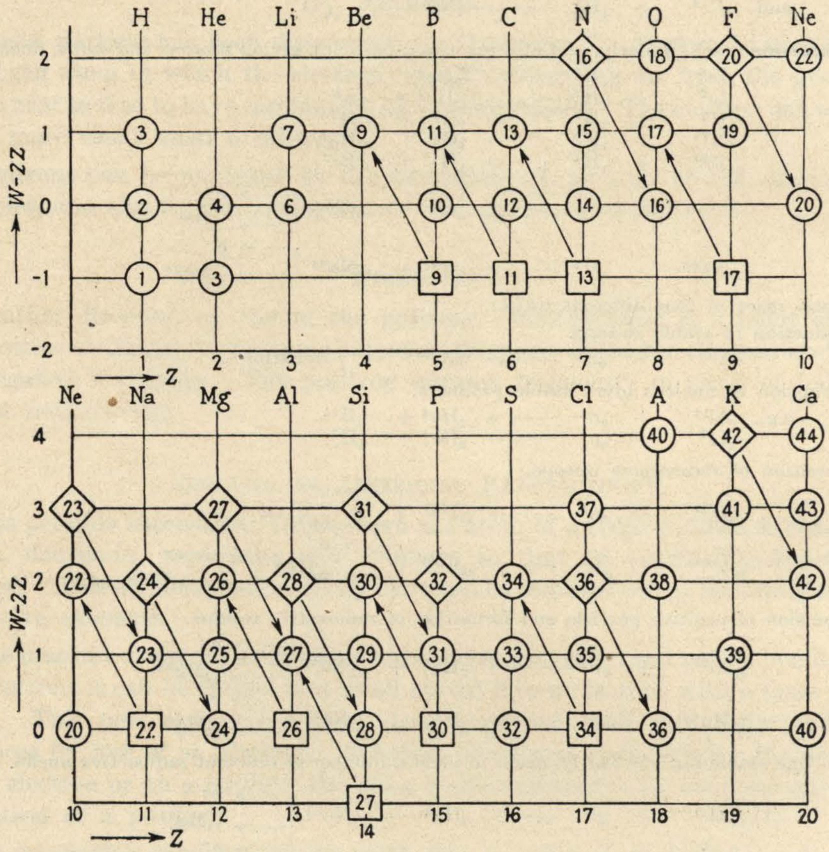

Fig. 1.

The numbers give the masses of the isotopes, and those in a vertical column belong to one element, indicated by the chemical symbol at the top.

○ = stable isotope. □ = positron emitter. <> = electron emitter.

Arrows indicate the end products of decay of these unstable isotopes.

References.

(1) *Phys. Rev., 37,* 1178 (1931). *J. Amer. Chem. Soc., 54,* 616 (1932).

(2) *Phys. Rev., 35,* 285 (1930) ; *37,* 1178 (1931).

(3) Allison, Bishop, Sommer and Christensen : *J. Amer. Chem. Soc., 54,* 613 (1932).

(4) Yagoda : *Phys. Rev., 40,* 1017 (1932).

(5) Weeks : "The Discovery of the Elements", published (1934) by the *Journal of Chemical Education,* page 329.

(6) Polanyi : *Nature, 135,* 19 (1935).

Other References.

Sugden : "Artificial Radioactivity".
Science Progress, 30, 16, 1935.

J. G. Crowther : "The Progress of Science", published by Kegan, Paul, Trench, Trubner & Co., 1934, pages 1 and 162.

* This table appears, almost exactly as it appears here, in *Science Progress*, 30, p. 16 (1935).