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## SEPERATION OF ISOTOPES :

Address delivered by
**F. W. ASTON,** F.R.S., D.Sc., Nobel Laureate.

*(Substance of an address delivered on the occasion of the award of the Joy Kissen Mookerjee medal, January 6th, 1938.)*

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# SEPARATION OF ISOTOPES

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The separation of isotopes, that is atoms of different mass occupying the same place in the Periodic Table, is a difficult problem, in fact it is this inseparability which led to their original discovery. Boltwood in 1906 noticed that if by chance thorium and ionium compounds became mixed it was impossible to separate them by any chemical means. Similar identities were found among other products of radio-activity and this led Soddy to publish in 1910 his theory that the same chemical element could have atoms of different weights which he subsequently called 'Isotopes'.

The first partial separation of the isotopes of neon I achieved by diffusion through pipeclay. The possibility of this rests on the fact that the rates of diffusion of atoms in a gas are inversely proportional to the square roots of their masses. As even in the favourable case

of neon atoms of masses 20 and 22 respectively the 21st root is involved, the method is extremely laborious, but after many months of work I was able to show a change in density of 0.7 per cent. with a possible error of 0.1 per cent. This result I announced at the British Association meeting at Birmingham in 1913, the same meeting at which Soddy gave his amplified theory of isotopes in radioactive disintegrations. I remember, years later, in 1920 when the isotopic nature of chlorine had been fully demonstrated by means of the mass-spectrograph, talking with Sir W. Pope who was of the opinion that we should have tons of chlorine 35 and chlorine 37 separated in a year or two. My own experience enabled me to assure him that this was by no means the case, and that the separation of isotopes was too difficult for it to affect the ordinary work of the chemist for many years to come, a conclusion which subsequent events have fully justified.

Diffusion through porous media was used by Harkins in his pioneer experiments on HCl vapour. He worked on a large scale and in 1920 was able to show that a small change in the atomic weight of chlorine had been obtained. Brönsted and Hevesy obtained

partial separation of the isotopes of mercury by the elegant method of slow distillation in a vacuum so perfect that none of the evaporating atoms could return to the surface of the liquid. Under these conditions the lighter isotopes escape more freely than the heavier ones and it was found that the increase of density in the residue, though exceedingly small, was exactly in agreement with theory.

Separation should be possible by the action of gravity and Lindemann has suggested that the neon in a sample of air from the upper part of the stratosphere should be lighter than normal neon. This experiment has not yet been carried out. Many attempts have been made to apply the high gravitational field available in centrifuges to the problem but with no success. This failure is generally attributed to the impossibility of eliminating vibration. Research in this method is still going on in Oxford and other places by the use of the modern ultra-centrifuges. If the technical difficulties can be overcome this is probably the most promising method of general application for separation on a practical scale. Ionic migration in gelatine under electric fields was tried by Kendall but though this method separated substances as similar as two of the rare earths

from each other, no success was obtained with isotopes. A very beautiful photochemical method is that of allowing light of very restricted wave-length to fall on $COCl_2$ vapour. If the wave-length is chosen correctly the lighter isotope of chlorine will be dissociated preferentially. This method has given positive results but the change in atomic weight and the quantities obtained are very small.

To turn to more recent successful work remarkable results with neon have been obtained by Herz who devoted many years to the problem. By means of an ingenious system requiring the simultaneous working of 48 mercury diffusion pumps he is able to obtain either the light or the heavy isotope in small quantities up to 99 per cent purity. This is a technical triumph of a high order but unfortunately not only is the apparatus extremely difficult to work but it only seems to function properly with the inert gases, which are of little interest to chemists.

Another method giving perfect separation is by using a mass-spectrograph to resolve beams of the isotopes and collecting these on targets cooled with liquid air. The difficulty here is to obtain beams of sufficient intensity to produce an appreciable yield in a reasonable

time. This was done in the Cavendish Laboratory in the case of the isotopes of lithium 6 and 7. Pure specimens of these bodies were prepared and, although only containing micrograms, were sufficient for use in the transmutation apparatus of Lord Rutherford and his colleagues, who were able to investigate the reactions of each isotope separately, and so solve the problems involved in the artificial disintegration of the element lithium. Mass-spectrum separation has also been applied with success to the element potassium in America, and at the present time every effort is being made to use it to obtain pure specimens of the isotopes of boron 10 and 11, but so far without success.

The most remarkable case of separation on a chemical scale is the unique one of the isotopes of hydrogen 1 and 2. The latter is only present to the extent of about 1 in 5000 but the difference in mass is so large that separation can be obtained without serious difficulty by electrolysis. Heavy hydrogen is therefore of such importance in chemistry that it has been named Deuterium by Urey, its discoverer and has been given a separate symbol D. Pure heavy water $D_2O$ is made in large quantities at hydro electric works in

Scandinavia and elsewhere at a moderate cost. Further electrolysis of heavy water should result in a concentration of the still heavier isotope of mass 3, which is certainly formed in some nuclear transformations, but direct analysis by the mass-spectrograph of the concentrates from very large volumes of heavy water has shown that this isotope does not exist to any appreciable extent in normal hydrogen.

A few months ago it was reported that Urey had succeeded in a partial separation of the isotopes of nitrogen 14 and 15 by a differential diffusion of ammonia in a very long absorption tower. This result is of particular importance for the preparation of heavy nitrogen, even if impure, would open up a new and interesting field in biochemistry as the movements of this element could then be traced in the metabolism of living organisms.