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THE DISCOVERIES, PROPERTIES AND USES OF DEUTERIUM.

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Instructor....Schrieber.

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The Discovery, Properties and Uses of Deuterium.

Deuterium, or double weight hydrogen, was discovered by Professor Harold C. Urey, Ph.D., Professor of Chemistry, Columbia University. He had noticed a disagreement in the results of two different methods of determining the mass of the hydrogen atom. The difference could be explained if it were assumed that 1 part of hydrogen of atomic weight 2 were present in every 4500 parts of hydrogen of atomic weight 1. This indicated that if the isotope were present in natural hydrogen, it was so rare that none of the methods used for its detection would be successful. Using Bohr's theory, that the wavelengths of light emitted by hydrogen atoms depend on the mass of these atoms, it was found that the four spectrum lines of hydrogen, lying in the red, blue-green, and two in the violet were displaced toward the violet by 1.8, 1.3, 1.17 and 1.08 Angstroms respectively. These satelites were present both in ordinary hydrogen and in the concentrated sample, thus proving the existence of the isotope.

Professor Urey suggested that the isotope of mass 1 be called "protium", and the isotope of mass 2, "deuterium", while thenucleus, which is efficient as a projectile in transform--ing matter, be called deuteron, or deuton. The name "diplogen" for the new isotope, and "diplon" for the nucleus has been suggested by Lord Rutherford, of the Royal Society, and is in favor in England. The symbol D for the heavy isotope seems appopriate.

It was proposed by Wm.D.Harkins, of the University of Chicago, that the nomenclature suggested by Urey be modified to make it more general. Instead of giving a separate name to each isotope of each element, which would be very confusing, the atomic and isotopic numbers are used to name it, as follows: If P is the whole number closest to the atomic mass, the isotopic number(I), is given by $I = P-2Z$ where Z is the atomic number. Light hydrogen is 1,-1. Heavy hydrogen is 1,0. They are called protohydrogen and deutohydrogen respectively. Heavy water is $(1,0)_2(8,0)$ or dideutohydrogen oxide. The old system called it dideuterium-hekaidekatium. By this system also, the negative electron is (-1,2). The positive electron is(1,-2). The neutron is (0,1). However, most writers on the subject seem to favor the name deuterium for the atom, deuton for the nucleus, and deuterium oxide for heavy water, with the respective symbols: D, D_1^2, and D_2O.

The two hydrogen isotopes show marked differences in physical and chemical properties. Bainbridge found, using a modification of the positive ray method, that the mass of the deuterium atom is 2.0136 and that of the protium atom is 1.0078, in terms of O as 16. The melting points of the two isotopes differ by 4.7°C. They are 13.9° and 18.6° above absolute zero.

The characteristics of heavy water and ordinary water also differ. The density of D_2O is 10% greater than that of H_2O. Its specific gravity is 1.1078 at 77°F.(25°C). Its freezing point is 3.8°C. Its boiling point is 101.42°C. There is no difference in taste.

The vapor pressure of heavy water varies markedly from the normal,and the latent heat is higher.Both the surface tension and inductive capacity are lower,while the viscosity is greater.

A research was carried on at Princeton in which 3 ounces of heavy water were made from 10 tons of industrial electrolytic liquor,which contains 1 part D to 2000 parts H. Ordinary rain water contains 1 part in 5000. 3 ounces of deuterium can be made from 25 tons ordinary water.

Lewis and MacDonald found that the concentration of D was rapidly enriched by continued electrolysis.Nickel electrodes were used,with Na OH as the electrolyte.It was found that the escape of H was from 5 to 6 times faster than that of D,relative to their concentrations in solution. There was,in consequence,a steady accumulation of the heavy isotope in the water in the process until nearly pure heavy water was obtained.This contains 1 part in about 50,000 of another isotope of mass three.The present cost of production is $5 per gram.

The discovery of heavy water is of great significance not only because of its physical nature,but also because of its effects on the processes of life in the biological field. G.N.Lewis,of the University of California,found that it would not support life,by showing that seeds of a certain tobacco plant did not germinate in pure heavy water,but did so when the concentration was 50%.Still more significant are the experiments of W.W.Swingle,of Princeton,who recently showed that heavy water is lethal to small fresh water animals. Green frog tadpoles survived only an hour when placed in it, although they lived happily when placed in water containing only 30% heavy water. Paramecia, one celled organisms, lived for twenty four hours, but fresh water fish, such as guppies, and fresh water worms were killed. Professor Urey beleives that, although experiments seem to indicate the opposite, both plants and animals can be acclimatized to high concentrations of heavy water, but their living processes will be much slower. Some scientists have advanced the idea that the drinking of heavy water by humans might produce a fever, and so become useful as a medicinal agent. According to Professor Urey, however, the contribution which deuterium will make to medicine will be through the better understanding of the fundamentals of living processes, rather than through its use as a medicine directly.

Perhaps the most important result of the discovery of deuterium is in the use of the deuton as a projectile in the transmutation of the elements. According to Lord Rutheford, the deuton is 10 times as efficient as the proton.

Oliphant and Rutherford bombarded lithium with deutons, and found that it breaks down into two alpha particles and a neutron, according to the formula: $Li^{7}_{3} + D^{2}_{1} \rightarrow He^{4}_{2} + He^{4}_{2} + n^{1}_{0}$
In addition to the fast alpha particles, they observed a distribution of alpha particles of ranges from 7.8 cms. to 1 cm. in air. Taking into account the changes in mass and energies of the expelled particles, this reaction is in close accord with the Conservation of Energy.

Dee and Walton bombarded the lithium isotope of mass 6 with deutons, and found that two fast alpha particles resulted. They photographed the reaction and found that the two alpha particles were shot out in opposite directions with a speed greater than that of the swiftest alpha particle from radioactive substances. $Li^{6}_{3} + D^{2}_{1} \rightarrow He^{4}_{2} + He^{4}_{2}$.

Recent experiments made in Cambridge by Oliphant and Harteck showed that when deutons are used to bombard NH_4Cl and $(NH_4)_2SO_4$ in which H was to some extent replaced by D , enormous numbers of fast protons were emitted. The main group had a range in air of 14 cms., corresponding to an energy of 3,000,000 volts. Another group of simply charged particles of range in air of only 1.6 cms. was observed. Both groups contained an equal number of particles. To account for this, it seems likely that a deuton occasionally unites with a struck deuton to form a helium nucleus of mass 4 and charge 2, but containing a large excess of energy over the ordinary helium nucleus. It is in consequence explosive, and breaks up into two parts, a fast proton, and a new isotope of hydrogen of mass three, (H^{3}_{1}). The H^{3}_{1} particles should fly apart in opposite directions. Rutherford verified this theory by bombarding deuterium atoms with deutons, and succeeded in producing an H atom of atomic weight 1 and another H atom of atomic weight 3. which he observed to be present in natural hydrogen to the extent of about 1 part in 10 billion.

The reason for the efficiency of deutons as projectiles is probably that a larger number of those entering the nucleus are retained by it, causing violent disintegration.

Also ,perhaps,the deuton breaks down into its component parts. The appearance of protons and neutrons may be connected with the the structure of the deuton.

By comparing the scattering of alpha particles when passing through deuterium and hydrogen,Kempton and Rutherford found that as a result of collision with an alpha particle, the recoiling deuton travels 8% faster than a proton in a corresponding collision.This result seems to indicate that the field of force around the deuton is very similar to that around the proton,

Lawrence,from a study of the bombardment of elements by deutons,suggest that the deuton may break up into a proton and a neutron in the strong electric field close to the bombarded nucleus,but interpretation of his results are not yet certain.

Experimental results are not yet sufficient to give a definite decision with regard to the structure of the deuton, and as to the question of possible industrial uses,no safe prediction can yet be made.

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