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Nobel Prize in Chemistry 1934

Harold Clayton Urey

The Nobel Prize in Chemistry 1934 was awarded to Harold C. Urey *"for his discovery of heavy hydrogen"*.

RESEARCH INFORMATION:

A short time ago a politician of prominent rank, when speaking on a festal occasion, remarked that at the present day it might appear to be an actual desideratum for the activity of the inventor in the technical field to be checked and given pause for some little time to come. That rather startling utterance was prompted by the volume of the existing unemployment and by the risk there is of that unemployment being further augmented, if technical ingenuity and skill are to continue to have free play.

In the minds of some chemists a somewhat similar chain of reasoning may be awakened, when they are brought to contemplate the particular discovery to whose originator the Royal Swedish Academy of Sciences has resolved to award the Nobel Prize for Chemistry for the current year. For the fact is, that this discovery creates serious disorder in those trains of concepts along which we have latterly been accustomed to let our thoughts range with a certain degree of composure. Instances of similar character have occurred before both in chemistry and in other sciences, but so soon as time has allowed of an adjustment to the new outlook afforded by the discovery, one will realize as a matter of course that a big step forward has been achieved, in itself a cause for gratification.

In order to throw light upon the situation we are presented with, it is incumbent on me first of all to mention what is to be understood by *isotopes*. For ever so long past, the metal copper, for instance, has always been regarded as a simple element with an atomic weight 63.6, the latter fact implying that an atom of copper weighs 63.6 times as much as the arbitrarily adopted unit for atomic weights. The said unit is no longer, as it was formerly, the exact weight of an atom of hydrogen, being actually somewhat less; but, for our present purposes, we can ignore that fact and term the atomic weight of hydrogen the unit. However, as the result of work that has been pursued from the year 1910 onwards, principally by the English investigators, Soddy and Aston, both former Nobel Chemistry Prize winners, the very remarkable circumstance has been discovered that each of certain elements, hitherto regarded as completely homogeneous, consists as a matter of fact of an amalgamation of two or more substances with atomic weights that differ one from another but which are nevertheless from a chemical point of view, so far as has been hitherto ascertained, practically speaking identical. Aston has designed an instrument, the so-named mass spectrograph, which enables us with the aid of electrical and magnetic forces to prove the existence of these so-termed isotopes with the utmost certainty, and also to determine their respective atomic weights. Thus, it has been established that copper consists of an amalgamation of two isotopes with atomic weights of 63 and 65. An amalgamation of that character, in fitting proportions, can manifestly appear to have an intermediate atomic weight of, say, 63.6. In other instances the number of isotopes may be much larger - for tin for instance there have been shown to exist no less than eleven.

Aston discovered, however, in addition, that the atomic weights of these isotopes were always, at any rate very nearly, whole numbers, and also, as stated, that chemically no difference between the various isotopes was demonstrable; that explains how it came about that an amalgamation of them could be conceived to be a homogeneous chemical element.

The explanation, again according to the modern atomic theory, is that the chemical properties of the elements are dependent, not directly upon the magnitude of the atomic weights, but upon the number of positive, electric unit charges - consequently always of necessity a whole number - in the so-termed atomic nucleus, around which a corresponding number of free negative electricity units, the so-termed electrons, revolve like the planets round the sun.

Seeing that the isotopes had identical chemical properties, chemists accepted their discovery with tranquillity - indeed, after it had been established that the atomic weights of the isotopes were all whole numbers, with a degree of satisfaction, for thereby a justification was afforded for Prout's very attractive hypothesis, enunciated more than 100 years ago, that the atomic weights of all the elements were multiples of that of hydrogen and consequently whole numbers.

A little more than three years ago Harold C. Urey attacked the problem of finding out whether it might be possible to discover an isotope of the simplest of all the elements, viz. hydrogen. When he began that task, Urey was attached, as Assistant Professor of Chemistry, to that large and far-famed institution, the Columbia University in New York, and he advanced last spring to a full professorship there in the same subject.

As the atomic weight of hydrogen is approximately equal to 1, and as the atomic weights of the isotopes must differ by whole numbers, it follows that the nearest to ordinary hydrogen of any hydrogen isotopes there may be, must have an atomic weight of approximately 2, consequently double (100% more than) that of the hydrogen hitherto known. Now the atomic weights of hitherto known isotopes, namely those of elements with pretty large atomic weights, only differ from each other by a few units, the difference in their respective atomic weights being consequently only a few percents in isotopes of elements having large atomic weights. That might possibly be the explanation of how it is that isotopes of such elements have not shown any difference one from another in chemical respect. But how would matters stand with regard to a possible hydrogen isotope with an atomic weight 100% higher than that of the hydrogen previously known? That was the interesting question which presented itself, and the answer turned out to be, as I shall state more fully later on, that there proves to be a marked difference between the two hydrogen isotopes in chemical respect also. It is that circumstance which has perturbed chemists and roused them out of a state of mental tranquillity regarding this matter which had been induced in them, as above mentioned, by their foregoing contemplation of the isotopes.

When Urey set about his attack upon the question, it was not altogether untrodden ground, for there had been suppositions expressed as to the existence of a hydrogen isotope, a number of experiments having even been made to prove it, without however having led to any definite result. Urey proved to be the man to tackle the question in a rational way and to solve it. By the aid of modern theories he could calculate that the heavy hydrogen of mass 2 would be somewhat less volatile than the light hydrogen of mass 1, and that as a consequence it ought to be possible to a certain degree to separate the two isotopes one from another by a distillation of liquid hydrogen. For hydrogen, however, to assume the fluid form at all an exceedingly high degree of refrigeration must be attained, for the boiling point of hydrogen is round about - 250°C. Apparatus for the production of liquid hydrogen Urey had none, and consequently he applied to a friend of his, Dr. Brickwedde of the Bureau of Standards at Washington, requesting him at his Institution, which is very finely equipped, to carry out the desired distillation of liquid hydrogen, in order to obtain the isotope sought for in concentrated form. Meanwhile, with the aid of his assistant, Dr. Murphy, Urey worked out calculations as to what would be the appearance of the spectrum of the hydrogen isotope that he was awaiting. When he then obtained the expected sample it was subjected to examination by the spectroscopic method and the presence of the new isotope was established; in ordinary hydrogen it occurs in the approximate proportion of 1 to 5,000. The result was published in January 1932.

This was in itself already a matter of prime interest. Of considerably greater interest, however, is the fact that a difference in chemical respect between two isotopes became apparent here for the first time. As already stated no difference of the kind could previously been established. In this case, however, success had been achieved and thereby was affected in the first place our conception of water - of honest old water which had always been regarded as the typical example of a simple, respectable and straightforward chemical compound. The smallest particles of water, its molecules, are regarded as consisting of two atoms of hydrogen, with atomic weight 1, and one atom of oxygen, with atomic weight 16. As the whole molecule, taking the atomic weight of hydrogen as the unit, thus weights 18, water ought to consist of hydrogen to the extent of 2/18 or 1/9, i.e. to about 11%, the remainder being oxygen. If, however, the two hydrogen atoms are replaced by the atoms of the isotope, which are twice as heavy, the water will consist of four parts by weight of hydrogen and sixteen parts by weight of oxygen, i.e. will contain 20% of hydrogen. It should also be heavier, inasmuch as each particle is heavier in the proportion of 20 to 18.

In ordinary water both kinds of hydrogen must be present, since besides in other ways they can be obtained directly from water. The best method for separating off the heavy water from ordinary water is by electrolysing the water, i.e. by sending an electric current through water that has been rendered conductive by the addition to it for instance of caustic soda. Thereby hydrogen gas is generated at the negative pole and it is then found that the hydrogen gas given off contains proportionally a larger quantity of light hydrogen than the water itself, implying that the latter consequently becomes richer in heavy hydrogen. The original idea of adopting this method is attributable to the late Dr. E.W. Washburn, of the Bureau of Standards, Washington, who died on February 6, 1934, and the further development of the method was largely due to him too, though Urey collaborated by carrying out the spectroscopic examinations of the samples. In natural water the proportion existing between the molecules of heavy and ordinary water is approximately 1 to 5,000.

It has also proved possible to obtain heavy water in a pure form. This was accomplished first by G.N. Lewis and his co-workers, at Berkeley, California (July 1933). Whereas, as we know, one litre of ordinary water weighs one kilogramme, one litre of heavy water weighs about one kilogramme and one hectogramme, which approximately corresponds to the increase in the weight of the molecule. Its freezing-point is +3.8° instead of 0° (that of ordinary water), and its boiling-point is 1.4 degrees higher than that of ordinary water. It is more viscous than ordinary water and the solubility of salts in it is less, etc., etc. It has furthermore proved possible either wholly or partially to replace by heavy hydrogen the ordinary hydrogen that is a constituent of ammonia, hydrochloric acid, acetic acid, sugar, albumen, etc., etc. As heavy and light hydrogen thus - in contradistinction to previously known isotopes - possess different chemical characteristics, it has been thought advisable to bestow on them individual names. Urey calls heavy hydrogen *deuterium* and ordinary hydrogen *protium*. The reaction velocity for ordinary hydrogen or ordinary water respectively, as compared with deuterium or heavy water respectively, has proved to differ on occasion, as has also the ultimately obtained yield of the reaction. Among chemico-biological effects there may be noted: that alcoholic fermentation proceeds more slowly in heavy than in ordinary water, that the sprouting of tobacco seeds and the evolution of yeast fungi are delayed or checked, etc., etc. Atomic nuclei of heavy hydrogen, when propelled as rapid projectiles by an electric field have proved to be exceedingly effective in the breaking down of atoms and in transformation of elements in conjunction therewith. Radio-sodium produced by that process may perhaps prove to be of medicinal importance.

These initial discoveries are undoubtedly of great importance for chemical science. Whether and in what measure they will prove capable in the near future of bringing about anything of direct practical advantage to humanity, time will show.

Urey, who was born in 1893, has already been the recipient in America of a highly valued distinction, viz. the medal that perpetuates the memory of Willard Gibbs, the author of works of the greatest moment in theoretical chemistry. On the occasion of the presentation of the medal, last spring, Urey gave a lecture, in which he vividly described the history of the discovery, stating, for instance, that the idea of concentrating the isotope that was being sought for flashed into his mind while he was attending a lunch in August 1931. He goes on to say that he had then to wait for a couple of months for the samples of hydrogen gas from Washington, and that, after their arrival he and his assistant Murphy worked at the spectroscopic investigation practically day and night for a whole month, in that way accomplishing work that would otherwise have demanded four months. The most trying experience they had was when, for a considerable time, they were unable definitely to determine whether the new lines that they observed in the spectrum actually proceeded from the isotope they were seeking for, or were so-termed "ghost-lines" due to minor faults in the apparatus. Just then their consumption of cigarettes increased tenfold and they were quite insufferable in association with their fellows, including even Mrs. Urey, who for the time being was left completely in the cold.

Their haste was moreover fully justified, for, as already mentioned, there had been suggestions put forward in other quarters that there should exist a hydrogen isotope. And when the discovery was revealed in January 1932, scientists everywhere, primarily in the United States, but also in European countries and in Sweden amongst others, seized upon this sensational new idea to such purpose, that the number of treatises on questions related to the matter at the present time already amounts to two hundred. In the ranks of the other investigators the late E.W. Washburn, already alluded to, should undoubtedly be placed first, for his contributions to the problem of the production of heavy water. At the present time heavy water is produced technically in many places, more especially at Rjukan in Norway, where the Norsk Hydro Concern has established a gigantic plant for the production of hydrogen by the electrolytic process. They calculate there on obtaining half a kilogramme every twenty-four hours.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1934/press.html