fundamental science of physics, which enables the child later to appreciate even a qualitative presentation of modern biology, because he then knows that all experiment is based on precise measurement, and can appreciate stated laws and inductive reasoning."

A NEW KIND OF HYDROGEN.

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For about a century after Dalton first proposed his theory of atoms chemists believed that all the atoms of a given element possessed the same mass. This belief was, of course, quite consistent with all the facts known at the time. During the present century, however, the belief was shaken by the discovery of chemically similar but chemically inseparable radio-active atoms whose masses were undoubtedly different from one another. At first it seemed that such atoms, known as isotopes, were to be found only among the radio-active elements, but it was not long before it became quite clear that nearly every element is a mixture of atoms differing slightly from one another in mass, but identical in chemical behaviour. This discovery was perhaps a little disconcerting to chemists at first. It was not so troublesome as it appeared, since it was found that in nature the proportions of atoms of different weights in any element were always constant. Oxygen, the most abundant element in the earth's crust, consists almost entirely of atoms of mass 16 ; about one atom in ten thousand has a mass of 17, and this proportion is, as far as we know, quite invariable. Similarly silicon, whether it is derived from the earth's crust or from other bodies of the solar system in the form of meteorites, has always the same proportion of atoms of masses 28, 29 and 30 respectively. In other words, the atomic weight of an element as determined by chemical means is a constant and represents the average weight of the atoms. We do not know exactly how the constancy in the proportions of different isotopic atoms in an element came about. It may have arisen from properties inherent in the structures of the atoms themselves, or from a thorough mixing of isotopes during the gaseous and liquid states of the earth's crust. At all events the reverse process, the unmixing of the isotopes, has proved a very difficult one to effect.

On account of the identical chemical behaviour of oxygen atoms of masses 16 and 17 respectively, no separation of the two kinds can be achieved by chemical means. Similar remarks apply to the isotopes of all the other elements — with one exception, namely, hydrogen. Attempts have been made to separate isotopes by means of such physical processes as diffusion and evaporation with the result that a partial, but very incomplete separation of the isotopes of chlorine, of neon and of mercury has been achieved. The separation of the isotopes of chlorine, for example, has never been so complete as to enable chemists to prepare two different kinds of salt, $NaCl^{35}$ and $NaCl^{37}$. The masses of the two isotopic chlorine atoms are far too close to allow of their effective separation in bulk by physical means. But with hydrogen two (H^2) the most recently discovered (and certainly one of the most interesting of all isotopes) it is a very different story, since its mass is just twice that of hydrogen one (H^1). In no other case is there such a marked relative difference in the masses of two isotopic atoms, and it is not surprising, therefore, that such large differences in the masses are accompanied by correspondingly large differences in physical and chemical behaviour. The nucleus of hydrogen two (H^2), according to one of its discoverers, consists of a proton and a neutron. The latter is a recently discovered entity with an electrical charge of zero and a mass equal to that of a proton. Hence, while the charge on the nucleus of H^2 is unity (the same as on the nucleus of H^1), the combination of neutron and proton produces just double the mass of that of the nucleus of H^2.

H^2 is rather a rare atom in ordinary hydrogen, where it occurs to the extent of about one part in thirty thousand. It was first discovered spectroscopically in hydrogen which had been distilled at a temperature of $-477°$ F. The detection was rendered possible by the fact that distillation increased the concentration of (H^2) to about one part in a thousand. The most successful method of concentrating H^2 is fractional electrolysis, a process which makes use of the fact that atoms of H^1 are the more readily discharged at a cathode than are atoms of H^2. If a very large volume of water is electrolysed until $99 \cdot 99\%$ of it is changed into oxygen and hydrogen the residual water will contain a large proportion of a denser variety of water whose composition is H^2H^2O.* Water from commercial electrolytic cells which have been in operation for some time is quite likely to be perceptibly denser than ordinary

* This substance is now referred to as deuterium oxide.

water by reason of the fact that it contains appreciable quantities of H^2H^2O. Using the method of electrolysis, Professor G. N. Lewis of the University of California has prepared a small sample (0·3 cubic centimetre) of water consisting almost entirely of water of the composition H^2H^2O. "Heavy-weight" hydrogen of 99·5% purity was obtained from H^2H^2O by passing its vapour over red hot iron. This new kind of water has some very interesting properties. For example, it freezes at 3°·8 C., boils at 101°·4 C., has a density of 1·056 grm. $cm.^{-3}$ (under conditions for which the density of ordinary water is 1·000 grm. $cm.^{-3}$). Since H^2H^2O is approximately 10% denser than ordinary water, accurate density measurements afford one of the most sensitive and useful methods of detecting its presence. The temperature of its maximum density is 11°·6 C. H^2H^2O also shows some interesting biological effects. Thus, a number of seeds of a certain species of tobacco plant germinated quite readily in ordinary water, while other seeds from the same batch failed to do so in H^2H^2O. In a mixture of H^2H^2O and H^1H^1O their rate of germination was very considerably slowed down.

In the case of all the isotopic elements, except hydrogen, their masses differ so little from one another that their physical and chemical behaviour show extremely small differences. With H^1 and H^2 the differences are so much more marked that H^2 promises to be quite a useful chemical reagent. G. N. Lewis has gone so far as to suggest that a new organic chemistry may be at hand. In fact, the prospects for the use of H^2 are so promising that its commercial manufacture has been undertaken by at least one company, and is now well under way. Nature, by conducting her experiment over vast periods of time and by making use of different starting materials, namely, uranium and thorium, has produced two different kinds of lead; but the isolation of H^2 in a specimen of 99·5% purity is the first complete separation of isotopes to be effected in the laboratory. The preparation of the substance H^2H^2O in bulk is of a type unique in the annals of chemistry, and is unquestionably one of the most interesting chemical achievements of the last few years.