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Nobel Prize in Physics 1935

James Chadwick

The Nobel Prize in Physics 1935 was awarded to James Chadwick *"for the discovery of the neutron"*.

RESEARCH INFORMATION:

This year like two years ago the Academy of Sciences awards the Nobel Prize for Physics as a reward for discoveries in the world of atoms and molecules. However, a fundamental difference is to be observed between the prizewinners of this year and the prizes that were awarded last time. The latter formed the reward for investigations of more theoretical nature, viz. the discovery of laws regulating the great many phenomena having been brought into light by experimental research. This year the Nobel Prize for Physics is awarded as a reward for a discovery, confirmed in an experimental way, of a new fundamental building-stone of atoms and molecules, viz. the discovery of the so-called *neutron*. By a combination of intuition, logical thought, and experimental research Professor J. Chadwick, the laureate of this year, has succeeded in proving the existence of the neutron and establishing its properties.

One of the Nobel Prize winners for the year 1933, Professor Heisenberg, had concluded by his researches that, owing to reasons of principle as well as to the roughness of our senses and our instruments, it would be impossible for us to arrive at an exact knowledge of what takes place within the atoms. However, experimental research has made undaunted progress, and by the aid of refined methods and new instruments today's Nobel Prize winners in Physics and Chemistry have succeeded in presenting science with a new and deeper knowledge of the structure and qualities of matter.

The Nobel Prize for Physics for this year is awarded as a reward for the discovery of the *neutron*.

The neutron is a heavy particle without any electric charge and of the same weight as the nucleus of an atom of hydrogen.

At the decomposition of the radioactive substances and at the disintegration of atoms and molecules two kinds of particles were always found. One of them that has been called *electron*, has an extremely small weight, amounting to about 1/2000 of the weight of an atom of hydrogen. The electron is charged with negative electricity, the quantity of the charge being always the same, in whatever way the electron may have appeared. The other kind of particles proved to have a weight of the same size as that of the atom of hydrogen, or a multiple of the same. This heavy particle is always combined with a charge of positive electricity, whose quantity turned out to be equal to or a multiple of the charge of the electron. The smallest particle with positive charge, found in this way, consists of the nucleus of the atom of hydrogen, and its positive charge equals the negative charge of the electron. This smallest, heavy particle with positive charge has received the name of *proton*. Owing to the disintegration of atoms always resulting in protons and electrons, the theory was established that the atoms were composed of protons and electrons. The atom was thought of as having the form of a planetary system where the central body consists of protons, combined to a nucleus; outside this nucleus the negative light electrons circle like the planets round the sun. The number of electrons is different with different substances. The lightest element, hydrogen, has only one electron, helium has two, etc.

That the atom may be in a neutral state of electricity, the positive charge of the nucleus must be the same as the total charge of the exterior electrons. The simplest relation

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would here have been that the number of protons in the nucleus had been the same as that of the electrons circling about the nucleus. This proved, however, not to be the case. In the atoms belonging to different elements it was found that, apart from hydrogen, the nucleus had about twice as many protons as the number of exterior electrons. Thus e.g. helium has the weight four in relation to the nucleus of hydrogen but only two exterior electrons. That the atom may be neutral in electric respect, the supposition is necessary that the surplus of positive electricity that the nucleus thus receives owing to the greater number of protons, was compensated by negative electrons also entering the nucleus. The nucleus of helium was thus supposed to consist of four protons and two electrons, and about this nucleus there circle two electrons.

At first this idea of the atom could be made to agree fairly well with experience. The nucleus-charge resulting determines the character of the atom and its place among the elements. The number of exterior electrons and the distribution of their paths at different distances from the nucleus are determinative of the physical and chemical qualities of the element; if one electron suddenly passes from one path to another, light is emitted, and if electrons from the paths closer to the nucleus are flung from the atom, X-rays are emitted, and so on. If the number of protons is increased or diminished in a nucleus, but the charge of the nucleus is still kept unaltered by the addition or the loss of negative electrons, the same element is still obtained but with different atomic weight; a so-called isotope is obtained. Thus e.g. lead is found in several different forms with different weight; and heavy hydrogen, the object of last year's Nobel Prize for Chemistry, is a similar modification of normal hydrogen.

A continued study of the conditions of energy at the disintegration of the nuclei of atoms showed, however, that the theory of the nuclei being composed of protons and electrons could scarcely be brought to agree with theoretical and experimental facts. As often happens in these spheres, it was the discovery of new phenomena, difficult to explain, that gave rise to the solution of the problem about the structure of the nuclei of atoms. In 1930 the scientists Bothe and Becker had found a new strange radiation that appeared,

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when the substance *beryllium* was bombarded with nuclei of helium. This new radiation, which was called *the radiation of beryllium* proved extremely penetrating. The rays could pierce a brass plate, several centimeters thick, without any noteworthy loss of velocity. When hitting nuclei of atoms, this new radiation caused a disintegration of them, similar to an explosion.

As a matter of course the new rays became at once the object of intensive experimental research, in which today's Nobel Prize winners in Chemistry, the couple Joliot, have taken an active and important part. At that time it was generally supposed that the radiation of beryllium was of the same nature as the electromagnetic waves of extremely short wavelength arising at the disintegration of radioactive substances. This radiation has received the name of -radiation and has the same qualities as the well-known X-rays. However, it was found that the new radiation possessed a power considerably superior to that of the strongest radioactive -rays; a correspondent radiation from another element, boron, proved, however, still stronger.

During their investigations of the radiation of beryllium, the couple Joliot made the important observation that a block of paraffin or another substance containing hydrogen being bombarded with the new rays, will emit an intensive stream of protons. With the assistance of the expansion chamber, constructed by the Nobel Prize winner Wilson, in which the paths of particles with electric charge - protons or electrons - could be made visible, it was possible to calculate the energy of the protons emitted from paraffin and thus also that of the radiation of beryllium causing the stream of protons. Then it turned out that the values of energy obtained, if the radiation of beryllium was supposed to be a -radiation, became absurdly high. Nor could these values of energy be brought to agree with the energy to be reckoned with in the radiation giving rise to the radiation of beryllium. Chadwick, who had undertaken investigations of the radiation of beryllium, found a similar radiation from quite a number of other elements, e.g. helium, lithium, carbon, nitrogen, and argon. By his extensive studies and calculations on conditions of energy at collisions, he was soon convinced that the radiation of beryllium could not be a -radiation.

Already in 1920 Lord Rutherford had suggested that, apart from protons and electrons, there also existed particles of the same weight as a proton but without any electric charge. To this particle was given in advance the name of *neutron*. This neutron had long been searched for but without any result. It is also easily understood how difficult it would be to discover this particle without electric charge. The neutron and the proton are certainly, like the electron, both particles of extremely small dimensions. But owing to their charges, the proton as well as the electron are accompanied by electric fields, which make them act as bodies of considerably larger dimensions, and their charges are influenced by the charges of the atoms they pass; these charged particles are therefore strongly checked when passing through substantial bodies. The neutron, on the contrary, having no electric charge is not affected and is not checked in its way, until it directly hits another particle, which happens extremely seldom owing to the small dimensions of the particles in relation to the distance between them. This explains why a neutron may pass through several kilometers of air, before losing its energy of motion. The motion of a proton or an electron may be observed in the above-mentioned Wilson chamber, and these particles being charged with electricity, their courses will be curved, if they are exposed to electric or magnetic fields. This curve may be studied in the Wilson chamber. The neutron, on the other hand, being without any charge, is not affected by such fields and may be discovered only in the case of a direct collision with the nucleus of an atom.

Chadwick now studied how, at a collision between radiation of beryllium and nuclei of atoms, the exchange of energy would be, supposing that the radiation of beryllium consisted of neutrons flung out from beryllium, and he then found that the experimental results attained agreed well with his own calculations. The same was the case also with radiation from other substances. By these facts the existence of the neutron was beyond all doubt. Chadwick then examined the exchange of mass taking place when by collision the nuclei of different substances are changed into new nuclei, belonging to other substances, and into neutrons. As an example may be mentioned that the nucleus of helium, when meeting that of beryllium, gives rise to a nucleus of carbon plus a neutron. Knowing the masses of different nuclei, it is possible directly to calculate the mass of the neutron. By examining the exchange of mass at a great number of collisions between the nuclei of different elements Chadwick succeeded in determining exactly the mass of the neutron, and as was to be expected, he found it almost the same as that of the proton or that of the nucleus of hydrogen.

On the other hand these researches have given a new method for the exact calculation of the size of masses in the nuclei of different elements. As characteristic for the usefulness of this new method may be mentioned that in this way Chadwick obtained another value for hydrogen than the earlier one observed by Aston with his spectrograph of mass. Aston, having improved his spectrograph, has obtained new values for the mass of hydrogen agreeing with those obtained by Chadwick.

The existence of the neutron having thus been proved, it was no more necessary to suppose compensatory charges of electron in the nuclei. The nucleus of atoms is nowadays considered to be composed of a number of protons and neutrons. Thus the nucleus of helium consists of two protons and two neutrons; about the nucleus there circle in the atom two electrons. Isotopes are formed by surplus or lack of the number of neutrons in the solid atom.

Owing to its weight and its great penetrating power, the neutron has become a powerful resource to bring about the disintegration of atoms and of nuclei of atoms, and during the last few years this power of the neutron to split up atoms and molecules has been largely made use of.

The existence of the neutron having been fully established, scientists have, as has just been mentioned, come to a new conception of the structure of atoms which agrees better with the distribution of energy within the nuclei of atoms. It has proved obvious that the neutron forms one of the buildingstones of atoms and molecules and thus also of material universe.

However, there are still many questions to be answered, among others the one about the relations of protons and neutrons to each other. There are certain signs

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indicating that these two particles are modifications of one and the same primitive particle. The existence of the positive electron, found by Dirac by theoretical research, having now been experimentally proved, the task of physical science will be to examine, more closely, the relations existing between this electron and the parts of the nuclei of atoms - the proton and the neutron; the neutron discovered by Chadwick has here given a powerful instrument for future researches on the structure of atoms and molecules. If the qualities of the neutron are made use of, this will certainly in the immediate future give us a new and deeper knowledge of matter and its transformations.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1935/press.html