JAMES CHADWICK

Born: October 20, 1891; Manchester, England
Died: July 24, 1974; Cambridge, England
Area of Achievement: Nuclear physics
Contribution: With the discovery of the neutron, one of the elementary particles of matter, Chadwick opened a new era in nuclear physics research. He was a leader in the investigation of both military and civilian applications of that discovery.

Early Life

James Chadwick was born on October 20, 1891, in Manchester, England. The eldest son of John Joseph and Anne Mary (née Knowles) Chadwick, he lived with his grandmother and entered the local school when his father moved to Manchester to develop a laundry business. At the Manchester Municipal Secondary School, he showed great interest in mathematics and physics and was encouraged by a teacher to specialize in applied mathematics.

In 1908, Chadwick entered the Victoria University of Manchester on a scholarship. He majored in physics instead of the intended mathematics as a result of confusion in the registration procedure, and he became fascinated with the subject only after attending lectures on electromagnetism by Ernest Rutherford, the greatest experimental physicist since Michael Faraday and the world leader in the investigation of radioactivity.

After receiving a first-class honors degree in 1911, Chadwick remained in the Manchester laboratory. In that year, Rutherford made one of the most important scientific discoveries of this century: the nuclear structure of the atom. This picture of the atom was modified in 1913 by the Danish physicist Niels Bohr, a former student of Rutherford, when he merged the quantum concept of Max Planck with the theory of atomic structure and successfully explained the origin of atomic spectra. Chadwick, too, would make major contributions to the concept of the nuclear atom.

In 1913, Chadwick received his master of science degree and was awarded an Exhibition of 1851 Senior Research Studentship, the same as that which had brought Rutherford from New Zealand to Cambridge many years before. A condition of the award was that Chadwick work in another laboratory, and he chose to go to the Physikalisch-Technische Reichsanstalt near Berlin, to continue his studies of radioactivity with Hans Geiger, whom he had known when Geiger was a research assistant to Rutherford at Manchester. During his stay in Germany, before World War I, Chadwick discovered that the spectrum of beta rays was continuous. That was unexpected, for it was thought that the rays from a given radioactive material would have the same maximum range and not a variety of lesser energies. Years later, a new

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particle, the neutrino, was predicted and eventually found; it carried away the balance of energy.

The war ended this fruitful research work, and Chadwick was interned in a camp for enemy aliens. Very bad living conditions and poor nutrition left him with permanent digestion problems. Nevertheless, with help from sympathetic German physicists who provided him with equipment, he was able to do some experiments, using as a radioactive source thorium oxide, which was an ingredient in a brand of German toothpaste. It was also in this camp that Chadwick met Charles D. Ellis and encouraged him to enter physics, which made it possible for them to share with their professor the task of rewriting Rutherford's classic text, *Radiations from Radioactive Substances* (1930).

Life's Work

From 1919 to 1935, Chadwick worked in the Cavendish Laboratory of Cambridge University, most of the period as assistant director of research. Rutherford brought him there when he had succeeded his own teacher, J. J. Thomson, as the Cavendish Professor. Tall and slender, with straight dark hair, and by nature a shy and reserved man, Chadwick seemed to the new students to be severe and forbidding. They soon found him full of sympathy and kindness, however, and especially responsive to their needs for research apparatus, which was ever-difficult to provide in the poor laboratory.

Before he had left Manchester, Rutherford had succeeded in deliberately disintegrating the nuclei of nitrogen atoms, and he had recognized one of the products as a new elementary particle, the proton. In Cambridge, Chadwick joined Rutherford in disintegrating other elements by alpha-particle bombardment. A notable exception to this line of work was his confirmation in 1920 that the charge on the atomic nucleus was equal to the atomic number, as had been suggested by A. van den Broek and Henry Moseley several years before.

Chadwick's most important scientific discovery was his identification of the neutron in 1932. The neutron, which joined the electron and the proton as an elementary particle, has a mass almost equal to that of the proton, but has no charge. Its existence was predicted by Rutherford (as a combination of an electron and proton) in a 1920 lecture, and Chadwick soon came to share Rutherford's belief in it. Over several years they tried unsuccessfully to find the particle, looking especially at hydrogen, whose atom consists of a proton and an electron, and at beryllium, which unexpectedly did not disintegrate when struck by alpha particles. Rutherford's interest lagged, and Chadwick himself paid only occasional attention to the search.

Then, in 1930, the German physicists Walther Bothe and Hans Becker reported that a penetrating radiation, gamma rays they thought, was emitted from beryllium upon alpha bombardment. The French physicists Frédéric Joliot and Irène Joliot-Curie (daughter of Marie and Pierre Curie) next showed that the beryllium emission could eject protona (which are nuclei of hydrogen) from materials containing hydrogen atoms. They, too, interpreted the emission as gamma rays, of very short wavelength. Chadwick, however, upon reading the Joliots' paper, was certain that here was his long-sought neutron, not electromagnetic radiation.

He immediately duplicated the Joliots' experiment using a powerful alpha source and directed the strong beryllium radiation at other materials than those containing hydrogen. Protons were ejected from the nuclei of many elements. After some months of strenuous experimental work and mathematical calculation, Chadwick showed that the beryllium emission could not consist of gamma rays or any other electromagnetic waves; the laws of conservation of energy and momentum would be violated. On the other hand, he proved that the experimental facts were consistent with the view that the emission was a beam of neutral particles. A short time later, he showed by arguments from quantum theory that the neutron was an elemental particle rather than a combination of proton and electron.

Chadwick's discovery of the neutron not only explained the hitherto unresolved problem of just what particles composed the nuclei of atoms but also gave a powerful tool to explore the nature of these nuclei. Starting in the mid-1930's, Enrico Fermi and his group in Rome used neutrons as projectiles, since they are not repelled by the electrical charge on nuclei, to bombard many elements toward the high end of the periodic table. They found that neutrons that had lost energy by collision with atoms were more successful in initiating nuclear reactions, and they pioneered the complicated study of the interaction of neutrons with uranium, which led to the 1938 discovery of nuclear fission by Otto Hahn and Fritz Strassmann. All these contributions were vital to the ultimate release of nuclear energy, first in reactors and then in bombs.

For his discovery, Chadwick was awarded the 1932 Hughes Medal of the Royal Society and the 1935 Nobel Prize for Physics. In the remaining three years that he spent in the Cavendish Laboratory, Chadwick worked with several collaborators on a variety of topics, including the positive electron, the neutrino, disintegration of nuclei by neutrons, and the nuclear photoelectric effect. All were important subjects in nuclear physics.

In 1935, Chadwick accepted the Lyon Jones Chair of Physics at the University of Liverpool, where he had the opportunity to create his own laboratory and especially to realize his plan to build a cyclotron. He was convinced that such a machine, which accelerates particles to great energies and then directs the beam upon a target, was necessary to be at the forefront of nuclear physics. Rutherford, nearing retirement age, believed that his successor should determine the Cavendish Laboratory's direction and did not wish to saddle him with such an expensive device. Rutherford, furthermore, did not like large machines or spending money. This situation convinced Chadwick that he had made the right decision in leaving Cambridge.

After World War II began, Chadwick was closely involved in nuclear research for military purposes and was influential in furthering the atom-bomb projects of both the British government and the American government. When the two allies joined their efforts, Chadwick became head of the British Mission in Washington, D.C., a critical administrative position. His remarkable friendship with the combined project's military commander, General Leslie Groves, an able but tactless man whom most scientists disliked, went far toward minimizing the inevitable policy differences any two nations would have.

In peacetime, Chadwick urged the study of nuclear energy in all of its scientific, technological, social, political, and diplomatic aspects, and served on many committees with that goal in mind. He left Liverpool in 1948 to become master of Gonville and Caius College, one of the constituent colleges of Cambridge University and the one in which he had long been a fellow. A decade later he retired to a cottage in North Wales, and in 1969 he made his final move, back to Cambridge.

Summary

Discovery of the neutron and leadership in the development of nuclear energy for both military and civilian purposes were the two major contributions James Chadwick made to science and to society. The neutron was not merely the third elementary particle to be found, profound though that was; its discovery was also a turning point in the history of science. After that event, scientists' research programs changed and scientists' conception of nature changed; the key to the release of enormous amounts of energy had been made available. Chadwick, furthermore, was one of the early organizers of scientific activities at a time when it became a large-scale enterprise. As Rutherford's chief aide, he helped to build the Cavendish Laboratory into a mecca of experimental physics in the period between the two world wars. He recognized early the change from "little science" to "Big Science" and tried to direct this change for what he saw as the benefit of both science and society.

Bibliography

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Massie, Harrie, and Norman Feather. "James Chadwick." *Biographical Memoirs of the Fellows of the Royal Society* 22 (1976): 11-70. The most complete obituary notice and biography of James Chadwick. Divided into two parts, it gives a good chronological description of his life and scientific research. A useful bibliography of his publications is included.

Nobelstiften. *Physics*. New York: Elsevier Publishing Co., 1964. Contains Chadwick's prize lecture, which pursues the evolution of the idea of neutral particle to his own discovery of the neutron and describes its properties.

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