Topic Page: Rutherford, Baron Ernest (1871 - 1937)

Definition: **Rutherford** from *Merriam-Webster's Collegiate(R) Dictionary*

pronunciation

Ernest Rutherford 1871–1937 1st Baron *Rutherford of Nelson* Brit. physicist

Image from: **Ernest Rutherford, Baron Rutherford by Walter Stoneman, 1921** in *National Portrait Gallery Image Collection*

Summary Article: **Rutherford, Ernest (1871-1937)**
From *The Hutchinson Dictionary of Scientific Biography*

Place: Sweden

Subject: biography, physics

New Zealand-born British physicist who first explained that radioactivity is produced by the disintegration of atoms and discovered that alpha particles consist of helium nuclei. For these achievements, Rutherford was awarded the 1908 Nobel Prize for Chemistry. Rutherford went on to make two more discoveries of fundamental importance to nuclear physics: he was the first to determine the basic structure of the atom and show that it consists of a central nucleus surrounded by electrons, and he also produced the first artificial transformation, thereby changing one element into another.

Rutherford was born near Nelson on South Island on 30 August 1871. His father was a wheelwright and farmer who, like his mother, had emigrated from the UK to New Zealand when a child. Rutherford did not show any great aptitude for science as a child and when he entered Nelson College in 1887, he exhibited an all-round ability. He went on to Canterbury College, Christchurch, in 1889, receiving a BA degree in 1892. He then embarked on a study of mathematics and physics, gaining his MA in 1893 and then a BSc in 1894. Rutherford investigated the magnetic properties of iron by high-frequency electric discharges for his science degree, and constructed a very sensitive detector of radio waves as a result of his research. This was only six years after Heinrich Hertz had discovered radio waves, and the same year that Guglielmo Marconi began his radio experiments.

In 1895, Rutherford went to the UK to study at the Cavendish Laboratory, Cambridge. There he became the first research student to work under J J Thomson. Armed with his radio detector, Rutherford made a big impact on Cambridge, but under Thomson's guidance, he soon turned to the work in atomic physics that was to become his career. In 1898, helped by Thomson, Rutherford obtained his first academic position with a professorship in physics at McGill University, Montréal, Canada, which then boasted the best-equipped laboratory in the world. He was attracted back to the UK in 1907, when he succeeded Arthur Schuster (1851-1934) at Manchester, Schuster declaring that he would resign his chair only for Rutherford. Rutherford built up a renowned laboratory at Manchester, and it was there that he made his momentous discoveries of the nuclear atom and artificial transformation.

During World War I, Rutherford worked for the Admiralty on methods of locating submarines and then in 1919 moved to Cambridge to become professor of physics and director of the Cavendish Laboratory in succession to Thomson. He retained this position for the rest of his life, and was also professor of natural philosophy at the Royal Institution from 1921. Many honours were accorded to Rutherford in addition to the 1908 Nobel Prize for Chemistry. They included the Royal Society's Copley Medal in 1922, the presidency of the Royal Society 1925-30, a knighthood in 1914, the Order of Merit in 1925, and a peerage in 1921, Rutherford taking the title Baron Rutherford of Nelson. In his last years, Rutherford was active in helping refugee scientists who had escaped from Nazi Germany. Rutherford died in Cambridge on 19 October 1937 and is buried in Westminster Abbey, London.

When Rutherford first came to the Cavendish Laboratory, Thomson put him to work to study the effect that X-rays have on the discharge of electricity in gases. This was early in 1896, only a few weeks after Wilhelm Röntgen had discovered X-rays. Rutherford found that positive and negative ions are formed, and measured the mobility of the ions produced. In 1897 he went on to make a similar study of the effects of ultraviolet light and the radioactivity produced by uranium minerals, which had been discovered by Henri Becquerel the year before. Rutherford then became fascinated by radioactivity and began a series of investigations to explore its nature. In 1899, he found that there are two kinds of radioactivity with different penetrating power. The less penetrating he called alpha rays and the more penetrating beta rays. In 1900, Rutherford discovered a third type of radioactivity with great penetrating power, which he called gamma rays. (Alpha and beta rays were later found to consist of streams of particles and so are now known as alpha particles and beta particles. Gamma rays were found to be electromagnetic waves of very high frequency and so are still called gamma rays or gamma radiation.)

When Rutherford moved to Montréal in 1898, he began to use thorium as a source of radioactivity instead of uranium. He found that thorium produces an intensely radioactive gas, which he called emanation. This was a decay product of thorium and Rutherford discovered several more, including thorium X. To identify these products, Rutherford enlisted the aid of Frederick Soddy, who was later to discover isotopes. Analysis of the decay products enabled Rutherford and Soddy in 1903 to explain that radioactivity is an atomic phenomenon, caused by the breakdown of the atoms in the radioactive element to produce a new element. Rutherford found that the intensity of the radioactivity produced decreases at a rate governed by the element's half-life. The idea that atoms could change their identity was revolutionary, yet so compelling was Rutherford's explanation of radioactivity that it was accepted immediately with very little opposition.

Rutherford was now concerned to identify alpha rays, which he was sure consisted of positively charged particles and specifically either hydrogen or helium ions. Deflection of the rays in electric and magnetic fields proved in 1903 that they are positive particles, but Rutherford was unable to determine the amount of charge because his apparatus was not sensitive enough.

In 1904, with Bertram Boltwood (1870-1927), Rutherford worked out the series of transformations that radioactive elements undergo and showed that they end as lead. They were able to estimate the rates of change involved and in 1907 Boltwood calculated the ages of mineral samples, arriving at figures of more than a thousand million years. This was the first proof of the age of rocks, and the method of radioactive dating has since been developed into a precise way of finding the age of rocks, fossils, and ancient artefacts.

On returning to the UK in 1907, Rutherford continued to explore alpha particles. In conjunction with Hans Geiger, he developed ionization chambers and scintillation screens to count the particles produced by a source of radioactivity, and by dividing the total charge produced by the number of particles counted, arrived at the conclusion that each particle has two positive charges. The final proof that alpha particles are helium ions came in the same year, when Rutherford and Thomas Royds succeeded in trapping alpha particles in a glass tube and by sparking the gas produced showed from its spectrum that it was helium.

Rutherford's next major discovery came only a year later in 1909. He suggested to Geiger and a gifted student named Ernest Marsden that they investigate the scattering of alpha particles by gold foil. They used a scintillation counter that could be moved around the foil, which was struck by a beam of alpha particles from a radon source. Geiger and Marsden found that a few particles were deflected through angles of more than 90° by the foil. Rutherford was convinced that the explanation lay in the nature of the gold atoms in the foil, believing that each contained a positively charged nucleus surrounded by electrons. Only such nuclei could repulse the positively charged alpha particles that happened to strike them to produce such enormous deflections. But Rutherford needed proof of this theory. He worked out that the nucleus must have a diameter of about 10^{-13} cm/10^{-14} in - 100,000 times smaller than the atom - and calculated the numbers of particles that would be scattered at different angles. These predictions were confirmed experimentally by Geiger and Marsden, and Rutherford announced the nuclear structure of the atom in 1911.

Few were convinced that the atom could be almost entirely empty space as Rutherford contended. However, among those who agreed with Rutherford was Niels Bohr. He went to Manchester to work in 1912, and in 1913 produced his quantum model of the atom, which assumed a central positive nucleus surrounded by electrons orbiting at various energy levels. Also in 1913, another of Rutherford's co-workers, Henry Moseley, announced his discovery of the atomic number, which identifies elements, and showed that it could only be given by the number of positive charges on the nucleus, and thus the number of electrons around it. Rutherford's view of the nuclear atom was thereby vindicated, and universally accepted.

Several more important discoveries were made at Manchester. In 1914, Rutherford found that positive rays consist of hydrogen nuclei. Also in 1914, Rutherford and Edward Andrade showed that gamma rays are electromagnetic waves by diffracting them with a crystal. They measured the wavelengths of the rays and found that they lie beyond X-rays in the electromagnetic spectrum. Becquerel in 1900 had identified beta rays with cathode rays, which were shown to be electrons, and so the nature of radioactivity was now revealed in full.

Rutherford's work was now interrupted by war and he did not return to physics until 1917, when he made his last great discovery. He made it unaided, unlike most of his earlier discoveries, because all his colleagues and students were still engaged in war work. Rutherford followed up earlier work by Marsden in which scintillations were noticed in hydrogen bombarded by alpha particles well beyond their range in the gas. These were due to hydrogen nuclei knocked on by the alpha particles, which was not unexpected. However Rutherford now carried out the same experiment using nitrogen instead of hydrogen, and he found that hydrogen nuclei were still produced and not nitrogen nuclei. Rutherford announced his interpretation of this result in 1919, stating that the alpha particles had caused the nitrogen nuclei to disintegrate, forming hydrogen and oxygen nuclei. This was the first artificial transformation of one element into another. Rutherford found similar results with other elements and announced that the nucleus of any atom must be composed of hydrogen nuclei. At Rutherford's suggestion, the name proton was given to the hydrogen nucleus in 1920. He also speculated in the same year that uncharged particles, which were later called neutrons, must also exist in the nucleus.

Rutherford continued work on artificial transformation in the 1920s. Under his direction, Patrick Blackett in 1925 used a Wilson cloud chamber to record the tracks of disintegrated nuclei, showing that the bombarding alpha particles combines with the nucleus before disintegration and does not break the nucleus apart like a bullet. Bombardment with alpha particles had its limits as large nuclei repelled them without disintegrating, and Rutherford directed the construction of an accelerator to produce particles of the required energy. The first one was built by John Cockcroft and Ernest Walton, and went into operation at the Cavendish Laboratory in 1932. In the same year, another of Rutherford's colleagues, James Chadwick, discovered the neutron at the Cavendish Laboratory.

Rutherford was to make one final discovery of great significance. In 1934, using some of the heavy water recently discovered in the USA, Rutherford, Marcus Oliphant, and Paul Harteck bombarded deuterium with deuterons and produced tritium. This may be considered the first nuclear fusion reaction.

Rutherford may be considered the founder of nuclear physics, both for the fundamental discoveries that he made and for the encouragement and direction he gave to so many important physicists involved in the development of this science.

APA

Chicago

Harvard

MLA

Rutherford, Ernest (1871-1937). (2018). In Helicon (Ed.), *The Hutchinson dictionary of scientific biography*. Abington, UK: Helicon. Retrieved from https://search.credoreference.com/content/topic/rutherford_ernest_1871_1937

© *RM, 2018. All rights reserved.*

APA

Rutherford, Ernest (1871-1937). (2018). In Helicon (Ed.), *The Hutchinson dictionary of scientific biography*. Abington, UK: Helicon. Retrieved from https://search.credoreference.com/content/topic/rutherford_ernest_1871_1937

Chicago

"Rutherford, Ernest (1871-1937)." In *The Hutchinson Dictionary of Scientific Biography*, edited by Helicon. Helicon, 2018. https://search.credoreference.com/content/topic/rutherford_ernest_1871_1937

Harvard

Rutherford, Ernest (1871-1937). (2018). In Helicon (Ed.), *The Hutchinson dictionary of scientific biography*. [Online]. Abington: Helicon. Available from: https://search.credoreference.com/content/topic/rutherford_ernest_1871_1937 [Accessed 22 September 2019].

MLA

"Rutherford, Ernest (1871-1937)." *The Hutchinson Dictionary of Scientific Biography*, edited by Helicon, 2018. *Credo Reference*, https://search.credoreference.com/content/topic/rutherford_ernest_1871_1937. Accessed 22 Sep. 2019.