Ernest Rutherford

[**The Discovery of Radioactivity (Ernest Rutherford)**](http://chemed.chem.purdue.edu/genchem/history/radioactivity.html)

In 1899 Ernest Rutherford studied the absorption of radioactivity by thin sheets of metal foil and found two components: *alpha* () radiation, which is absorbed by a few thousandths of a centimeter of metal foil, and *beta* () radiation, which can pass through 100 times as much foil before it was absorbed. Shortly thereafter, a third form of radiation, named *gamma* () rays, was discovered that can penetrate as much as several centimeters of lead. The three kinds of radiation also differ in the way they are affected by electric and magnetic fields, as shown below.

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| (a) In her thesis, Marie Curie reported the drawing on the left which showed the effect of a magnetic field on the three forms of radioactivity.   Alpha-particles were deflected more slowly than beta-particles, which suggested that alpha-particles were heavier than beta-particles.  Gamma-rays were not affected by a magnetic field.  (b) The effect of an electric field on the different forms of radioactivity shows that alpha-particles and beta-particles are both electrically charged, but they carry charges with opposite signs.  Gamma-rays are not affected by an electric field and therefore have no electric charge. |

[**The Gold Foil Experiment (Ernest Rutherford)**](http://chemed.chem.purdue.edu/genchem/history/gold.html)

Rutherford began his graduate work by studying the effect of x-rays on various materials. Shortly after the discovery of radioactivity, he turned to the study of the -particles emitted by uranium metal and its compounds.

Before he could study the effect of -particles on matter, Rutherford had to develop a way of counting individual -particles. He found that a screen coated with zinc sulfide emitted a flash of light each time it was hit by an -particle. Rutherford and his assistant, **Hans Geiger**, would sit in the dark until his eyes became sensitive enough. They would then try to count the flashes of light given off by the ZnS screen. (It is not surprising that **Geiger** was motivated to develop the electronic radioactivity counter that carries his name.)

Rutherford found that a narrow beam of -particles was broadened when it passed through a thin film of mica or metal. He therefore had **Geiger** measure the angle through which these -particles were scattered by a thin piece of metal foil. Because it is unusually ductile, gold can be made into a foil that is only 0.00004 cm thick. When this foil was bombarded with -particles, **Geiger** found that the scattering was small, on the order of one degree.

These results were consistent with Rutherford's expectations. He knew that the -particle had a considerable mass and moved quite rapidly. He therefore anticipated that virtually all of the -particles would be able to penetrate the metal foil, although they would be scattered slightly by collisions with the atoms through which they passed. In other words, Rutherford expected the -particles to pass through the metal foil the way a rifle bullet would penetrate a bag of sand.

One day, **Geiger** suggested that a research project should be given to **Ernest Marsden**, who was working in Rutherford's laboratory. Rutherford responded, "Why not let him see whether any -particles can be scattered through a large angle?" When this experiment was done, **Marsden** found that a small fraction (perhaps 1 in 20,000) of the -particles were scattered through angles larger than 90o (see Figure 6.7*a*). Many years later, reflecting on his reaction to these results, Rutherford said: "It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

Rutherford concluded that there was only one way to explain these results. He assumed that the positive charge and the mass of an atom are concentrated in a small fraction of the total volume and then derived mathematical equations for the scattering that would occur. These equations predicted that the number of -particles scattered through a given angle should be proportional to the thickness of the foil and the square of the charge on the nucleus, and inversely proportional to the velocity with which the -particles moved raised to the fourth power. In a series of experiments, **Geiger** and **Marsden** verified each of these predictions.

When he published the results of these experiments in 1911, Rutherford proposed a model for the structure of the atom that is still accepted today. He concluded that all of the positive charge and essentially all of the mass of the atom is concentrated in an infinitesimally small fraction of the total volume of the atom, which he called the nucleus (from the Latin for little nut).

Most of the -particles were able to pass through the gold foil without encountering anything large enough to significantly deflect their path. A small fraction of the -particles came close to the nucleus of a gold atom as they passed through the foil. When this happened, the force of repulsion between the positively charged -particle and the nucleus deflected the -particle by a small angle. Occasionally, an -particle traveled along a path that would eventually lead to a direct collision with the nucleus of one of the 2000 or so atoms it had to pass through. When this happened, repulsion between the nucleus and the -particle deflected the -particle through an angle of 90o or more.

By carefully measuring the fraction of the -particles deflected through large angles, Rutherford was able to estimate the size of the nucleus. According to his calculations, the radius of the nucleus is at least 10,000 times smaller than the radius of the atom. The vast majority of the volume of an atom is therefore empty space.

[**Naming the Proton (Ernest Rutherford)**](http://chemed.chem.purdue.edu/genchem/history/proton.html)

Shortly after the World War I, in 1920, Rutherford proposed the name proton for the positively charged particles in the nucleus of an atom.

[**Proposing the Neutron (Ernest Rutherford)**](http://chemed.chem.purdue.edu/genchem/history/neutron.html)

At the same time that Rutherford proposed the name *proton* for the positively charged particle in the nucleus of an atom, he proposed that the nucleus also contained a neutral particle, eventually named the neutron. It was not until 1932, however, that [James Chadwick](http://chemed.chem.purdue.edu/genchem/history/chadwick.html) was able to prove that these neutral particles exist.