Rutherford's Gold Foil Experiment

31st Dec 2019 @ 5 min read

Physical Chemistry

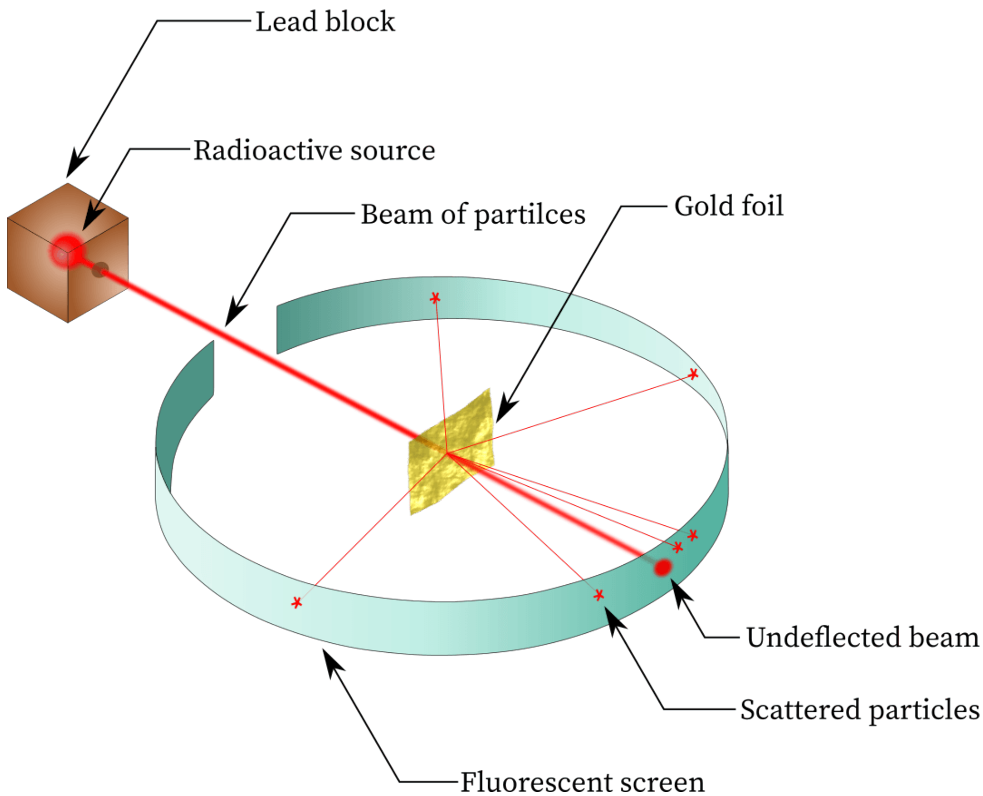
The Rutherford gold foil experiment or alpha particles scattering experiment remains a famous experiment in the history of science. Between 1908 and 1913, a series of experiments were performed by Hans Geiger and Ernest Marsden under the guidance of Ernest Rutherford.

From left to right: Ernest Rutherford, Hans Geiger, and Ernest Marsden

Because of the experiments were performed by Geiger and Marsden, it is also called as the Geiger-Marsden experiments. The experiments led to the discovery of the nucleus and gave birth to the nuclear model of the atom. The outcomes of the experiments debunked the idea the positive charge was uniformly distributed in the atom and demonstrated the presence of a central nucleus, where all of its positive charge is concentrated.

Rutherford's gold foil experiment

The experiment was not a single experiment but a series of experiments. All the experiments can be summarized using the illustration below.



Rutherford's gold foil experiment

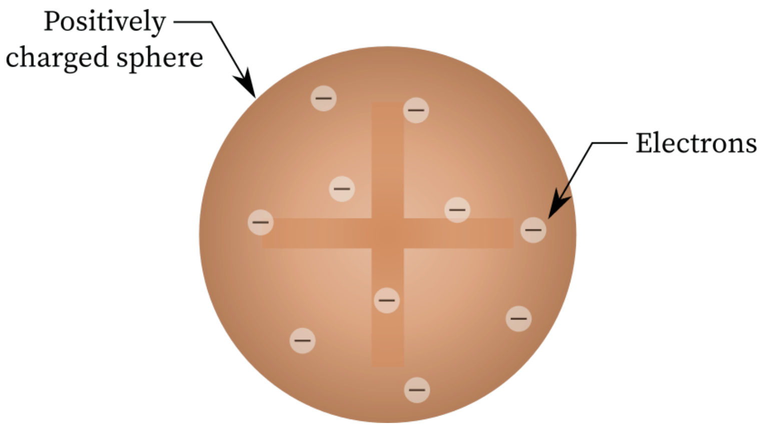
When Rutherford along with his colleague shot alpha particles, the positively charged helium nuclei, on a very thin gold foil, unexpected scattering of the particles was observed. The illustration above depicts a radioactive source enclosed in a lead block liberates alpha particles. The lead block acts as a shield and sharpens the beam. The beam moves through space and strikes the gold foil of a few thousand atoms thick. A circular zinc sulphide fluorescent screen surrounds the foil. The particles leaving the foil after the strike make tiny glowing flashes on the screen called scintillations, which can be measured using a microscope.

As we can see from the figure, most particles remain undeflected, i.e. they continue to travel a straight path as if the gold foil was absent. Most particles which are scattered have less than 90° deflection while few particles cross 90°.

Before proceeding to analyse the outcomes of the experiment, let's quickly review Thomson's atomic model.

Thomson's view on atoms

In the 1900s, Thomson's atomic model was dominant. He explained an atom as a sea of positive charge with floating negatively charged electrons. According to him, the positive charge was uniform throughout the atom, and the magnitude of it was equal to negative charges.



J.J. Thomson's atomic model

Contrast between the experiment and Thomson's model

The experiment results obtained from the alpha particles scattering experiment contradict Thomson's model. Rutherford was astonished by this. According to Thomson's model, the positive charge is uniformly spread throughout the atom, which creates a weak electric field. When alpha particles, which are heavy energetic radiation, were bombarded on the gold foil, it was expected that the beam would penetrate the foil with slight divergence and with a reduction in speed. The deviation of the beam would be small. No bouncing back of the particles was expected. However, the observations were different. They are summarized into three main points.

i. Most α-particles passed the foil without much deviation.
ii. A small number of particles were deflected by the foil, and this deflection was very small.
iii. A very small fraction of the particles were deflected by large angles (greater than 90°); a minuscule number of particles were deflected by angles greater than 150°.

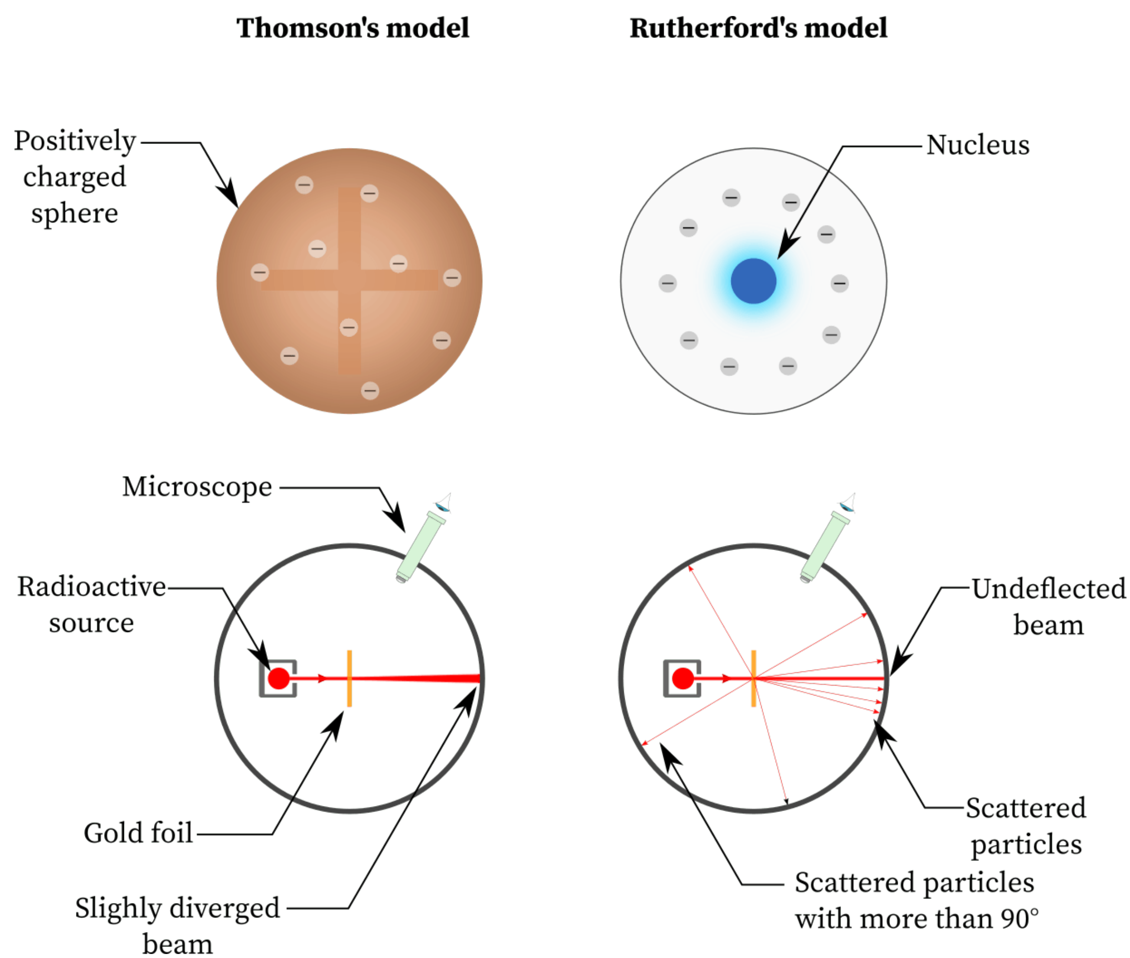
Rutherford's conclusions

Based on the above observations, Rutherford argued the following points:

i. Since most particles were not deviated, the atom must mostly be empty.
ii. A small fraction of the particles were deflected by large angles. Thus, there should be a

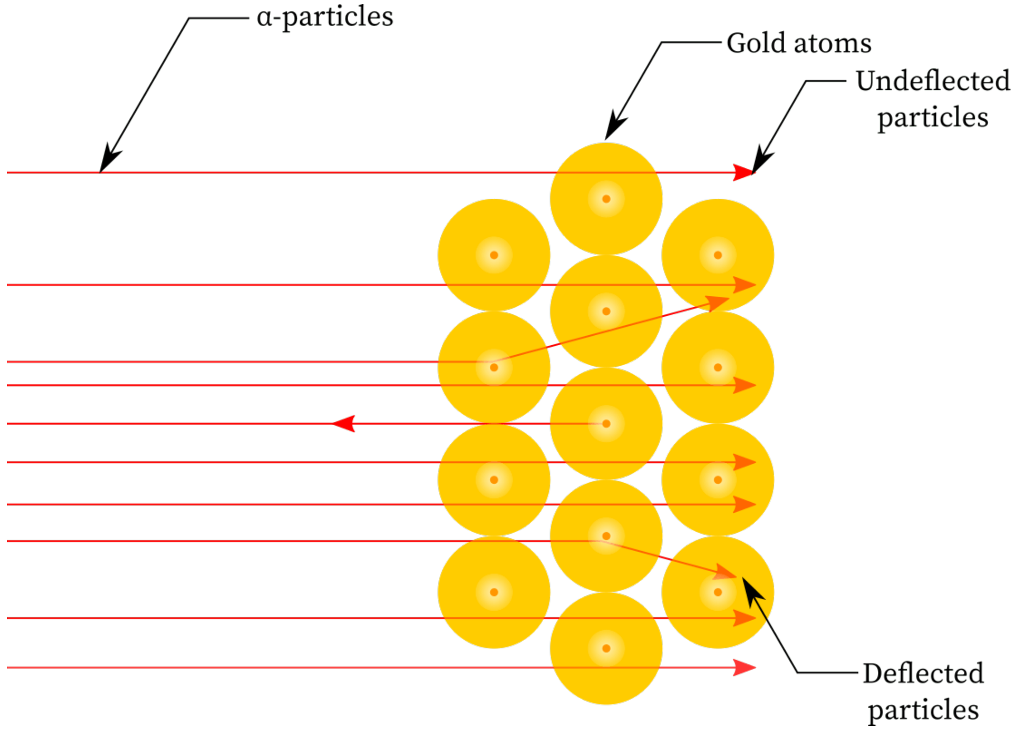
strong repulsive force in an atom. Rutherford proposed the presence of a central positively charged nucleus. Furthermore, he estimated the size of the nucleus of the gold atom was very small in comparison with the atom.

From these conclusions, he conceptualized a new atomic theory, that we now called Rutherford's atomic model. It says the atom has a central positively charged nucleus that is surrounded by electrons. This model superseded Thomson's model.



Thomson vs Rutherford's model

The figure below shows α-particles can easily penetrate the gold foil without much hindrance and few of them do bounce back.



α-particles striking the gold foil at the molecular level

History

J. J. Thomson's atomic theory was prominent before the discovery of the nucleus. However, Thomson himself was never fully content with his theory. A few critics existed at that time who opposed Thomson's model. One of them was Hantaro Nagaoka, a Japanese physicist. He denounced Thomson's model in 1904 and predicted a planetary model in which the positively charged nucleus is surrounded by electrons. An analogy between the planetary system and the structure of the atom was proposed by him. Nagaoka argued that the positive and negative charge cannot embody each other. His thoughts were not recognized until Rutherford proved the presence of the nucleus.

Ernest Rutherford was an extraordinary physicist and also known as the father of nuclear physics. He is also credited for the discovery of alpha, beta, and gamma rays. With its vast knowledge in radiation, he and Hans Geiger, who was a German scientist, decided to investigate alpha particles. Initially, they did a few experiments. But after not much success, Rutherford forwarded the work to Geiger and Ernest Marsden, who was a student of Geiger. Consequently, Geiger and Marsden did numerous experiments under the direction of Rutherford. They used a gold foil because of its high malleability and radon as a radioactive source. After several hours spent in a dark room, the observations of the experiments were definitely staggering. In 1913, Rutherford confirmed the presence of the nucleus. It brought a new era in the atomic world.

He was overwhelmed and uttered:

> 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.

Associated articles

- Plum pudding atomic model
- J. J. Thomson's cathode ray tube experiments

Join the Newsletter

Subscribe to get latest content in your inbox.

We won't send you spam.