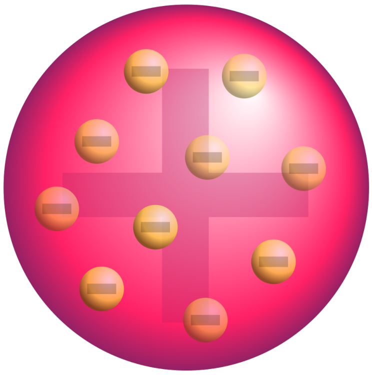
FLIPPED around PHYSICS

8.1 Rutherford scattering

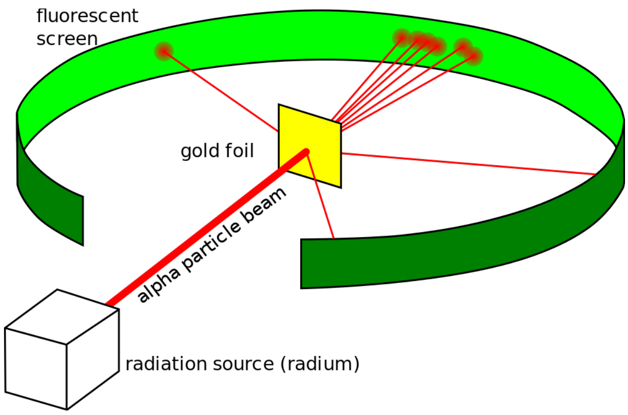
The Geiger-Marsden experiment (sometimes called the "Rutherford gold foil experiment") marked an important development in our understanding of the structure of the atom. Hans Geiger and Ernest Marsden carried out a series of experiments between 1908 and 1913 (under the direction of Ernest Rutherford at the University of Manchester), that determined that the all atoms contain a nucleus in which there is a concentrated positive charge and a concentrated mass.

videos



Prior to these experiments, J.J. Thompson had discovered the electron (1897) and developed a model of the atom called the 'plum pudding' model. In this model, the negative electrons are embedded in a distributed positively charged material – like plums in pudding dough.

The gold foil experiment



A radioactive source was used to produce a narrow stream of alpha particles which were directed at a thin sheet of gold.

(1)✐ Why do you think gold foil was used?

The experiment was contained in a container in which the air had been evacuated.

(2)✐ Why do you think the air needed to be removed?

They used a fluorescent screen to detect the angle through which the alpha particles were deflected. A flash of light was produced (a "scintillation") when an alpha particle hit the fluorescent screen.

(3)✐ Why do you think the beam of alpha particles needed to be narrow?

Their findings:

1) *Most of the alpha particles passed through without being deflected.*
2) *Some alpha particles (about 1 in 2000) were deflected through angles larger than predicted by the "plum pudding" model.*
3) *A very small number (about 1 in 10000) were deflected by more than* 90°.

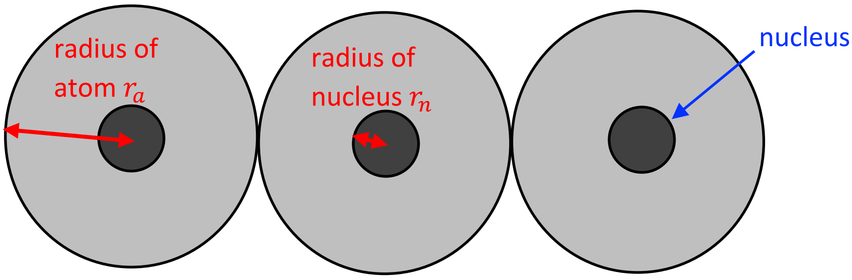
(4)✐Which of the findings, above, shows that the atom consists mostly of empty space?

(5)✐Which of the findings, above, shows that charge is concentrated in a nucleus. Explain.

(6)✐Which of the findings, above, shows that mass and charge are concentrated in a nucleus. Explain.

Estimating the size of the nucleus

Consider observing a layer of atoms in the surface of the gold foil (not to scale), with alpha particles being fired downwards into the page.



Any alpha particles that are on a collision course with the nucleus will be repelled backwards (i.e. at an angle greater than 90°). The rest of the alpha particles will pass through this layer of gold atoms (although some will be deflected).

The fraction that are deflected backwards will be related to the cross-sectional area of the nucleus compared to the cross-sectional area of the atom (to a rough approximation).

$$fraction\ deflected\ more\ than\ 90°\ in\ each\ atomic\ layer \approx \frac{\pi {r_n}^2}{\pi {r_a}^2}$$

Even though the gold foil is extremely thin, it consists of around 10000 layers of atoms.

(7)✐If 1 in 10000 are deflected by more than 90° *in the whole thickness of foil, what fraction are deflected by more than* 90° *in each atomic layer?*

(8)✏ *What is the ratio* $\frac{X\text{−sectional area of nucleus}}{X\text{−sectional area of atom}}$*?*

(9)✏ *From the ratio, above, work out the ratio* $\frac{\text{radius of nucleus}}{\text{radius of atom}}$*.*

(10)✏ *The diameter of an atom is* $\approx 10^{-10} m$*. What is the approximate diameter of the nucleus?*