Rutherford Scattering

New Zealand physicist Ernest Rutherford (1871–1937) was among the first and most influencing researchers in nuclear physics. Soon after the discovery of radioactivity (in 1896 by French physicist Antoine Henri Becquerel), Rutherford identified the three main constituents of this radiation and named them α-, β- and γ-rays. Rutherford investigated the structure of atoms with the help of α-rays. He was the first to describe an atom as consisting of a very dense nucleus surrounded by electrons.

Making the structure of an atom visible requires a charged particle getting so close to the nucleus that the positively charged nucleus is no longer shielded by the negatively charged electron shell.

Prerequisite: You know how to apply the conservation of energy law to charged particles in an electric field.

Goals:

- You are aware of one of a landmark experiment in nuclear physics.
- You get used to dealing with the unit eV.

Time: You can work on the problem for 20 minutes.

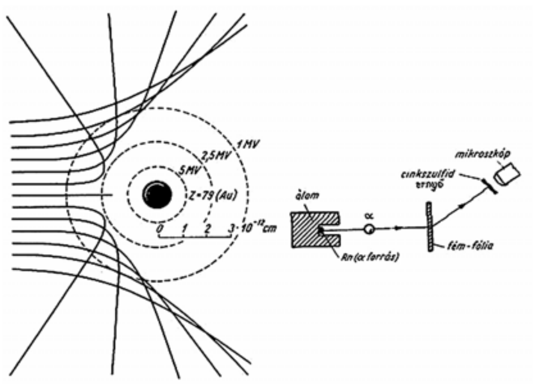
Problem

For his investigation of the atomic structure, Rutherford used α-particles (nuclei of Helium atoms, m_α = 3'660 MeV/c^2) from a radioactive source which emanated the particles with a kinetic energy of some 5 MeV. A thin gold foil was used as a target.

How close to the gold nucleus can an α-particle get?

Instructions

1. Calculate the initial velocity (as a fraction of the speed of light) of the α-particle.
2. Determine the charges (as multiples of the elementary charge) of a gold nucleus and an α-particle.
3. Draw a picture showing the gold nucleus and the α-particle in situation A (very far away) and situation B (point of closest approximation). What can you say about the α-particle's velocity in these two situations?
4. Give formal expressions for the α-particle's total energy (sum of kinetic and electric potential energy) for situations A and B respectively.
5. Derive a formal expression for the smallest distance between the α-particle and the gold nucleus (hint: conservation of energy law).
6. Calculate the numerical value of this distance for a 5 MeV α-particle. Compare your result with typical values for the radius of an atom and a nucleus (see FoTa). What is your conclusion on the structure of an atom?



Numerical solutions: 1. 0.052 · c; 6. 4.6 · 10^{-14} m