Lesson 39: Rutherford's Planetary Model

Ernest Rutherford was curious about what **alpha particles** did when you shot them at various materials.

Rutherford's work with alpha particles doesn't end here. In later lessons we will learn how they relate to radioactive decays.

- Alpha particles are **helium nuclei** (He^{2+} or α^{2+}) released by some radioactive materials.
- Rutherford was able to measure that the alpha particles were traveling at high speeds of about 2.5e7 m/s.
    - Rutherford thought it would be a good idea to shoot these alpha particles at an atom to see what it was made of.

In the classic **Rutherford Scattering experiment** (aka the **Gold Foil experiment**), Hans Geiger and Ernest Marsden set up a radioactive sample of radium inside a lead box with a small hole cut in one side.

- This hole allows a stream of alpha particles to exit the box and travel towards a thin sheet of gold.
    - Gold is great to use because of its malleability. It can be hammered down to a sheet that is only a few atoms thick... you can even faintly see through it!
- Forming a loop on the other side was a screen coated in zinc sulphide.
    - If an alpha particle got through the gold, it would cause a spot to glow on the zinc sulphide screen.
    - By putting the screen in various positions, Rutherford was able to measure how often alpha particles came through the gold at different angles.

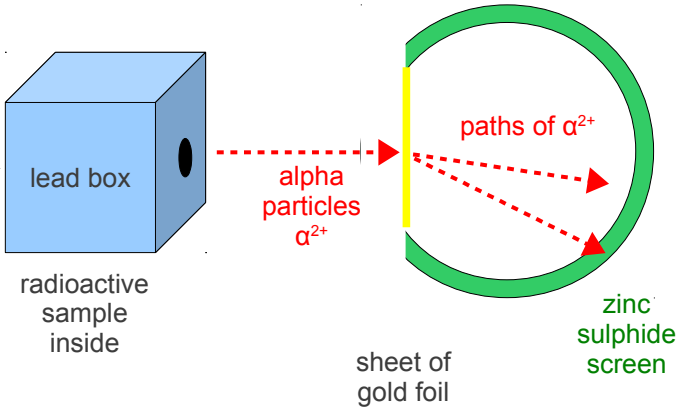

Illustration 1: Rutherford's Scattering Experiment

The actual results surprised Rutherford.

- If Thomson's Plum Pudding Model was correct, the positive charge of the atom is spread out over a relatively large area.
    - This would mean that the effect of this positive charge would be very weak on other charges, because it is so spread out.
    - The negative electrons are unimportant since they are all over the place, spaced out, and tiny.
    - This would result in very small (if any!) scattering angles for the alpha particles, since the alpha particles would just about sail straight through.

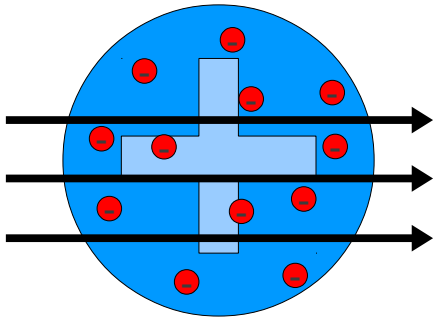

Illustration 2: In the Plum Pudding Model, we expect alpha particles to basically go straight through.

- Rutherford found that the angles of deflection showed something different.
    - Most particles did go off at small angles, but some went off at very large angles.
    - A small number of alpha particles even came bouncing right back in the direction they came from.
        - Rutherford described this in a lecture by saying it "was almost as incredible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

- The only model that could explain this was a concentration of positive charge in the centre of the atom, a bunch of empty space, and electrons in orbit.
  - A bunch of empty space and the electrons far out in orbit meant that the alpha particles often went almost straight through.
  - The concentrated positive charge in the centre would explain when the alpha particles deflected at big angles, and if it hit the centre straight on would result in the alpha particle bouncing straight back.

This is the basis of **Rutherford's Planetary Model**.

- The nucleus is where all the positive charge is found (this is why this model is sometimes called the **Nuclear Model**).
- The electrons orbit around the nucleus at pretty much random positions.
  - Although Rutherford still accepted Thomson's work showing that electrons were there, he didn't have any reason from his own experiments to think they were any special spot other than in orbit.
- As a note, there is no mention of neutrons yet, since no one had discovered them by this time.

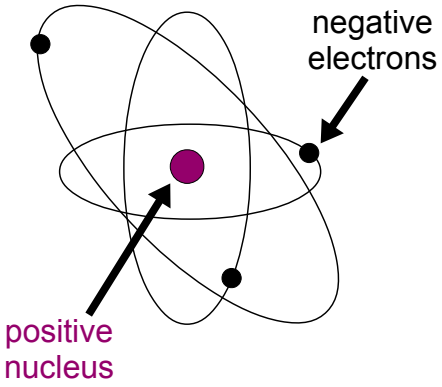

Illustration 3: Rutherford's Nuclear Model.

Unfortunately, about as soon as the model was published it was realized that there was a serious flaw.

- The electrons that are orbiting the nucleus are doing so in circular pattern (the simplest way).
- Since the electrons are moving in a circle, they are accelerating (centripetal acceleration).
- According to Maxwell's Theory of Electromagnetic Radiation, any accelerating charge will create EMR.
  - As the moving electrons release this EMR, they are really releasing photons of energy.
  - This means that the electrons are ***losing*** energy!
- If this is true, the electrons should spiral in towards the nucleus and crash. In fact, it should happen in about 10 nanoseconds!
  - We know that this does **not** happen, since atoms are actually very stable.
  - So, what's the answer? Do we have to modify...
    - Rutherford's Planetary Model
    - Maxwell's Theory of EMR
    - ... or, come up with a whole new idea???

Homework

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