2.4 Early Experiments to Characterize the Atom
Early Experiments to Characterize the Atom

• J. J. Thomson (1856-1940) - postulated the existence of negatively charged particles called electrons using cathode ray tubes.

• Ernest Rutherford (1871-1937) - explained the nuclear atom, containing a dense nucleus with electrons traveling around the nucleus at a large distance.
Cathode Ray Tube (the negative electrode)
Figure 2.8 Deflection of Cathode Rays by an Applied Electric Field determined the charge-to-mass ratio of an electron

$$\frac{e}{m} = -1.76 \times 10^8 \text{ C/g}$$
Figure 2.9  The Plum Pudding Model of the Atom proposed by Thomson
Robert Millikan's Oil Drop Experiment

A schematic representation of the apparatus Millikan used to determine the charge on an electron. The fall of charged oil droplets due to gravity can be halted by adjusting the voltage across the two plates. This voltage and the mass of the oil drop can then be used to calculate the charge on the oil drop. Millikan was able to calculate the mass of the electron as $9.11 \times 10^{-31}$ kilogram.

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QUESTION

J.J. Thomson’s early work helped us understand that atoms could be divided into smaller parts such as electrons. A moving charged particle follows a curved path through a magnetic field. The curvature of the path through that field is most affected by the particle’s charge to mass ratio. Of the following, which would have the greater curvature through the same magnetic field?

1. An electron
2. A proton
3. A neutron
4. I am not sure which would curve the most, a particle with greater or with lesser charge to mass ratio?
Choice 1 (the electron) would have the greater charge to mass ratio due to the extremely small mass and a $-1$ unit charge. Note the proton has a greater mass, with a $+1$ unit charge so it would have a smaller charge to mass ratio.
Learning Check

• Calculate the charge in coulombs for a single electron using Millikan’s mass and Thomson’s charge-to-mass ratio of the electron they calculated.
Discovery of radioactivity using a piece of mineral containing uranium could produce its image on a photographic plate without light. This was attributed to a spontaneous emission of radiation by the uranium.

Henri Becquerel (1852-1908)

Types of radioactive decay later discovered by Rutherford include alpha (α) emission, beta (β) emission, and gamma (γ) emission.
Ernest Rutherford (1871-1937) performed many of the pioneering experiments to explore radioactivity, carried out an experiment to test Thomson’s plum pudding model.

Separation of alpha, beta, and gamma particles by applying an electric field by Ernest Rutherford.
Figure 2.12 Rutherford's Experiment On $\alpha$-Particle Bombardment of Metal Foil
Rutherford’s Gold Foil Experiment

loading...
Rutherford’s “Gold Foil” experiment helped shape what tenet of atomic theory? What aspect of the experiment led to this conclusion?
1. Electrons are embedded in atoms like “plums in a pudding”—most alpha particles go through the gold atoms.
2. Atoms must have a nucleus—only a very narrow beam of alpha particles could exit the lead box.
3. Atoms must have a nucleus—most, but not all, alphas encountered empty space inside of atoms.
4. Electrons are negative particles—only a few positive alpha particles backscattered because the negative electrons were able to neutralize them.
**ANSWER**

Choice 3 describes the correct conclusion, for the correct reason. Since most alpha particles passed through the atom unaltered there must be mostly empty space. However, a few backscattered and calculations were able to point out that only a very small, very dense nucleus would produce those results.