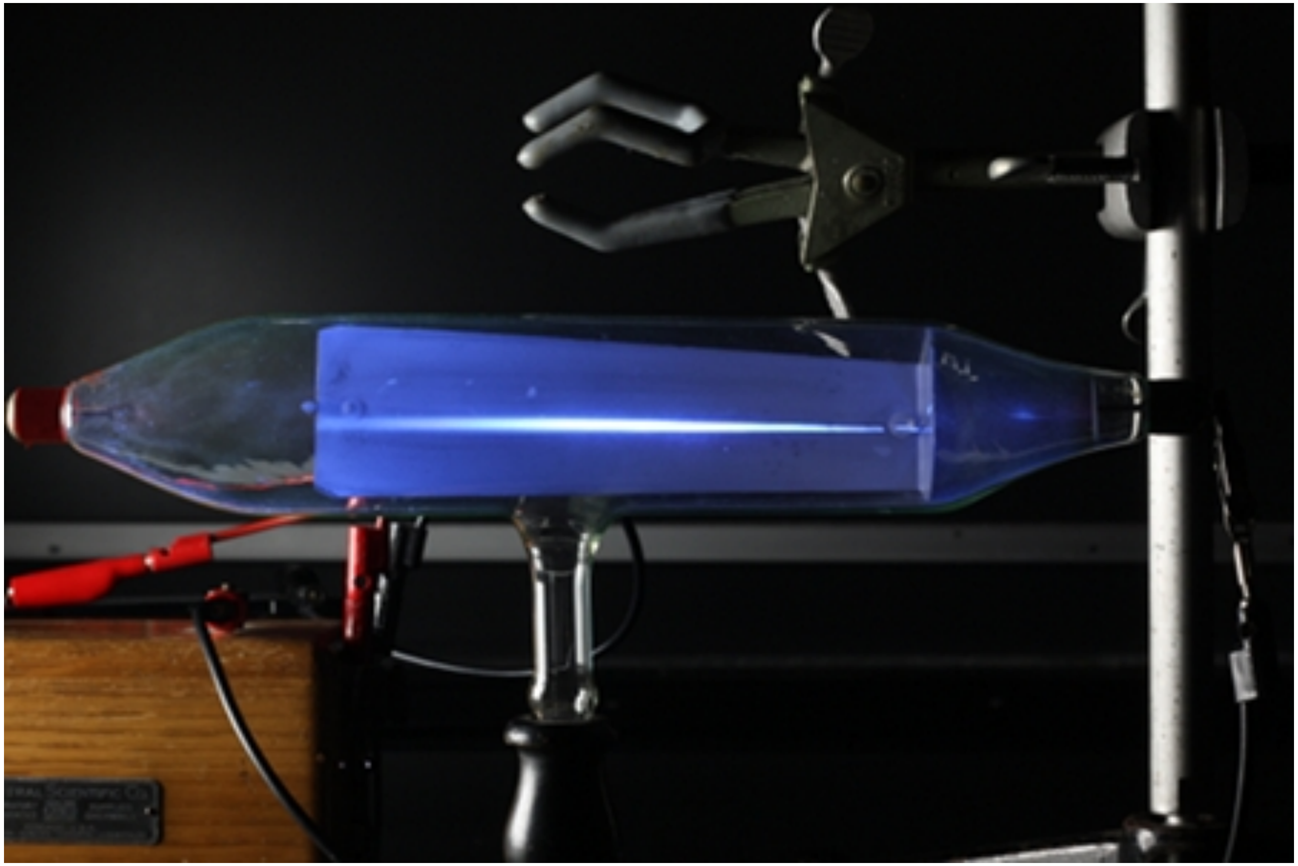
Going Further into Atomic Structure

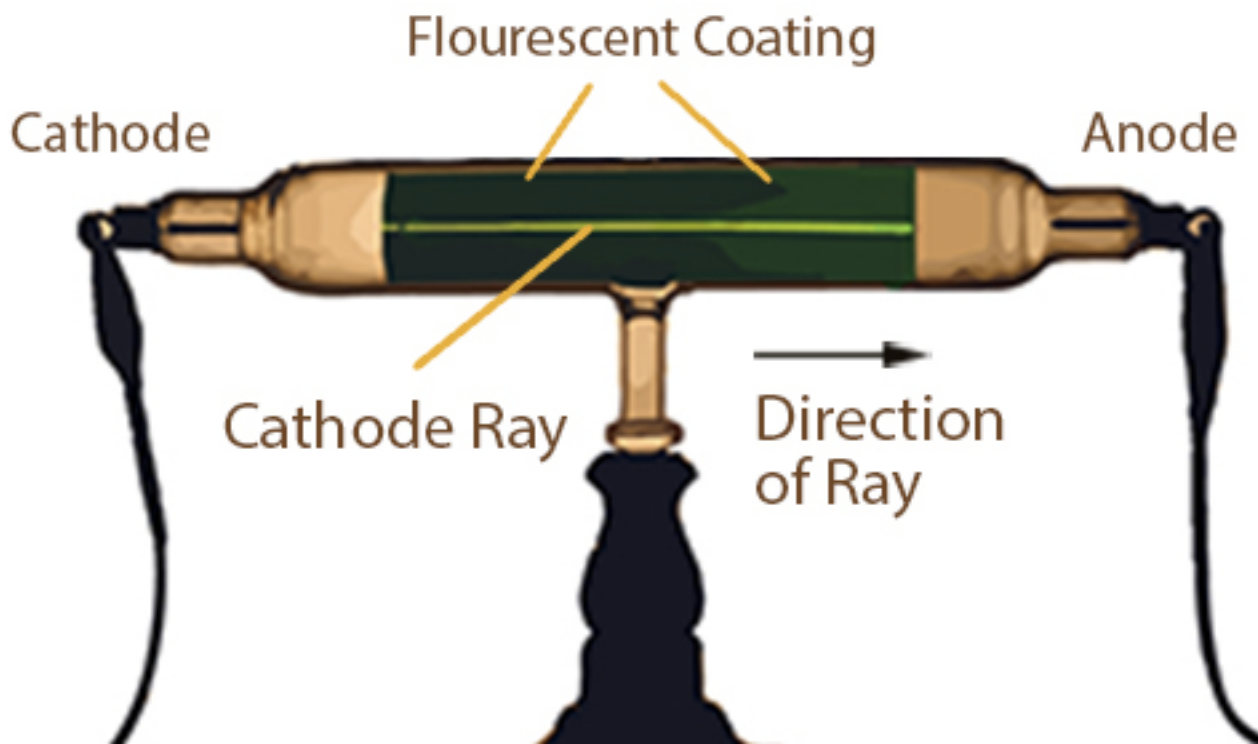
Thomson, Rutherford, and Millikan

Crookes Tubes (~1870)

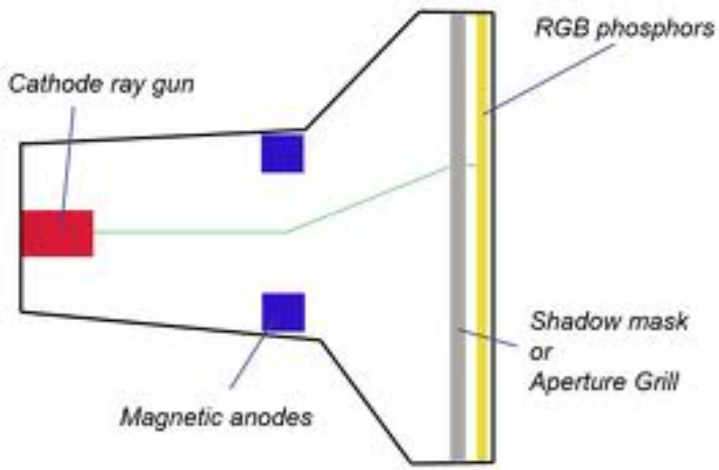


Crookes Tubes

- Contain two metal plates in sealed glass tube
- One metal plate (the "cathode") emits a glowing "ray" when electrical current is applied

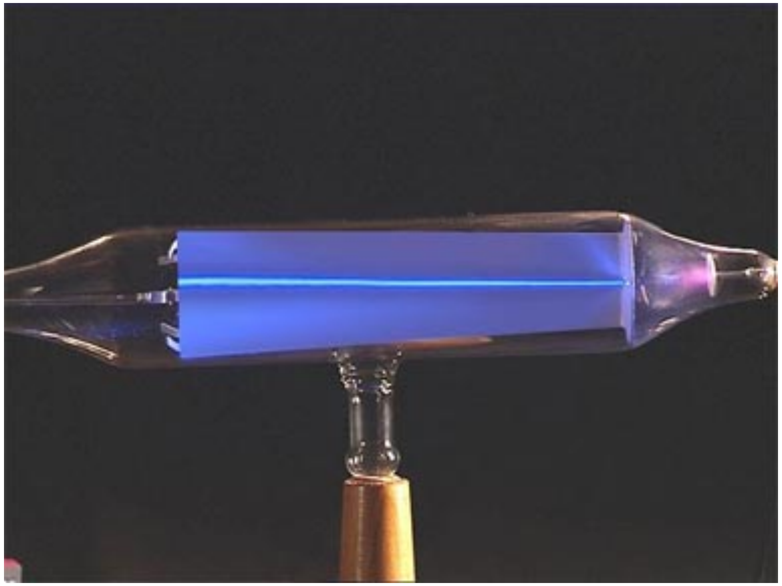


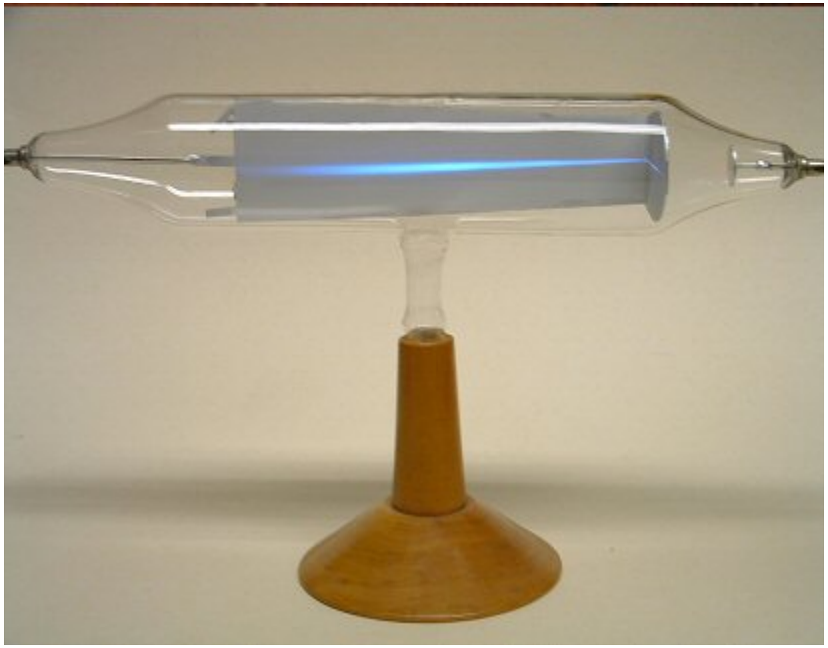
Cathode ray tubes



- Formerly used in TVs, computer monitors

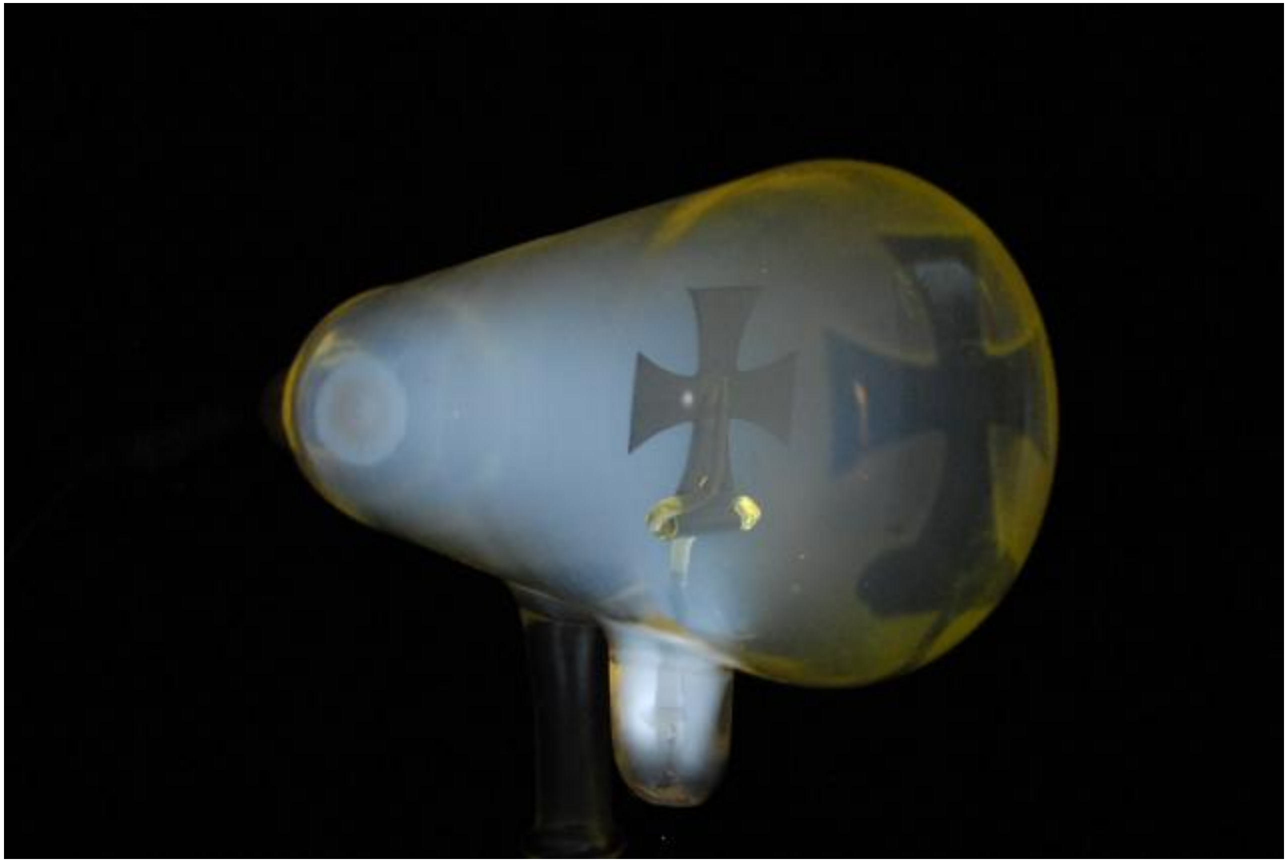
What is the nature of these "cathode rays"?





Cathode rays cast a shadow

- Video



Cathode rays can turn a paddlewheel

Cathode Ray Behaviors

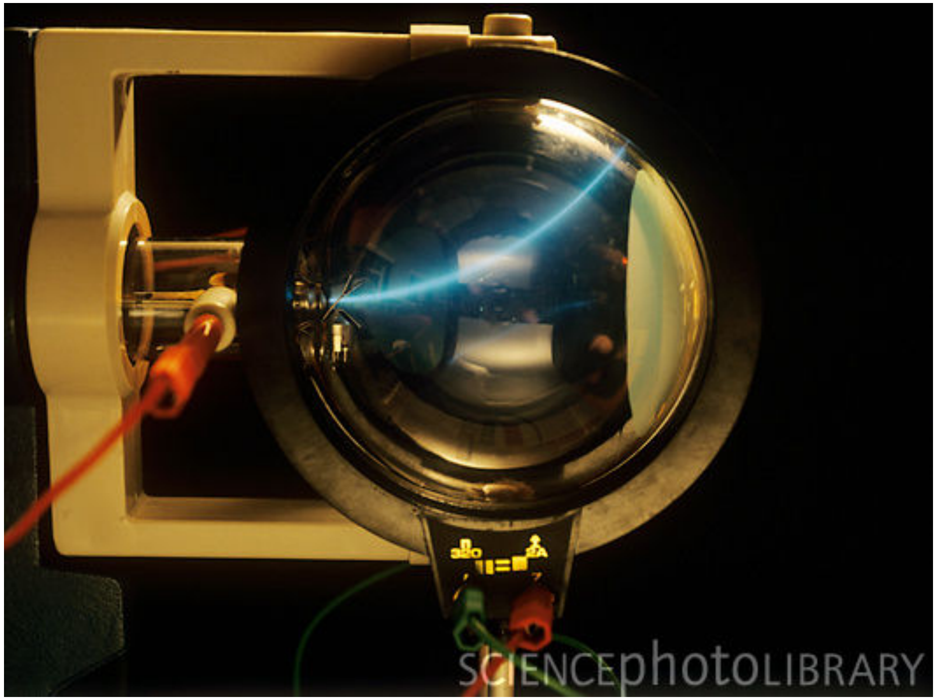
- Cathode rays could be produced by just about any metal tested
- If directed on a piece of metal, the rays could make the metal glow

Cathode rays and magnets

- Video

Cathode rays and magnets

- Cathode rays bend ("are deflected") in the presence of a magnetic field

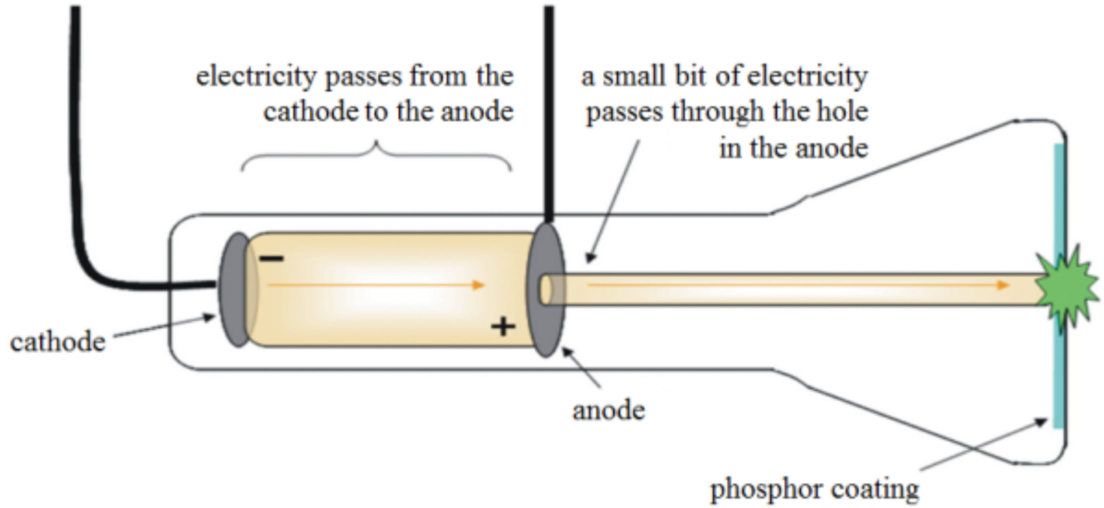


J. J. Thomson

- English physicist, 1856-1940
- Earned scholarship to Cambridge University
- Nobel Laureate in Physics, 1906
- Trained 7 Nobel Laureates

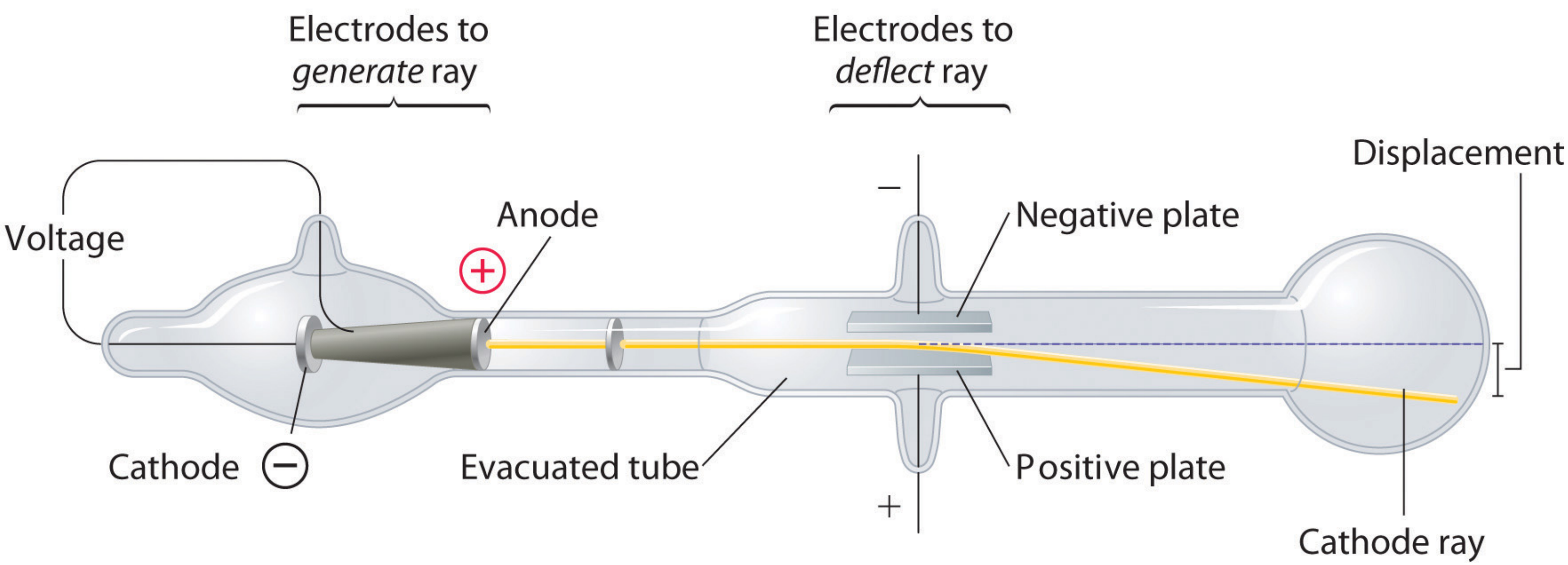
1897 Experiments

- Thomson studied the behavior of cathode rays in the presence of an electric field
  - Animation



1897 Experiments

- Deflection data supported negative charge of cathode rays
- Thomson measured the mass to charge ratio of cathode rays



Thomson’s conclusions

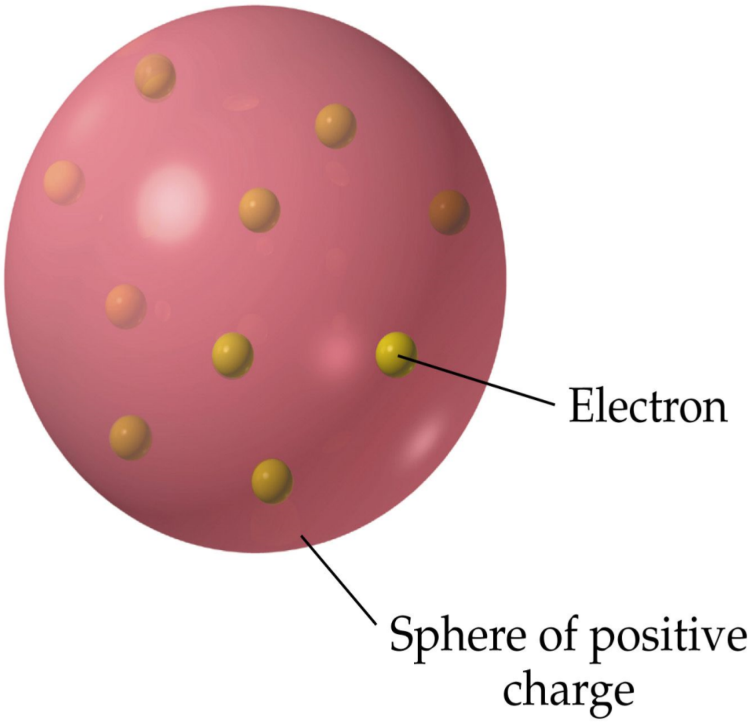
- Cathode rays are made of tiny, negatively charged particles
  - Eventually called electrons

Thomson's conclusions

- All atoms contain electrons
- Atoms known to be electrically neutral, so there must be positive charge in with the electrons

Thomson's model of the atom

- Proposed that electrons were embedded in gel-like positive charge
- Called the "plum pudding model"



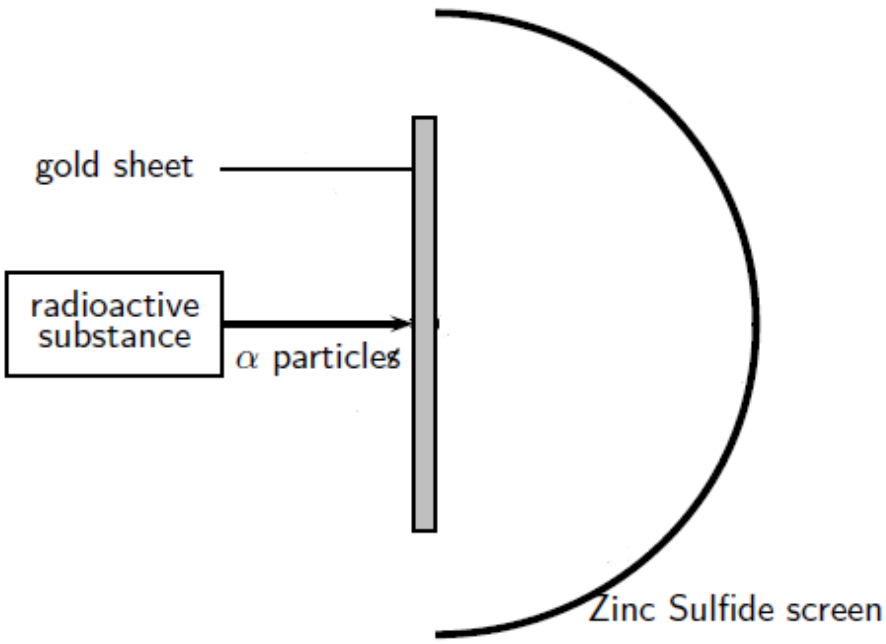
Ernest Rutherford

Video

- New Zealand native
- Won scholarship to Cambridge University
  - Studied with J. J. Thomson
- Taught at McGill, Manchester and Cambridge
- Ongoing interest in radioactivity
- 1908 Nobel Laureate

The Gold-Foil Experiment

- Decided to test Thomson's plum pudding model
- Worked with Hans Geiger and Hans Marsden from 1909-1913



The Gold-Foil Experiment

- Alpha particles α
  - big, positively charged particles
  - Nucleus of a helium atom

- Beam of "alpha particles" was directed at thin gold foil and the paths followed by a detection screen

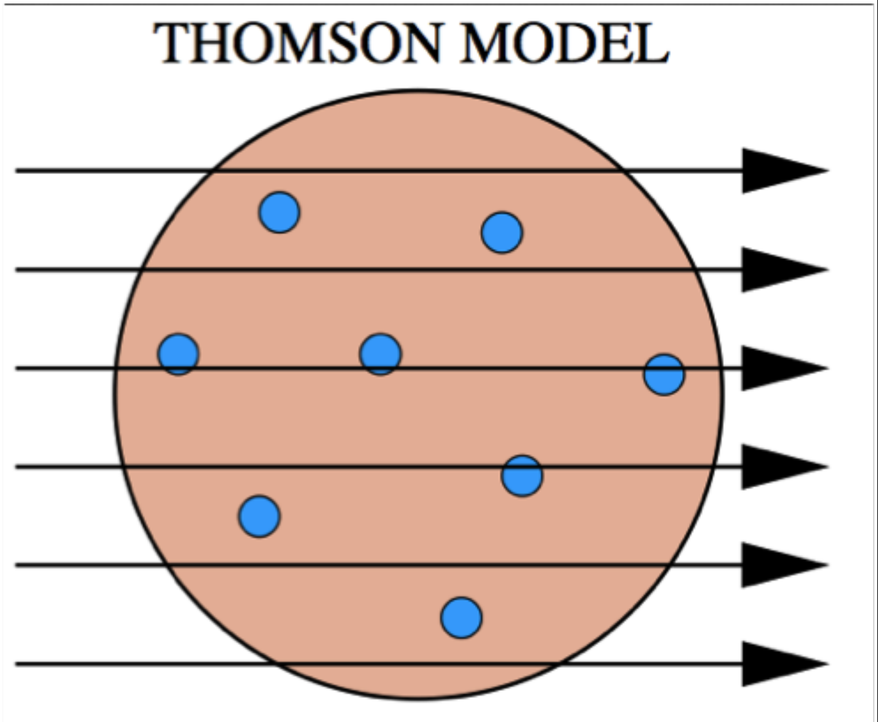
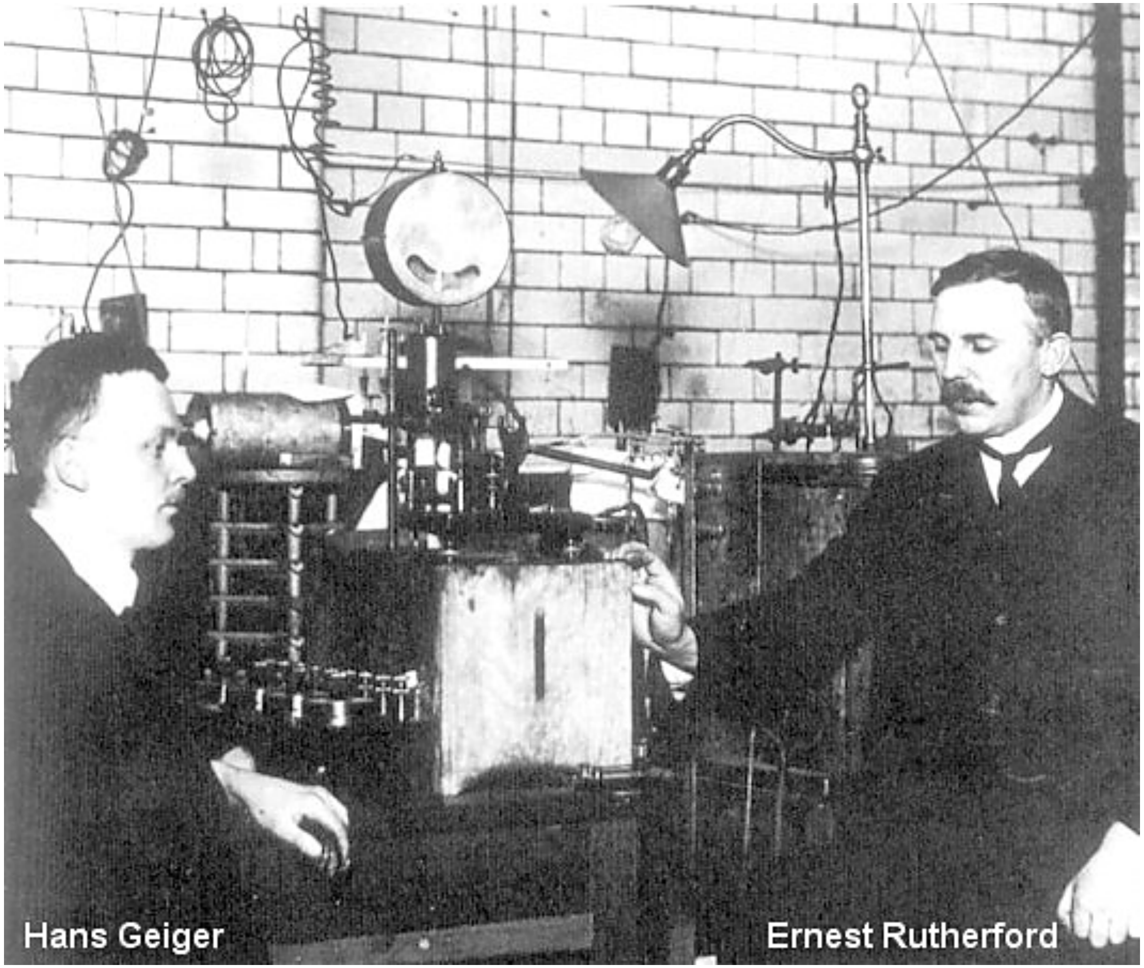


Fig – Thomson Lpum Pudding Model Source - Wikipedia

Expectations vs. Results

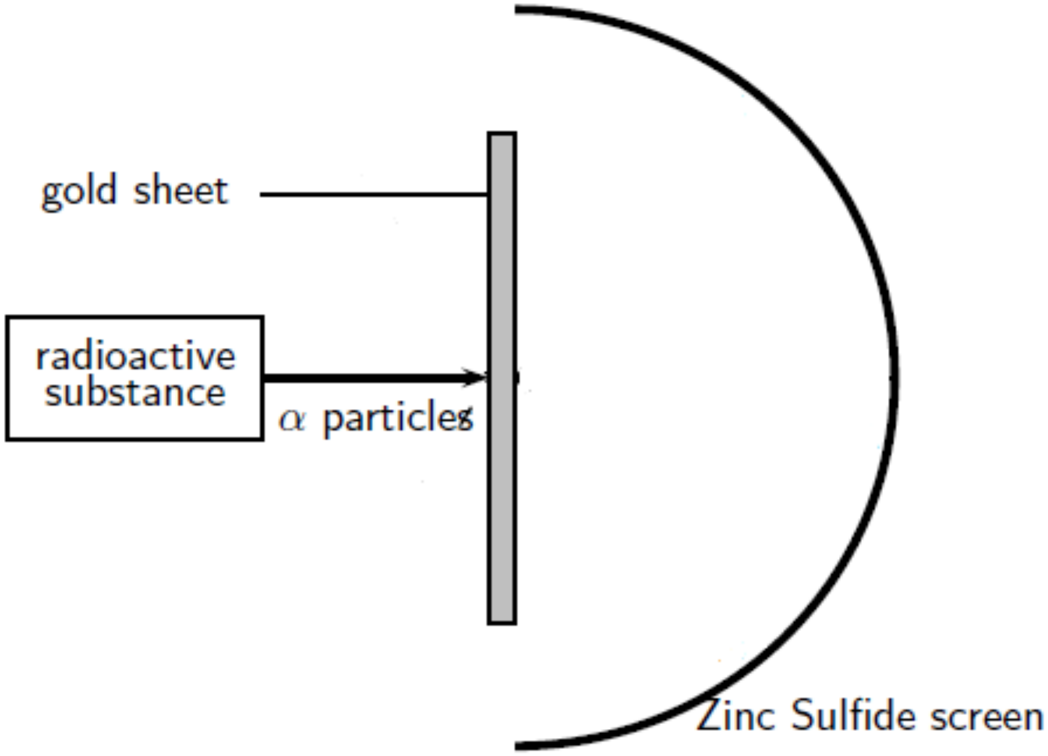
- If Thomson's model is correct, what should the alpha particles do when they hit the foil?
- The alpha particles were expected to go straight through the foil

In the lab

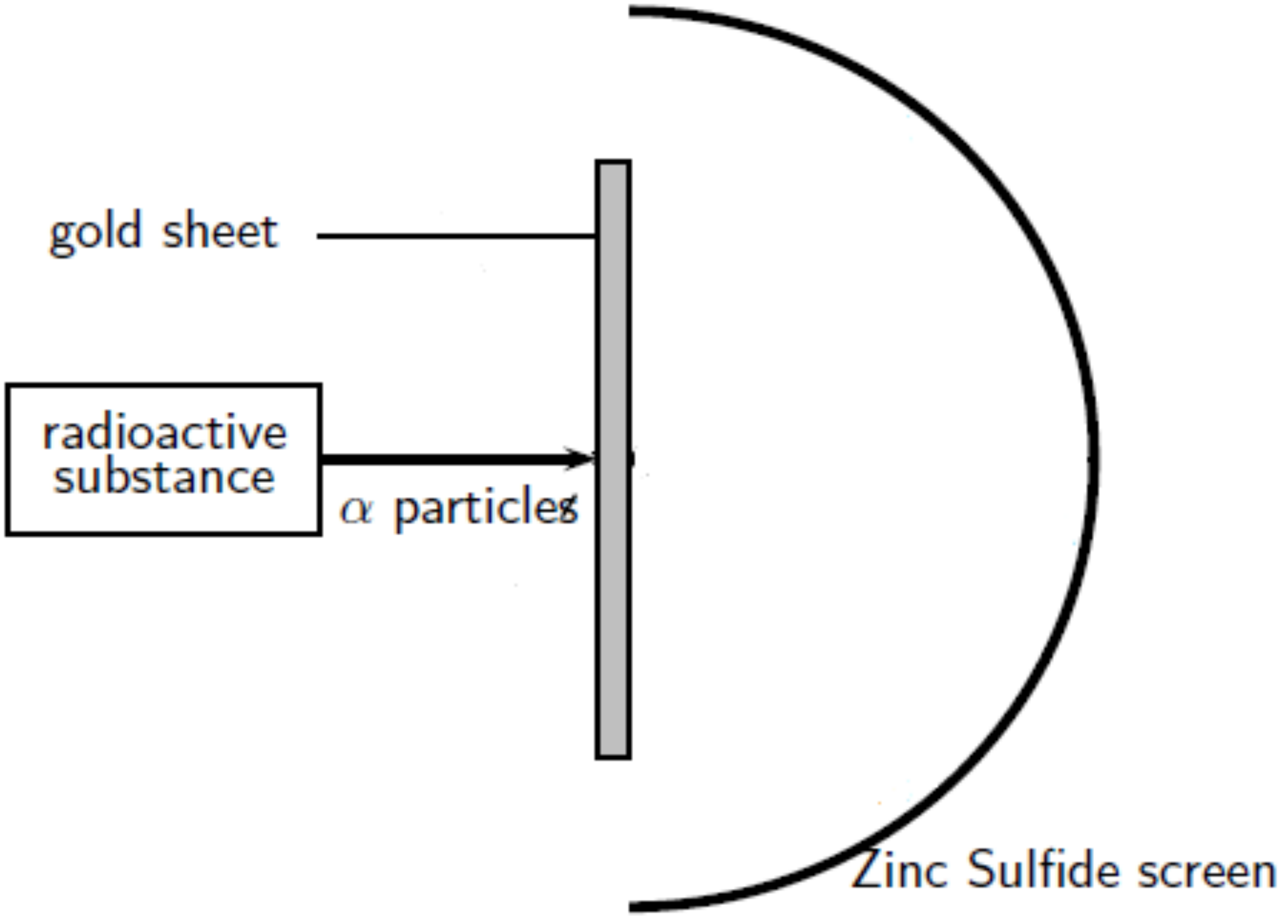


What did they observe?

- Animation



Actual results



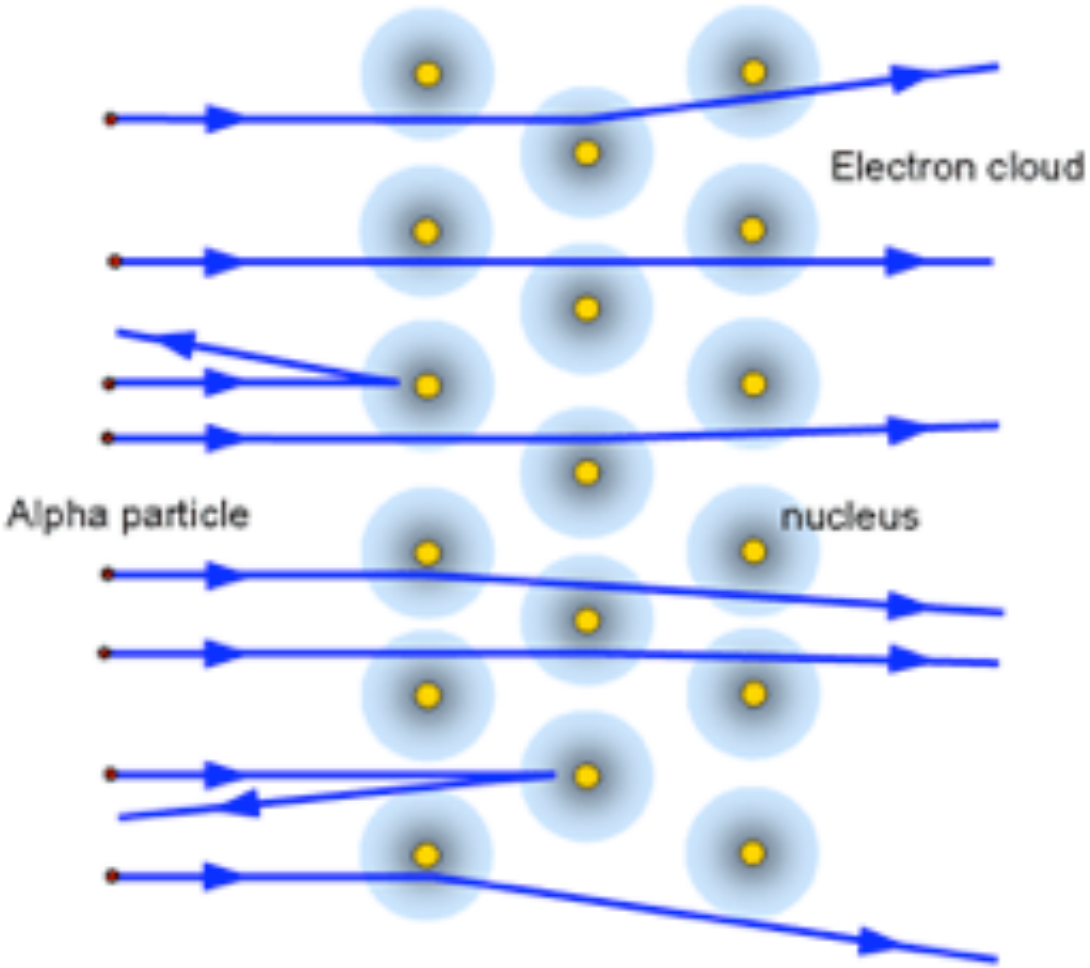
Expectations vs. Results

- A very small percentage of particles showed "backscattering" when they hit the foil
- Thomson's model didn't hold up to the evidence
- Rutherford proposed a modified theory

Rutherford's atomic model

- Most of the mass and positive charge of an atom is concentrated in the center (the nucleus)
  - Positively charged subatomic particles called "protons" identified early 1920's
    - Atomic number = number of protons
  - Neutrons were identified in 1932 by James Chadwick

Visual model



Rutherford's atomic model

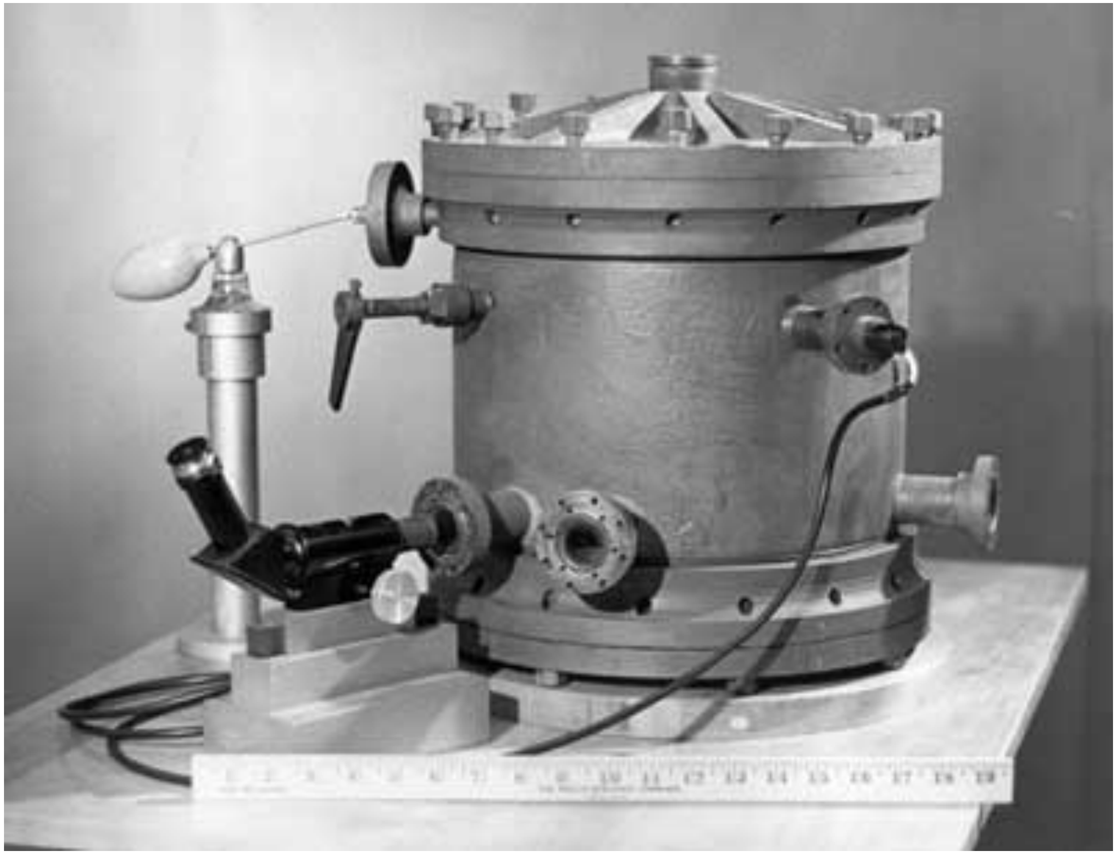
- Electrons surround the nucleus
  - Most of the volume of an atom is due to the electrons
  - Most of the atom consists of empty space
  - # protons = # electrons in neutral atoms

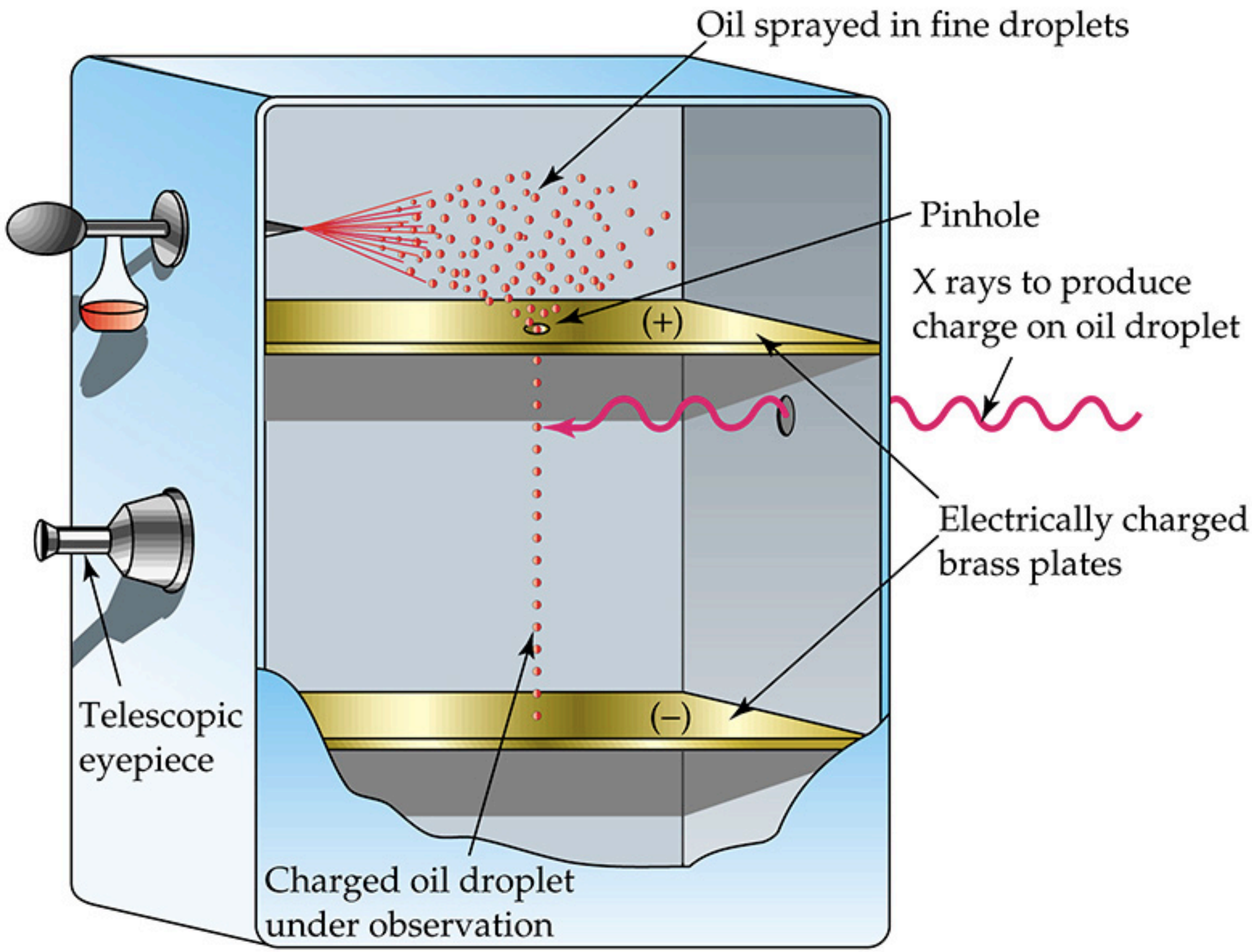
Robert Millikan

- U.S. physicist
- University of Chicago
- Nobel Prize, 1923
- First major success: finding the charge of an electron

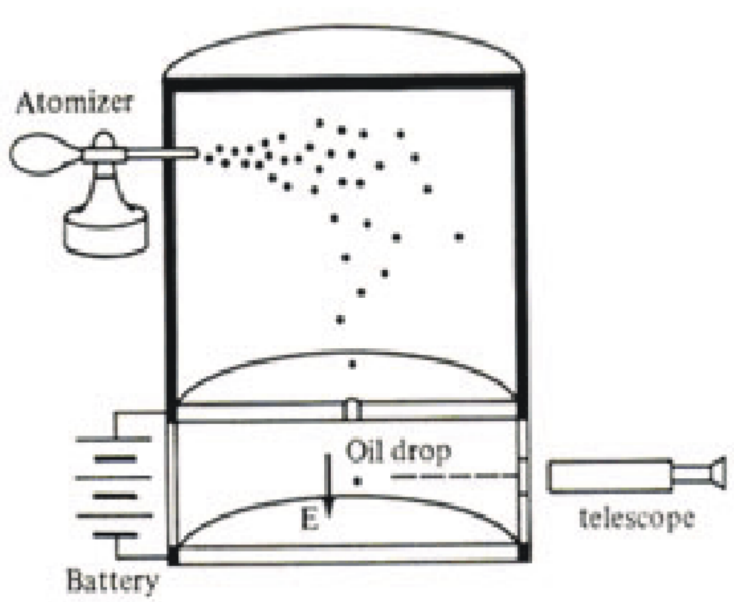
Oil Drop Experiment

- Video
- Animation




Oil sprayed in fine droplets
Pinhole
(+)
X rays to produce charge on oil droplet
Electrically charged brass plates
(–)
Telescopic eyepiece
Charged oil droplet under observation

Oil Drop Experiment



- Isolate single charged oil droplet between two plates
- Adjust charge on plate to suspend droplet midair
- Amount of charge needed proportional to number of electrons on drop
  - $Q_C = -1.6 \times 10^{-19}$ coulombs
- Together with Thomson's results, could determine the mass of an electron