

Going Further into Atomic Structure

Thomson, Rutherford, and
Millikan

Geissler or Crookes Tubes

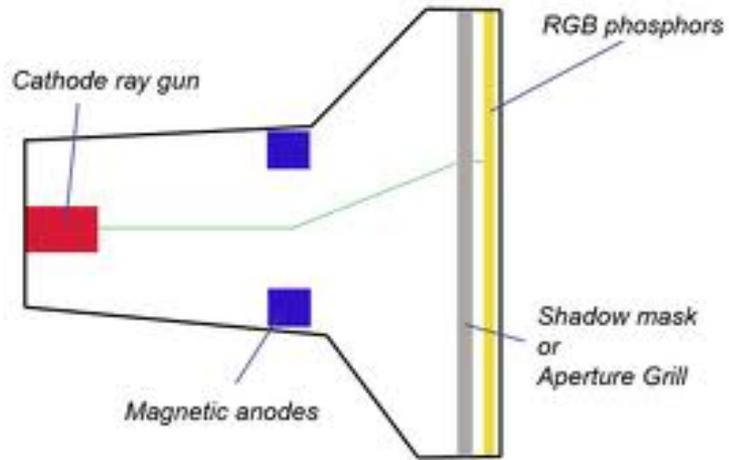


Geissler or Crookes Tubes



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

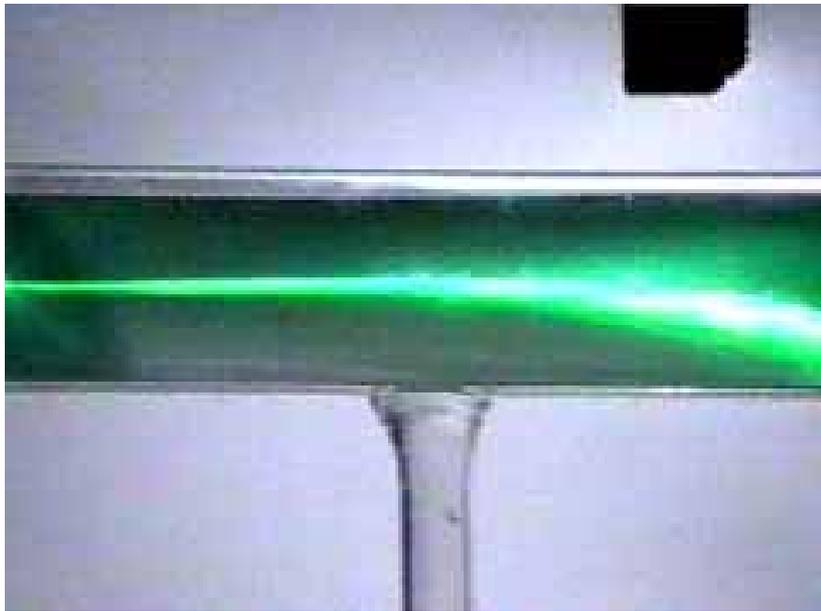
Cathode ray tubes



- Still used in TVs, computer monitors

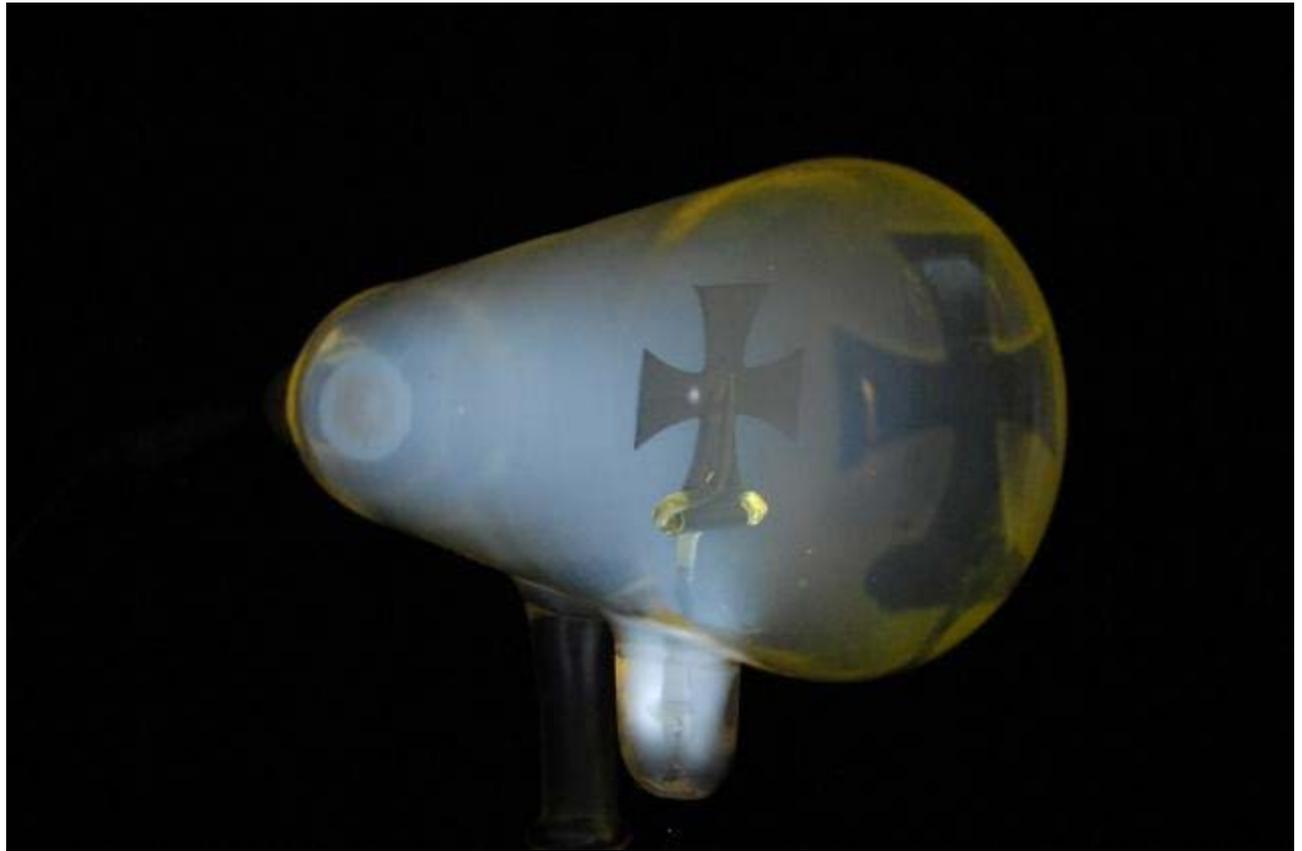


What is the nature of these
"cathode rays"?

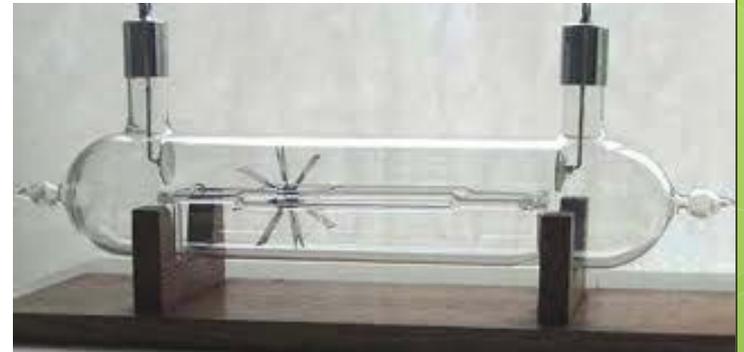


Cathode rays cast a shadow

- [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
- They showed strange behaviors in presence of magnets

Cathode rays and magnets

- [Video](#)

Cathode rays and magnets

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



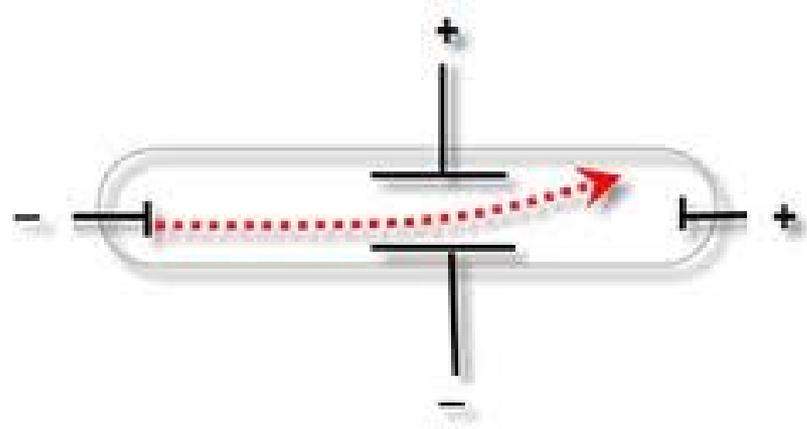
J. J. Thomson



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

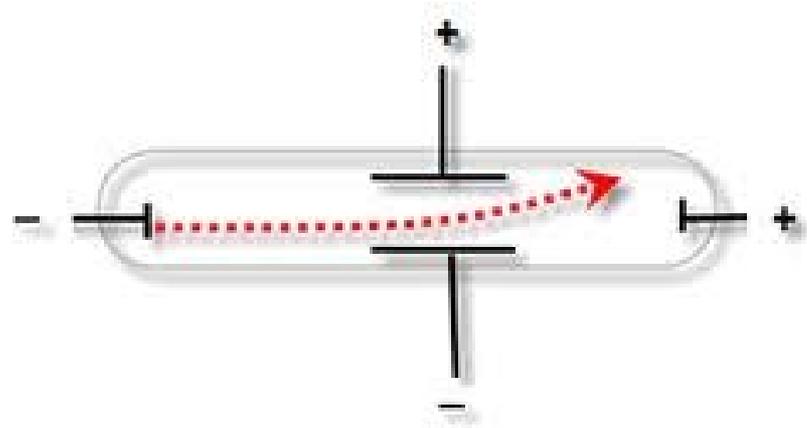
1897 Experiments

- 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

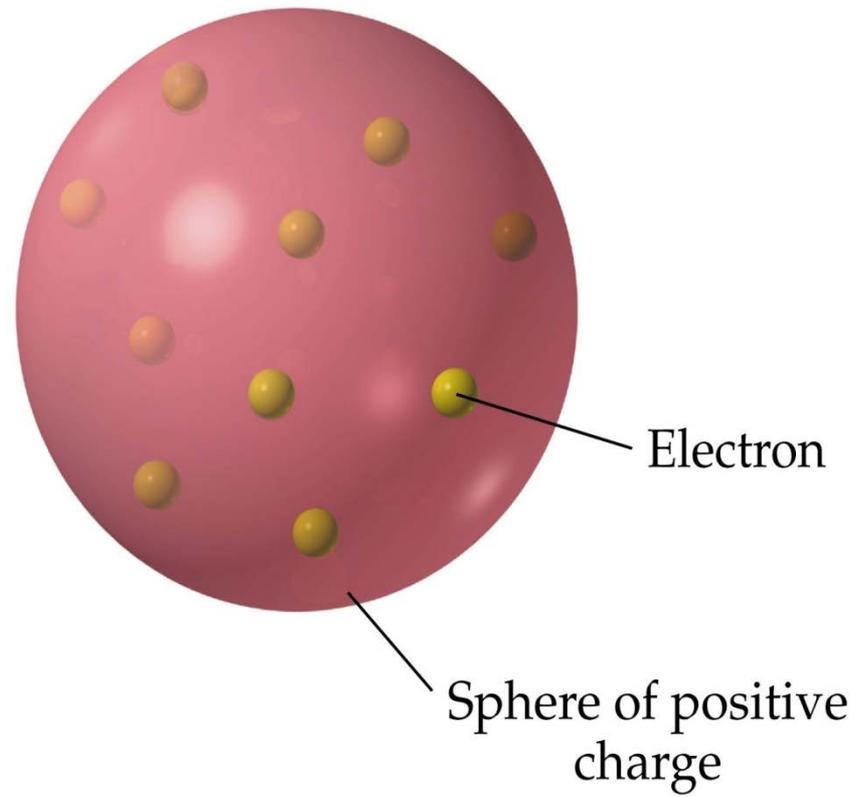
- Cathode rays are made of tiny, negatively charged particles
 - Eventually called electrons

Thomson's conclusions

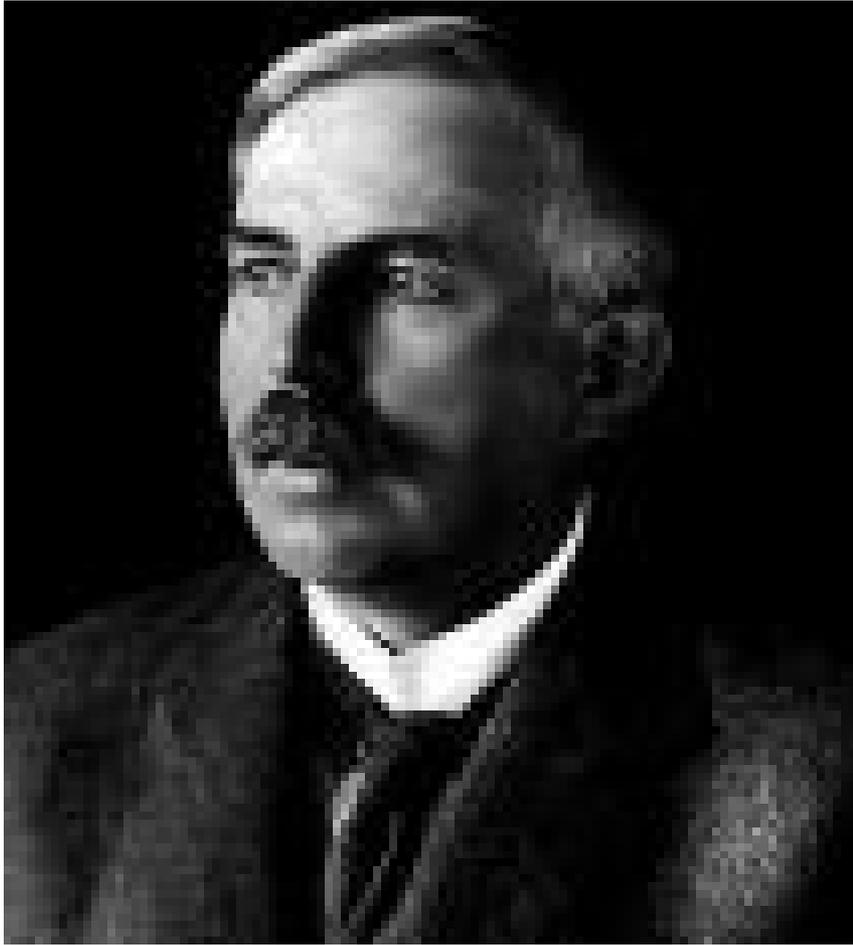
- Cathode rays are made of tiny, negatively charged particles
- All atoms contain electrons

Thomson's model of the atom

- Atoms known to be electrically neutral, so there must be positive charge in with the electrons
- Proposed that electrons were embedded in gel-like positive charge
- Called the "plum pudding model"



Ernest Rutherford



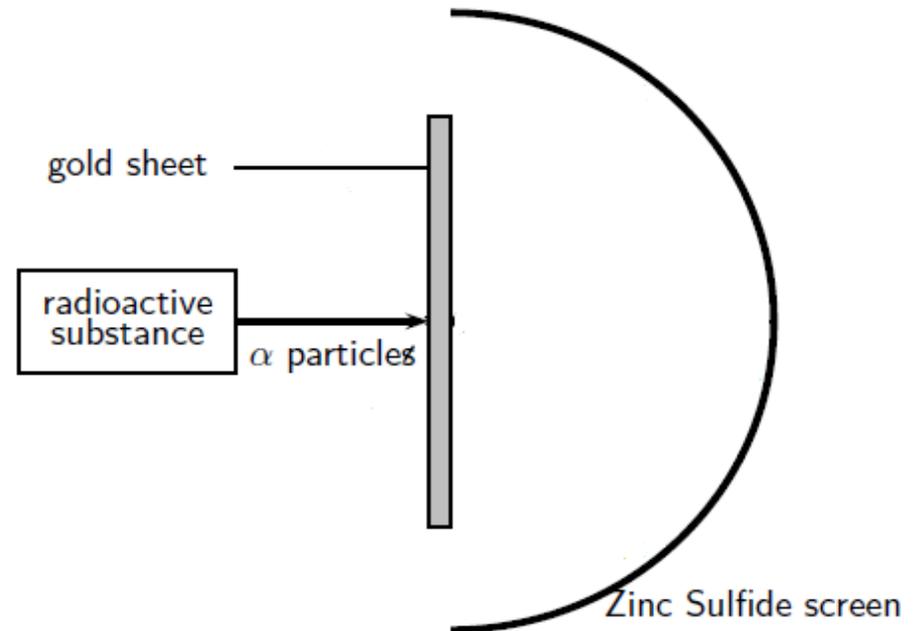
Video

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

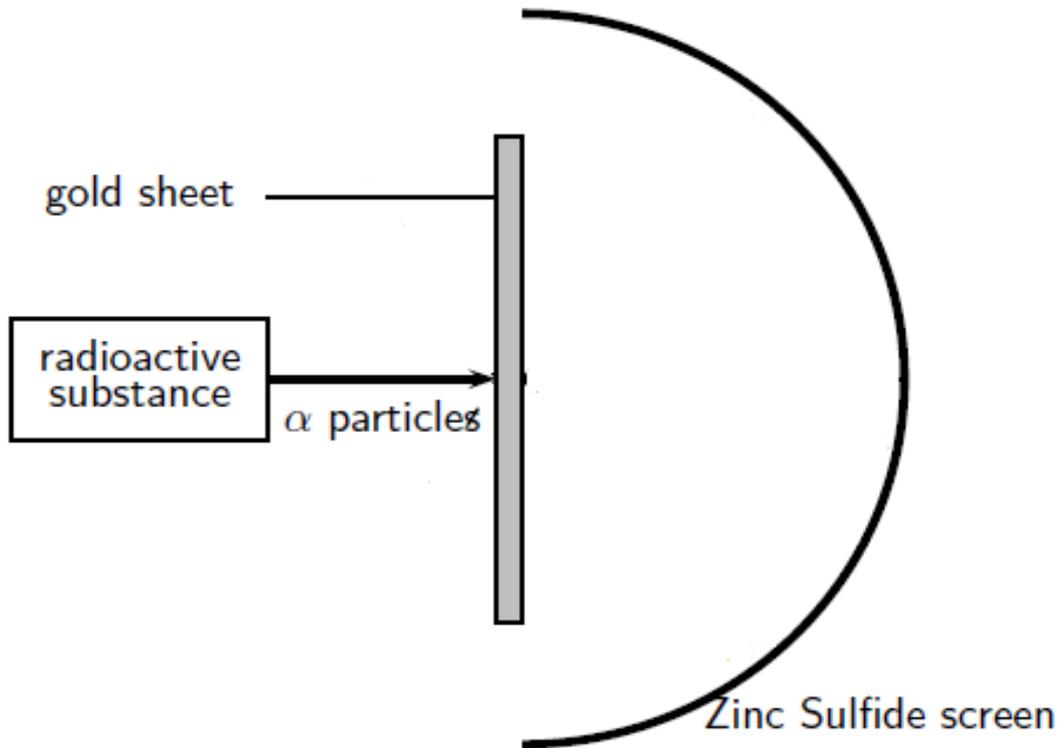
Alpha particles α
big, positively charged particles
Nucleus of a helium atom



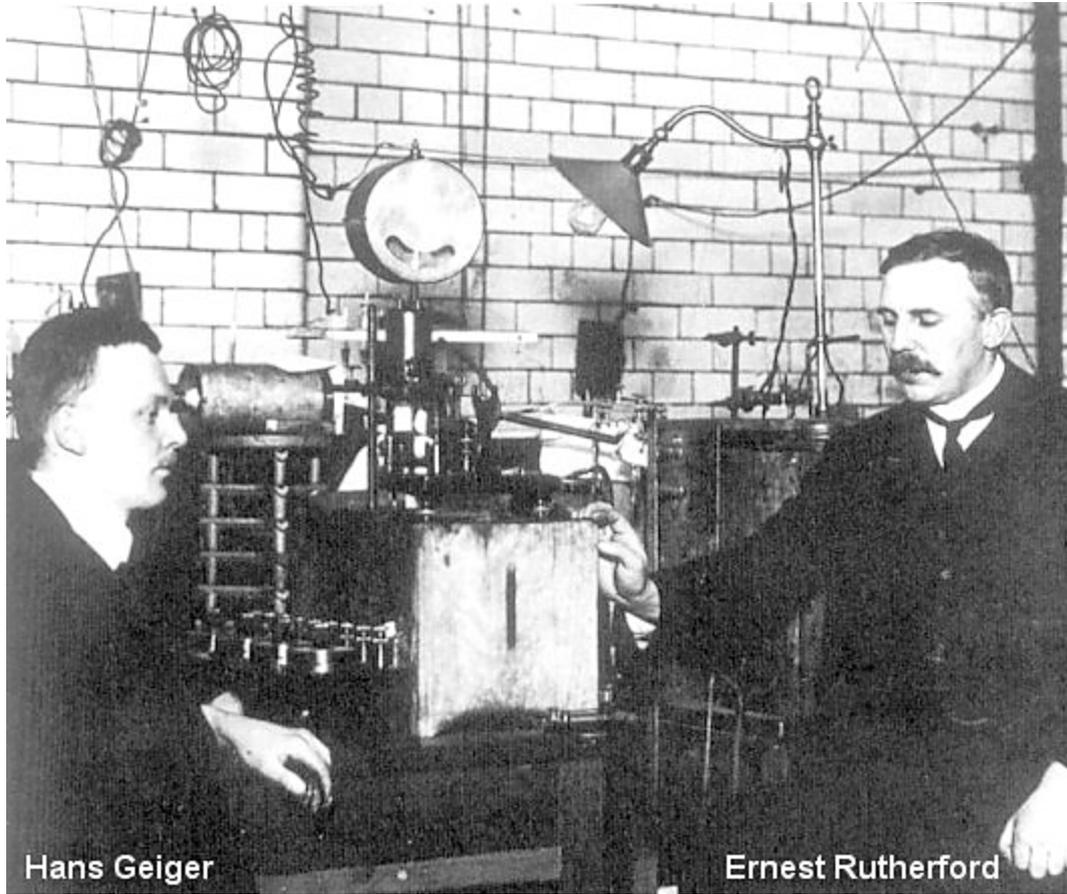
Expectations vs. Results

- 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

Expected results • [Animation](#)



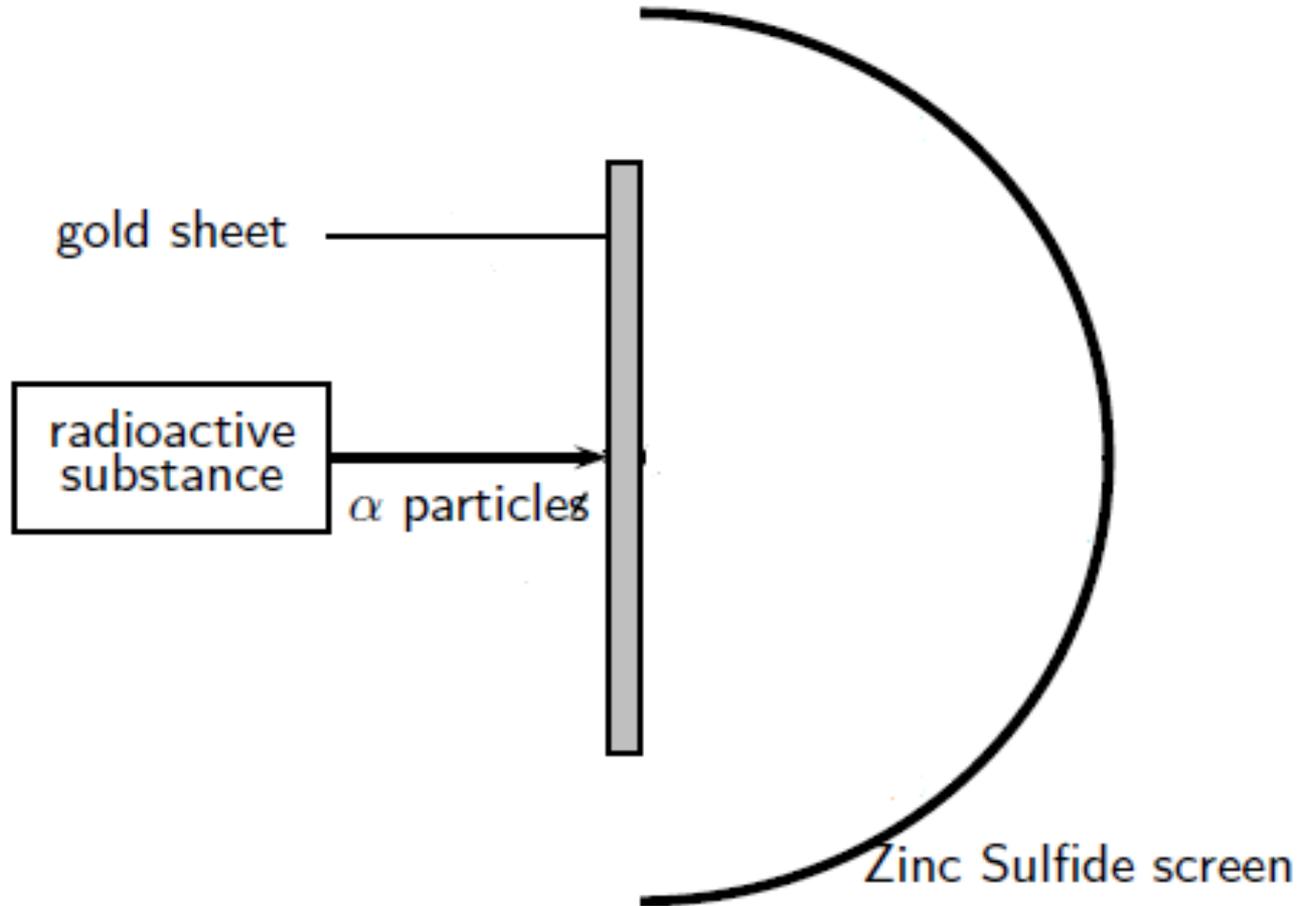
In the lab



Hans Geiger

Ernest Rutherford

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

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

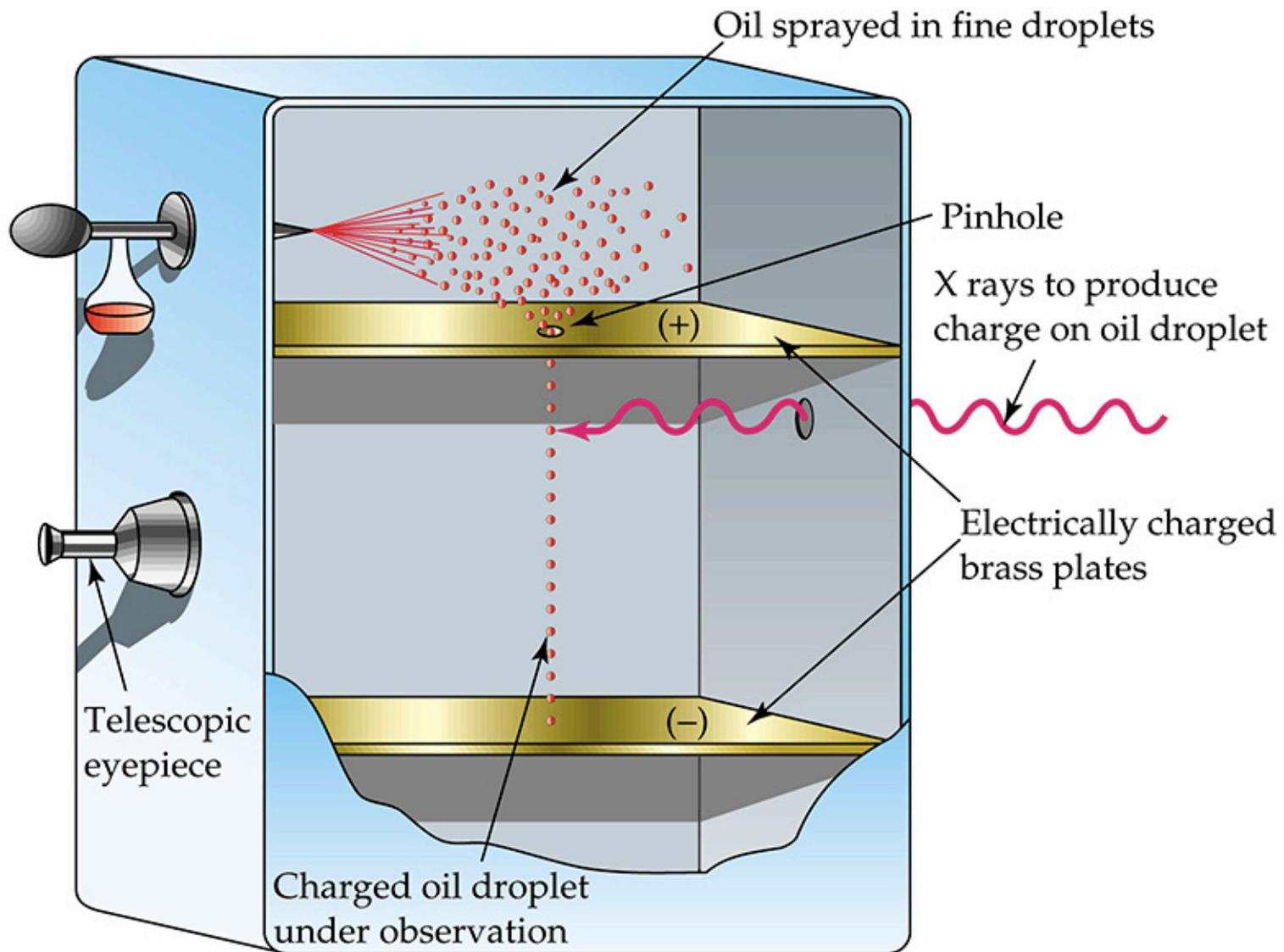
- U.S. physicist
- University of Chicago
- Nobel Prize, 1923
- First major success: finding the charge of an electron



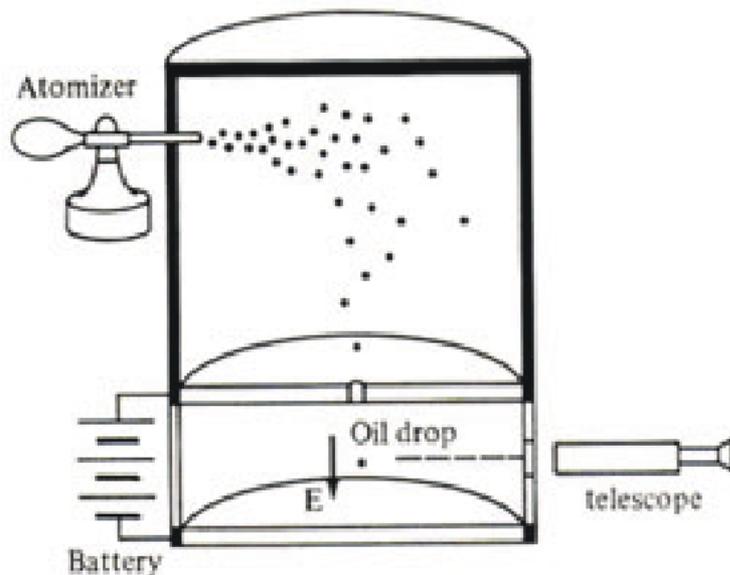
Oil Drop Experiment

- [Video](#)
- [Animation](#)





Oil 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