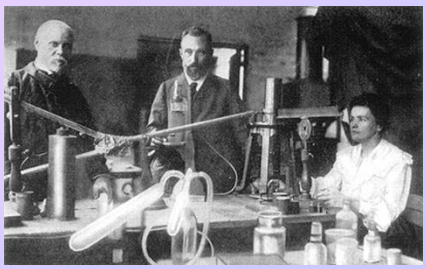
The atom is a very small, indivisible particle.

Or is it?

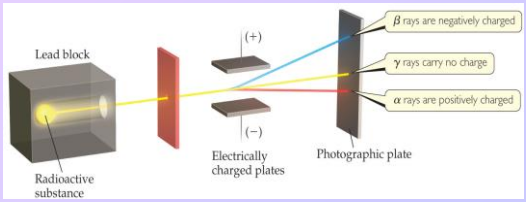
This idea was severely challenged by the discovery of:

1) **Static Electric Charge**
   - First observed/recorded in ancient Egypt
   - Two types: positive/negative
   - **Law of Electrostatic Attraction**: Like charges repel; Opposite charges attract

2) Radioactivity – spontaneous emission of high-energy radiation by an atom
- Becquerel discovered in 1896
- Studied also by Pierre Curie and Marie Curie



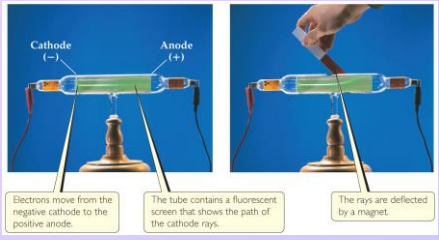
- Three types of radiation were discovered by Ernest Rutherford:
  - Alpha, α, particles (positively charged)
  - Beta, β, particles (negatively charged, like electrons)
  - Gamma, γ, rays (uncharged, no mass)



3) Cathode Rays

Produced in cathode ray tubes (CRTs)
- A partially evacuated glass tube
- Piece of metal (electrode) sealed in each end
- Neg. charge = cathode; pos. charge = anode
- Voltage applied produces cathode ray (emanates from cathode)
- Causes gases to glow/metals to heat
- Bends toward a positive charge
- A forerunner of neon signs, TV tubes, fluorescent lights

Cathode Ray Tube



Streams of negatively charged particles were found to emanate from cathode tubes, causing fluorescence.

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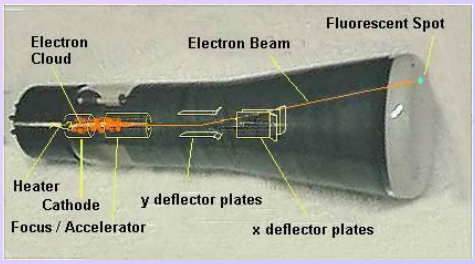


Cathode Ray Tube diagram

So why did scientists question the idea that atoms were the smallest particle of matter that existed??

Because they had evidence that:

Atoms can be divided and some divide spontaneously.

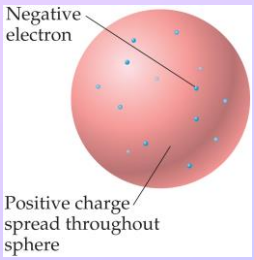
Beta/cathode ray particles are 1/1836 times as massive as the smallest atom, therefore must be subatomic

J.J. Thomson (1897)

- Determined that the cathode ray is a stream of negative particles (electrons)
- Determined the charge to mass ratio
  1.76×10^8 C/g (coulomb/gram)
- Used 20 different metals – same results
  - Electrons are common to all these metals/gases
  - Possibly to all atoms
- Nobel Prize in 1906

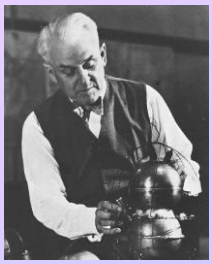
Plum Pudding Model

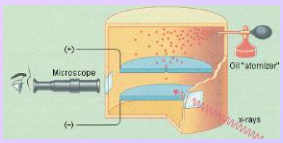
- the atom is a ball of positive charge
- embedded with negatively charged particles



Robert Millikan (1909)

- **Oil Drop Experiment**
  Measured the charge on the electron





- Atomizer - creates small droplets
- X-rays - place a negative charge on droplets
- Gravity – causes the drops to fall
- Voltage source – adjusts charge on the plates above and below to a point where the droplet is suspended

Result:

- Bigger droplets take more charge to suspend
- The various charges needed to suspend different droplets are all multiples of the smallest value

Explanation:

- The droplets have some whole number of negative particles attached (let's call these particles electrons)

Millikan then calculated:

the charge of an electron = 1.60×10^{-19} C

the mass of an electron = 9.10×10^{-28} g

E. Goldstein

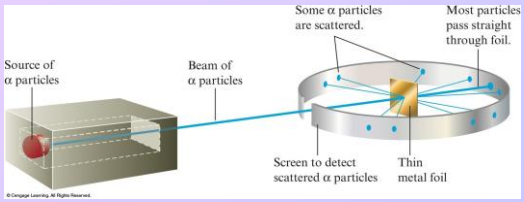
- Used a CRT with a perforated cathode
- Found a different beam of particles called "canal rays"
- Positively charged (protons)

Ernest Rutherford (1910)

- **Gold Foil Experiment**
  Shot alpha radiation at a thin sheet of gold foil

Results:

Most particles penetrated straight through
However: ~1/8000 was deflected
(some even directly back at source)



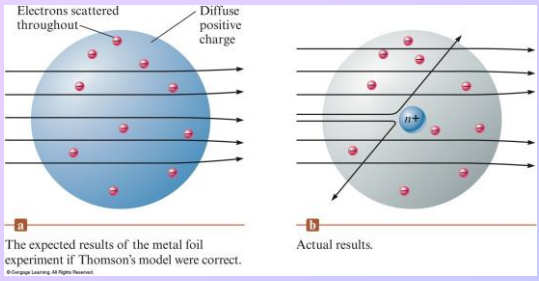


Figure 2-13 p53

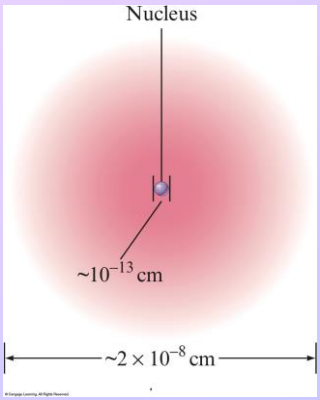
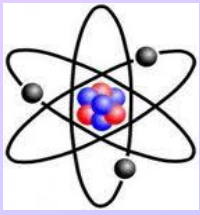


Figure 2-14 p54

p54

Conclusion:
The atom is mostly empty space with a very small, dense, positive region containing most of the atom's mass, called the **nucleus**



James Chadwick (1932)

- confirmed the existence of neutrons through a nuclear reaction
- difficult to find because they have no charge