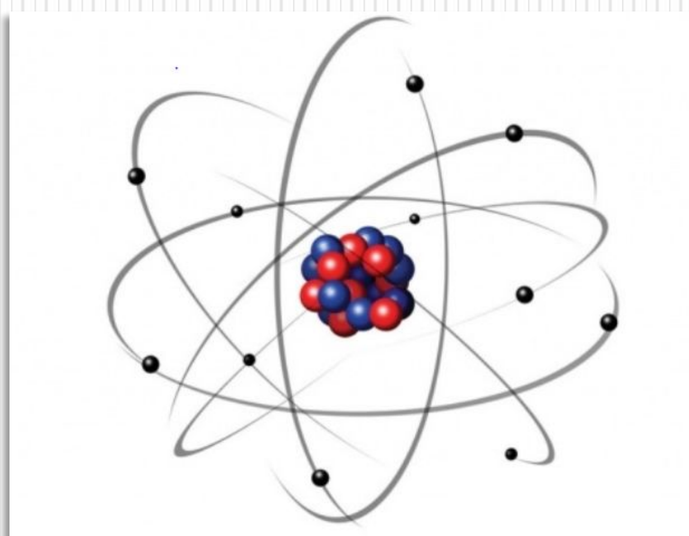
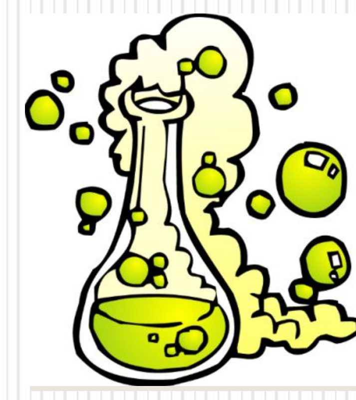
Atomic theory & Structure of an Atom





The Greek word of "*Atomos*" means "***Indivisible***"

- Around 440 BC, ***Leucippus*** originated the atom concept.
- One of his students, ***Democritus*** (460BC-371BC) extended it.
- There are **five major points** in their atomic concept:
  - All matter is composed of atoms, which are too small to be seen. **These atoms CANNOT be further split into smaller portions**.
  - There is empty space between atoms.
  - Atoms are completely solid.
  - Atoms are homogeneous同質, with no internal structure.
  - Atoms can differ in size, shape, and weight.

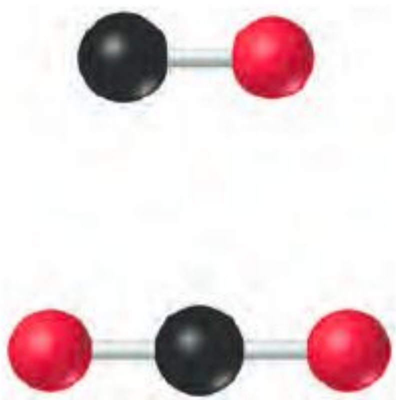
Dalton's Atomic Theory (1803-1808)

- 1.***Elements*** are composed of extremely small particles called ***atoms***原子.
- 2. All ***atoms*** of a given element **are identical, having the same size, mass and chemical properties**. **The atoms of one element are different from the atoms of all other elements.**
- ***3.*** ***Compounds***化合物are composed of *atoms of more than one element*. In any compound, the ratio of the numbers of atoms of any two of the elements present is either an integer or a simple fraction.
- 4. **A *chemical reaction* involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.**

Dalton’s Atomic Theory:

Law of multiple proportions

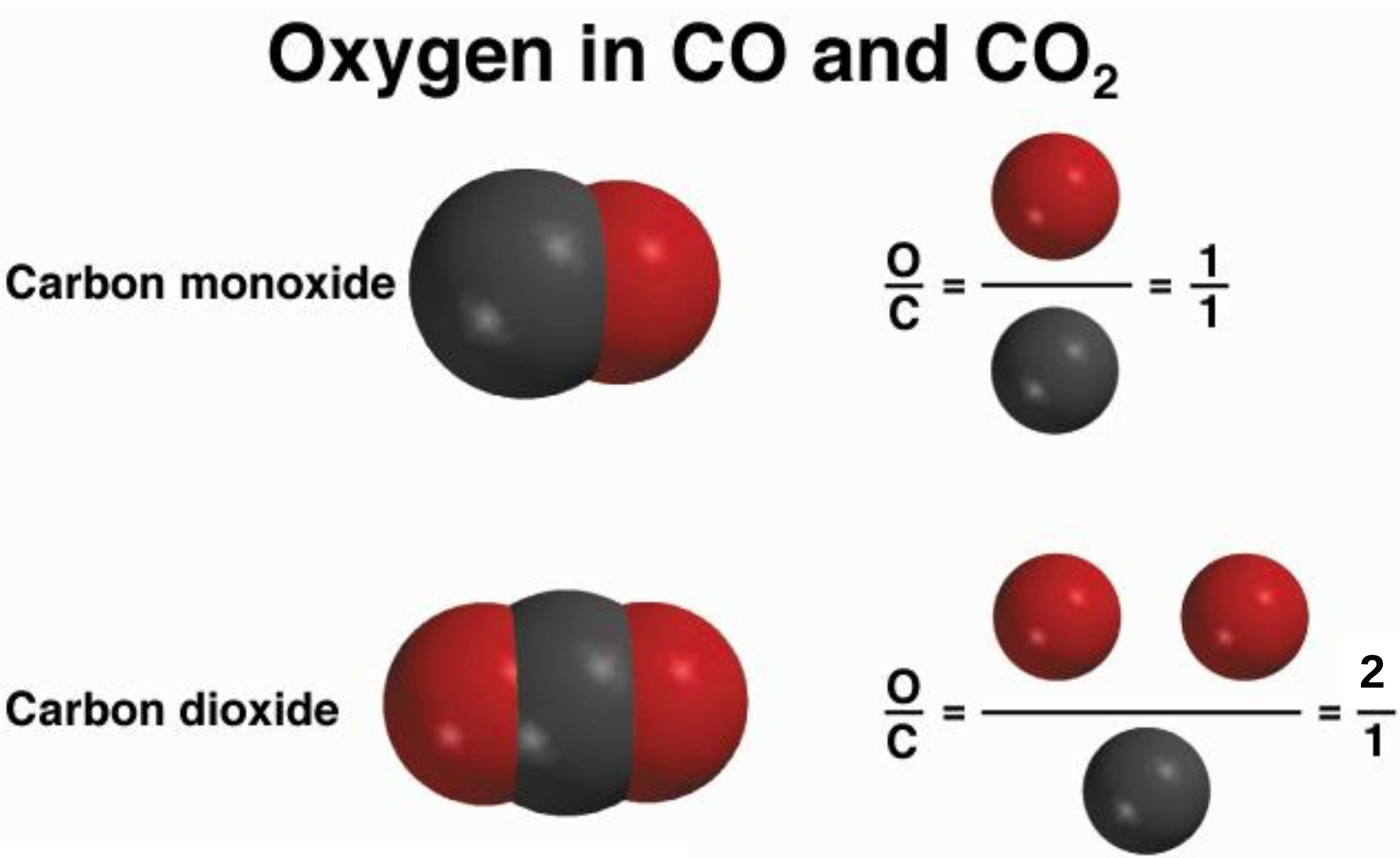
- **If two elements form more than a single compound, the masses of one element combined with a fixed mass of the second are in the ratio of small whole numbers.**



Molecules CO and CO_2 illustrating the law of multiple proportions

Example 1: The mass of carbon is the same in the two molecules, but the mass of oxygen in ***CO_2*** is twice the mass of oxygen in ***CO***. Thus, in accordance with the ***law of multiple proportions***, **the masses of oxygen in the two compounds, relative to a fixed mass of carbon, are in a ratio of small whole numbers, *2:1***.

Dalton's Atomic Theory



Law of Multiple Proportions

Dalton's Atomic Theory :

Law of multiple proportions

- ***Example 2:*** Nitrogen Oxides I & II
- Nitrogen Oxide I: 46.68% Nitrogen and 53.32% Oxygen

  Nitrogen Oxide II: 30.45% Nitrogen and 69.55% Oxygen

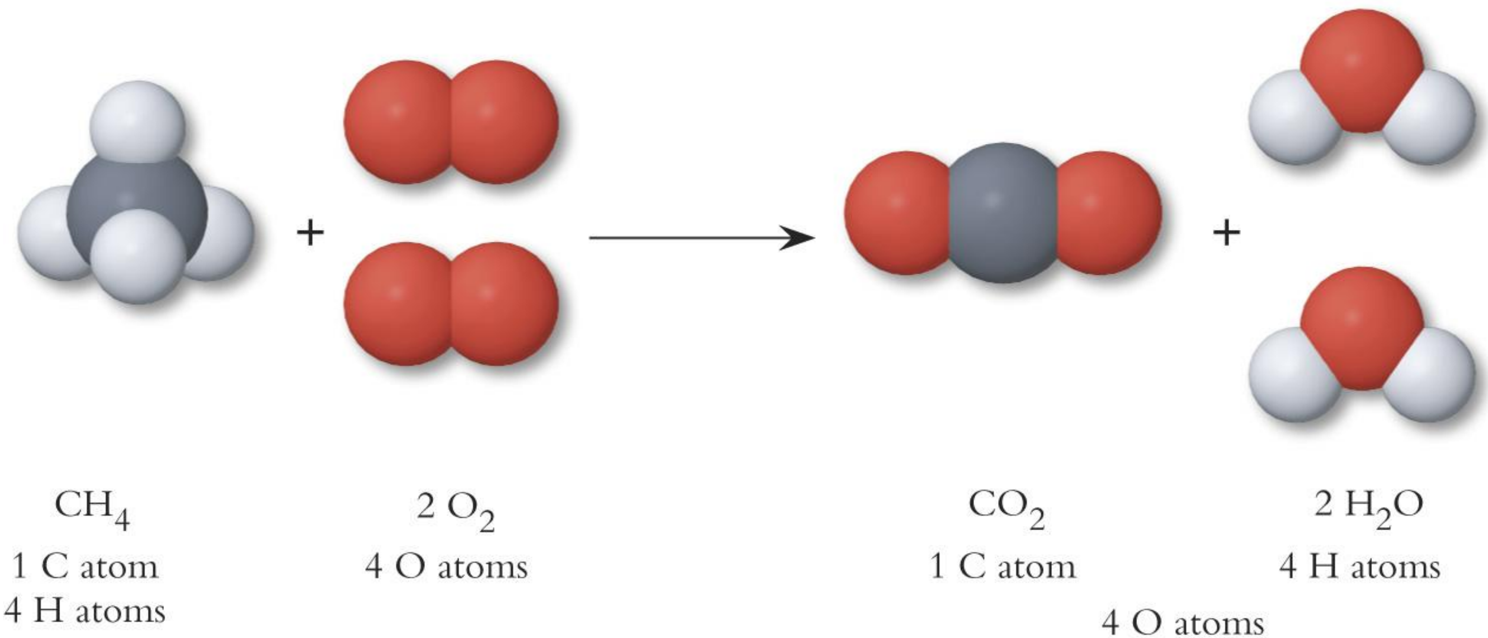
	Cmpd I	Cmpd II
in 100 g of each Compound: m(O) =	53.32 g	& 69.55 g
m(N) =	46.68 g	& 30.45 g
m(O) /m(N) =	1.142	& 2.284

$$\boxed{\frac{\text{Cmpd II } 2.284}{\text{Cmpd I } 1.142} = \frac{2}{1}}$$

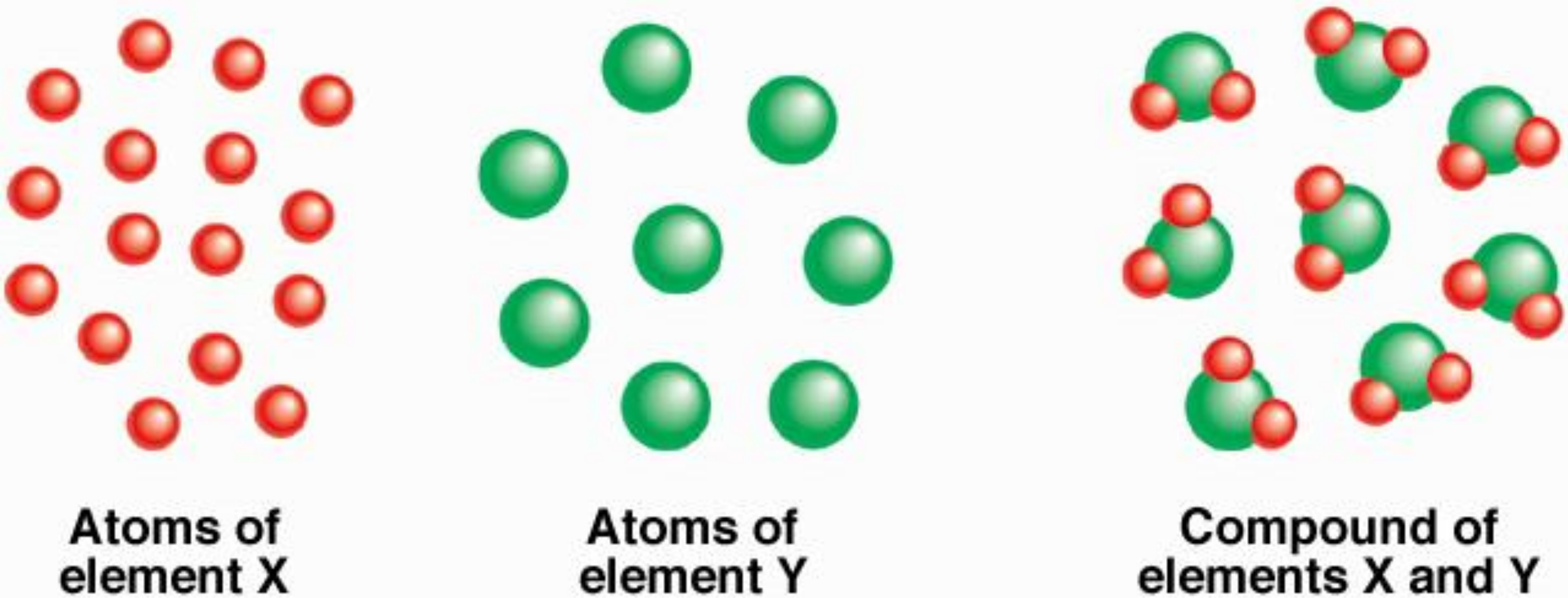
Dalton's Atomic Theory:

Law of Conservation of Mass

- **Atoms are neither created nor destroyed during physical or chemical processes**



Dalton's Atomic Theory



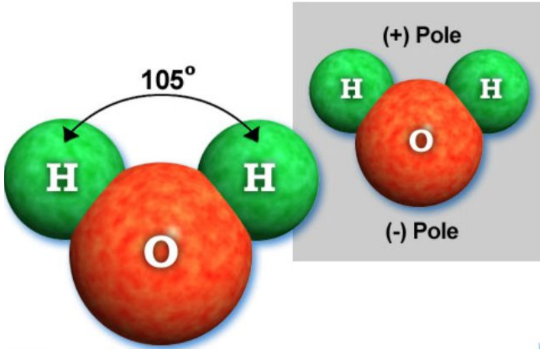
$$16\,X + 8\,Y \longrightarrow 8\,X_2Y$$

Law of Conservation of Mass

Dalton's Atomic Theory:

Law of Constant Composition

- **All samples of a compound have the same composition—the same proportions by mass of the constituent elements**.
- ***Example:*** Water is made up of two atoms of hydrogen (H) for every atom of oxygen (O), with chemical formula H_2O.

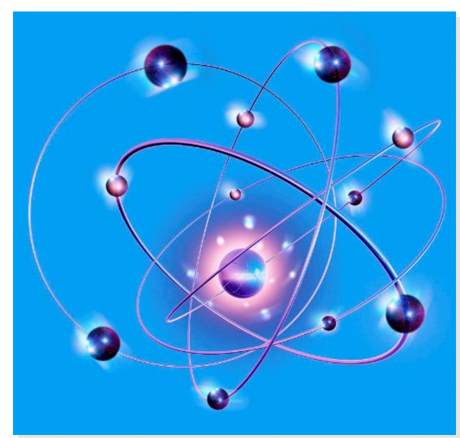


Sample A and Its Composition		Sample B and Its Composition	
10.000 g		27.000 g	
1.119 g H	% H = 11.19	3.021 g H	% H = 11.19
8.881 g O	% O = 88.81	23.979 g O	% O = 88.81

BUT!!! **Atoms** are still **DIVISIBLE**!!!

There are sub-atomic particles!

- Atom is made up of smaller parts, which can only be detected in experiments with special instruments.



The Discovery of Atomic Structure

J. J. Thomson's cathode rays experiment

- In 1897, J. J. Thomson did an experiment to **confirm the presence of the tiny negative particles – electrons**.
- **Thomson experiment** (1906 Nobel Prize in Physics)

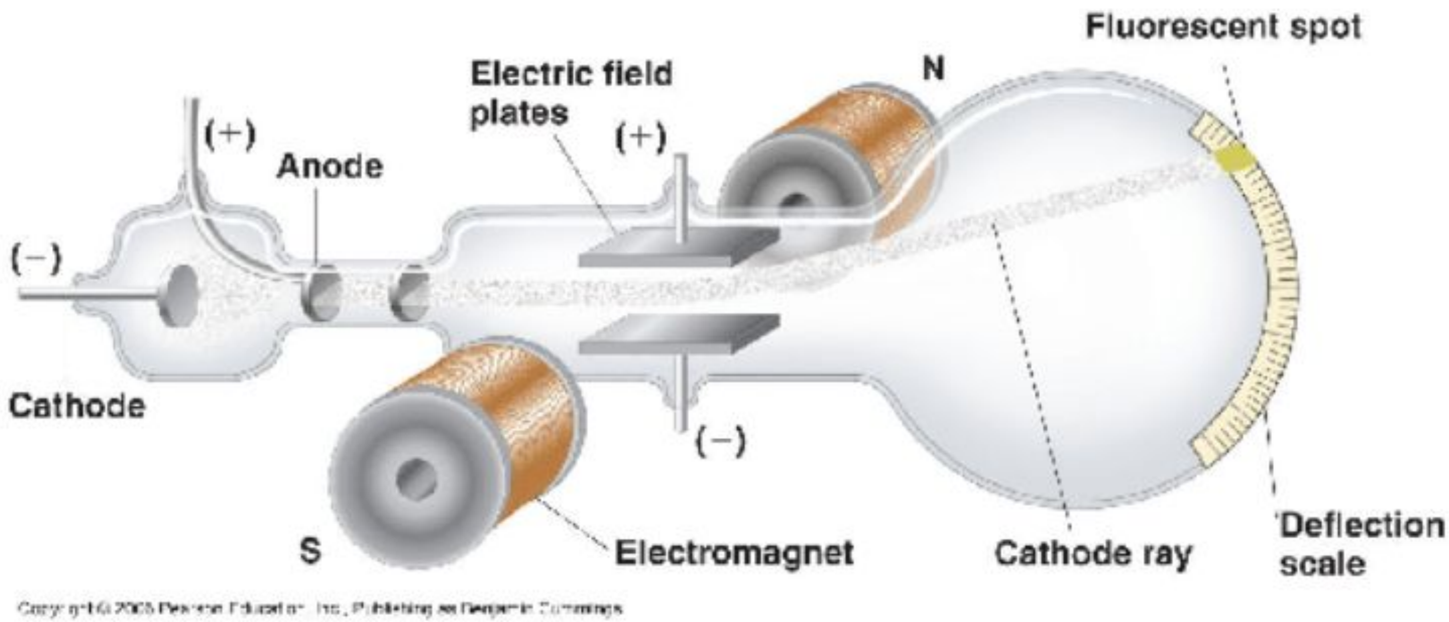


Figure 1: Schematic of J.J. Thomson's experiment.

The Discovery of Atomic Structure

J. J. Thomson's cathode rays experiment

- ***CRT***, the abbreviation for cathode-ray tube, is a hollow vessel with an electrode at either end. A high voltage is applied across the electrodes.
- The cathode rays produced in the CRT are invisible, and they can be detected only by the light emitted by materials that they strike.

The Discovery of Atomic Structure

J. J. Thomson's cathode rays experiment

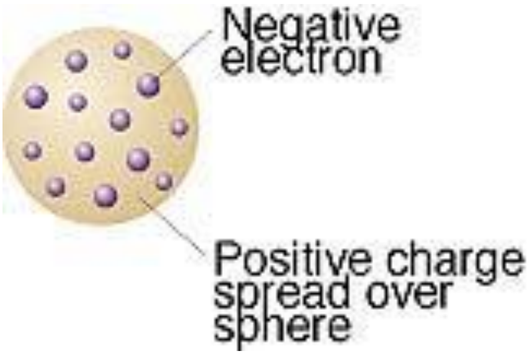
- When **gases are subjected to very high voltages at very low gas pressure, they ‘break down’ and conduct electricity**.
- **The voltage causes negative particles to move from the negative electrode to the positive electrode – cathode rays are produced**.
- Although the rays themselves could not be seen, their movement could be detected only by the light emitted by materials.

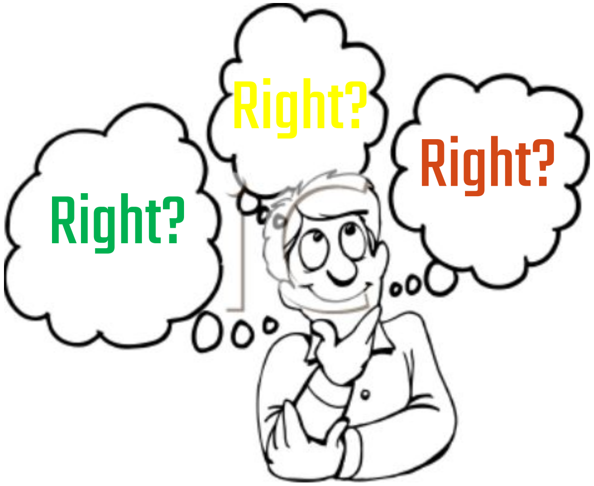
The Discovery of Atomic Structure

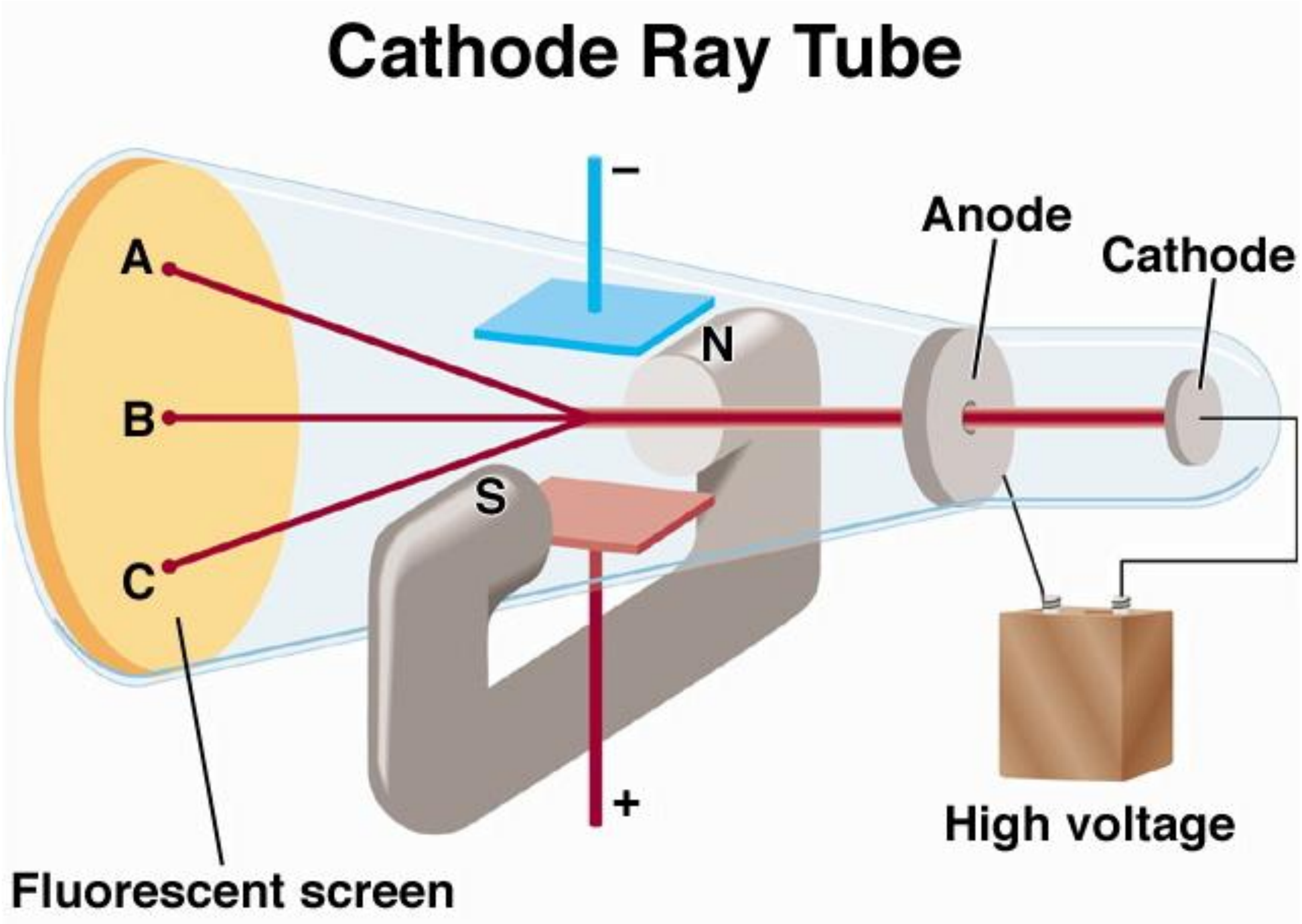
J. J. Thomson's cathode rays experiment

- **Conclusion:**

The atom consists of *positively and negatively charged entities*. However, Thomson did not know how the electrons in an atom were arranged. He proposed that the atom was a sphere of positively charged material. Spread throughout the atom were the negatively charged electrons.



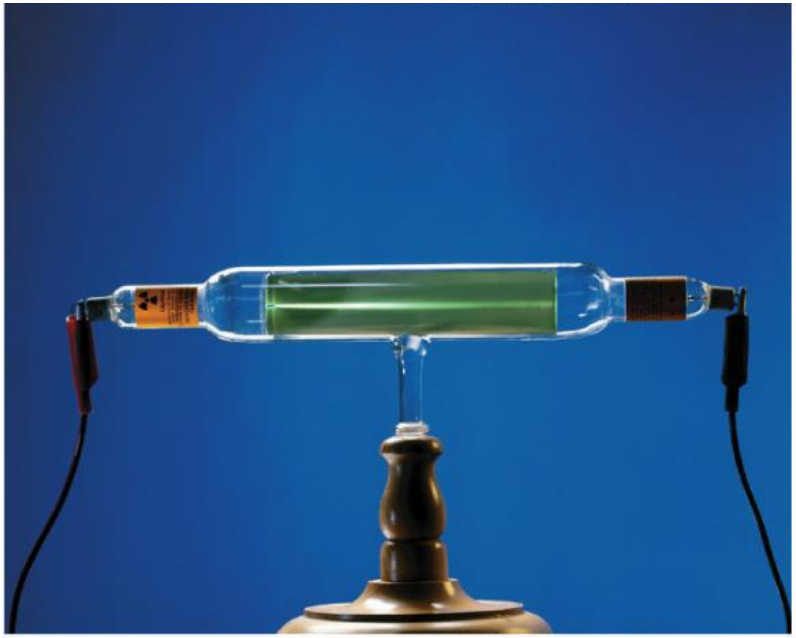


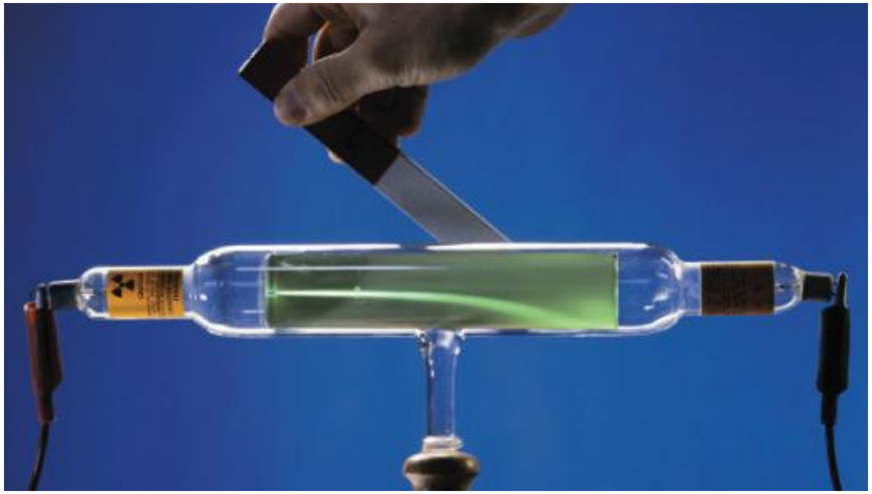


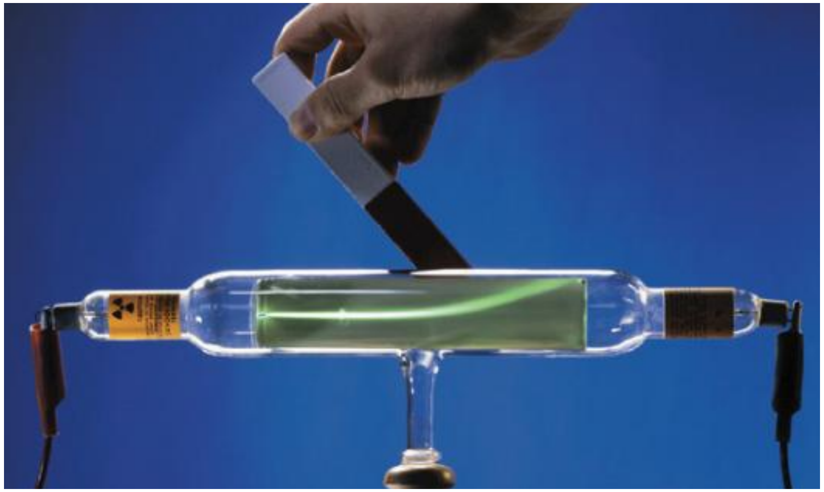
J.J. Thomson, measured mass/charge of e^-

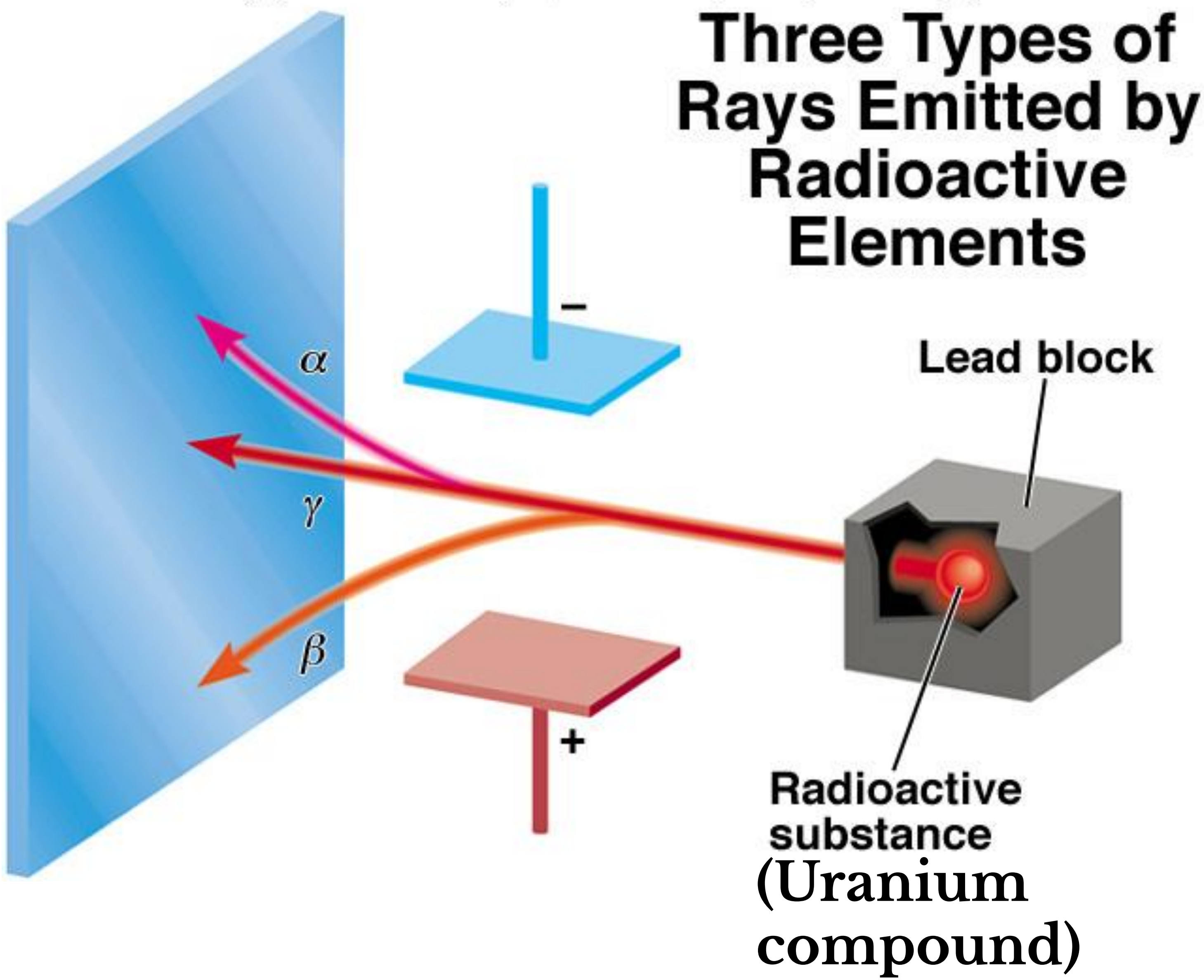
(1906 Nobel Prize in Physics)

Cathode Ray Tube





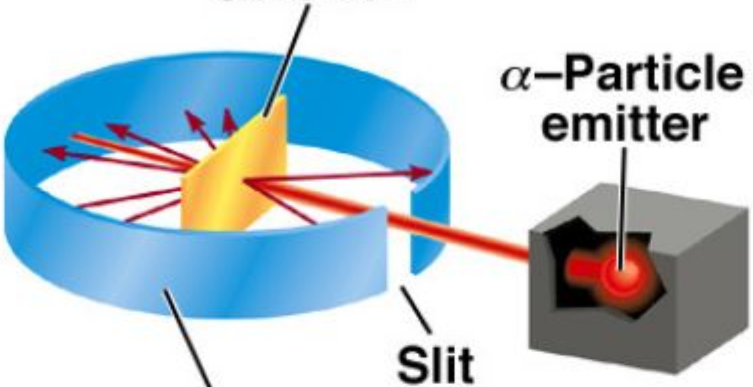


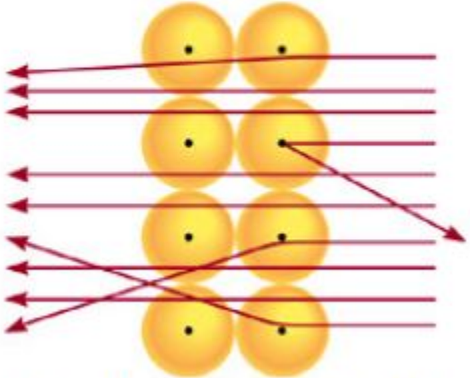

Three Types of Rays Emitted by Radioactive Elements
α
γ
β
−
+
Lead block
Radioactive substance
(Uranium compound)

The Discovery of Atomic Structure

Rutherford's Gold Foil Experiment

- 1908 Nobel Prize in Chemistry





α particle velocity ~ 1.4 x 10^7 m/s
(~5% speed of light)

The Discovery of Atomic Structure

Rutherford's Gold Foil Experiment

- When very thin foils of gold are bombarded with α particles, following ***phenomena*** is observed :
  - The ***majority*** of particles penetrated the foil ***undeflected***.
  - ***Some*** particles experienced ***slight deflections***.
  - ***A few*** (about 1 in every 20,000) suffered rather ***serious deflections*** as they penetrated the foil.
  - A similar number did not pass through the foil at all, but ***bounced back*** in the direction from which they had come.

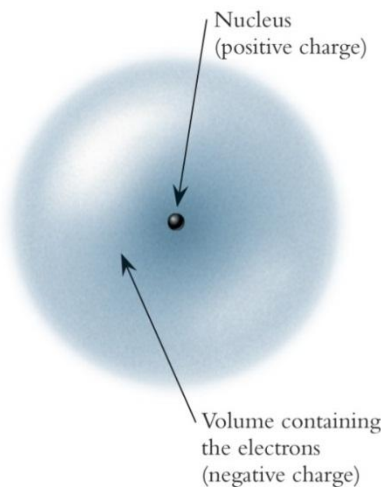
The Discovery of Atomic Structure

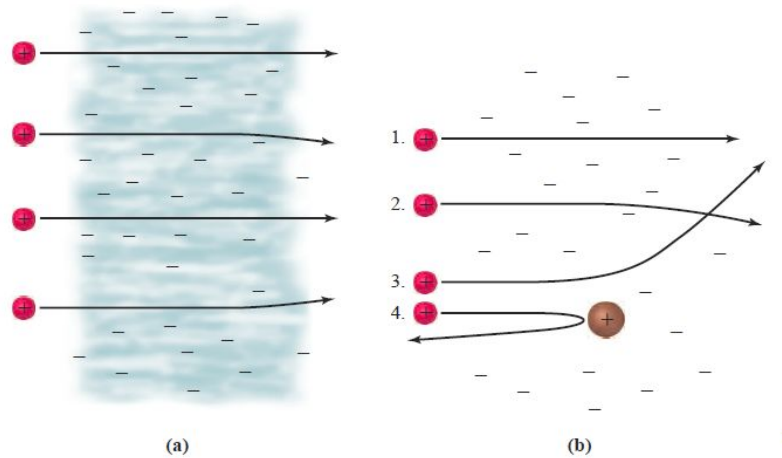
Rutherford's Gold Foil Experiment

- **Rutherford's explanation:**
  - Most of the mass and all of the positive charge of an atom are centered in a very small region called the ***nucleus***. The remainder of the atom is mostly ***empty space***.
  - The magnitude of the positive charge is different for different atoms and is approximately one-half the atomic weight of the element.
  - There are as many electrons outside the nucleus as there are units of positive charge on the nucleus. The atom as a whole is electrically neutral.

The Discovery of Atomic Structure

Rutherford's Gold Foil Experiment

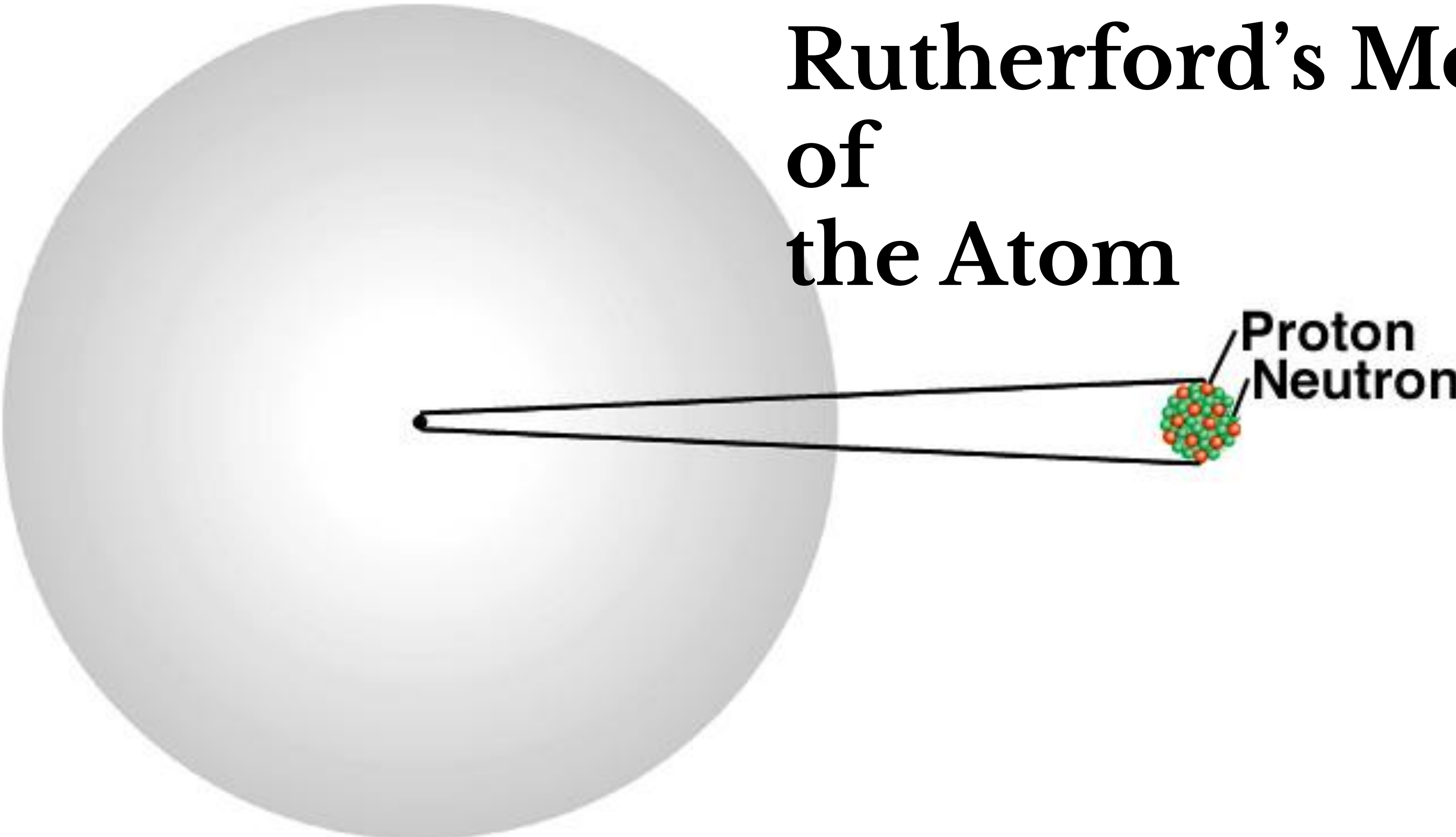




1. undeflected straight-line paths exhibited by most of the particles
2. slight deflections of particles passing close to electrons
3. severe deflections of particles passing close to a nucleus
4. reflections from the foil of a particles approaching a nucleus head-on

http://www.youtube.com/watch?v=NlDPPANIZXM

Rutherford's Model of the Atom



atomic radius ~ 100 pm = 1×10^{-10} m

nuclear radius ~ 5×10^{-3} pm = 5×10^{-15} m

The Discovery of Atomic Structure

Chadwick's Experiment (1932)

- 1935 Noble Prize in Physics

  H atoms - 1 p; He atoms - 2 p

  mass He/mass H should = 2

  measured mass He/mass H = 4 !!! (Why?)

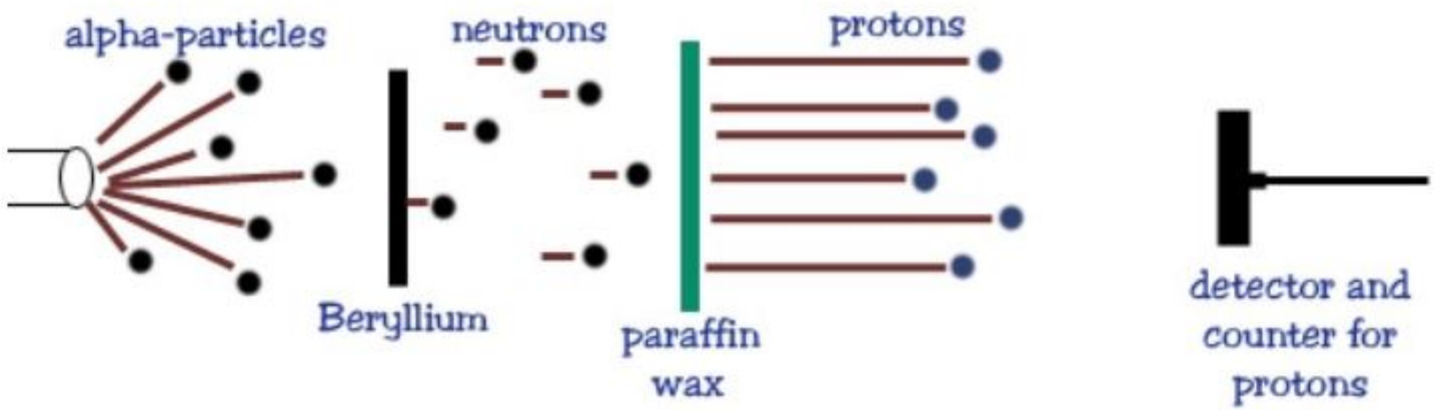
- Discovery of ***neutron*** !!!

  neutron (n) is neutral (charge = 0)

  n mass ~ p mass = 1.67×10^{-24} g

The Discovery of Atomic Structure

Chadwick's Experiment (1932)



$$\alpha + {}^{9}\mathrm{Be} \longrightarrow {}^{1}\mathrm{n} + {}^{12}\mathrm{C} + \text{energy}$$

Alpha particles are projected towards beryllium target. The emitted particles are allowed to fall on paraffin wax, which in turn releases another type of particles (protons). From the energy calculations, Chadwick showed that the particles released from beryllium are uncharged and have the same mass as protons. He called them ***neutrons***.

Summary

- **The atom consists *protons*, *electrons*, and *neutrons*.**
- Protons and neutrons are located in the nucleus of the atom, which is small. **Most of the mass of the atom is due to the nucleus.** (There can be a variable number of neutrons for the same number of protons. Isotopes have the same number of protons but different numbers of neutrons.)
- Electrons are located outside of the nucleus. Most of the volume of the atom is due to electrons.

Atomic building blocks

TABLE 2.1 Mass and Charge of Subatomic Particles

		Charge	
Particle	**Mass (g)**	**Coulomb**	**Charge Unit**
Electron*	9.10939×10^{-28}	-1.6022×10^{-19}	-1
Proton	1.67262×10^{-24}	$+1.6022 \times 10^{-19}$	$+1$
Neutron	1.67493×10^{-24}	0	0

*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

$$\boxed{\text{mass p} = \text{mass n} = 1840 \times \text{mass } e^-}$$

Notes: Mass of electron is very small relative to proton and neutron.
Proton and neutron have nearly same mass, neutron is heavier.
Electron and proton have the same charge, but opposite sign.