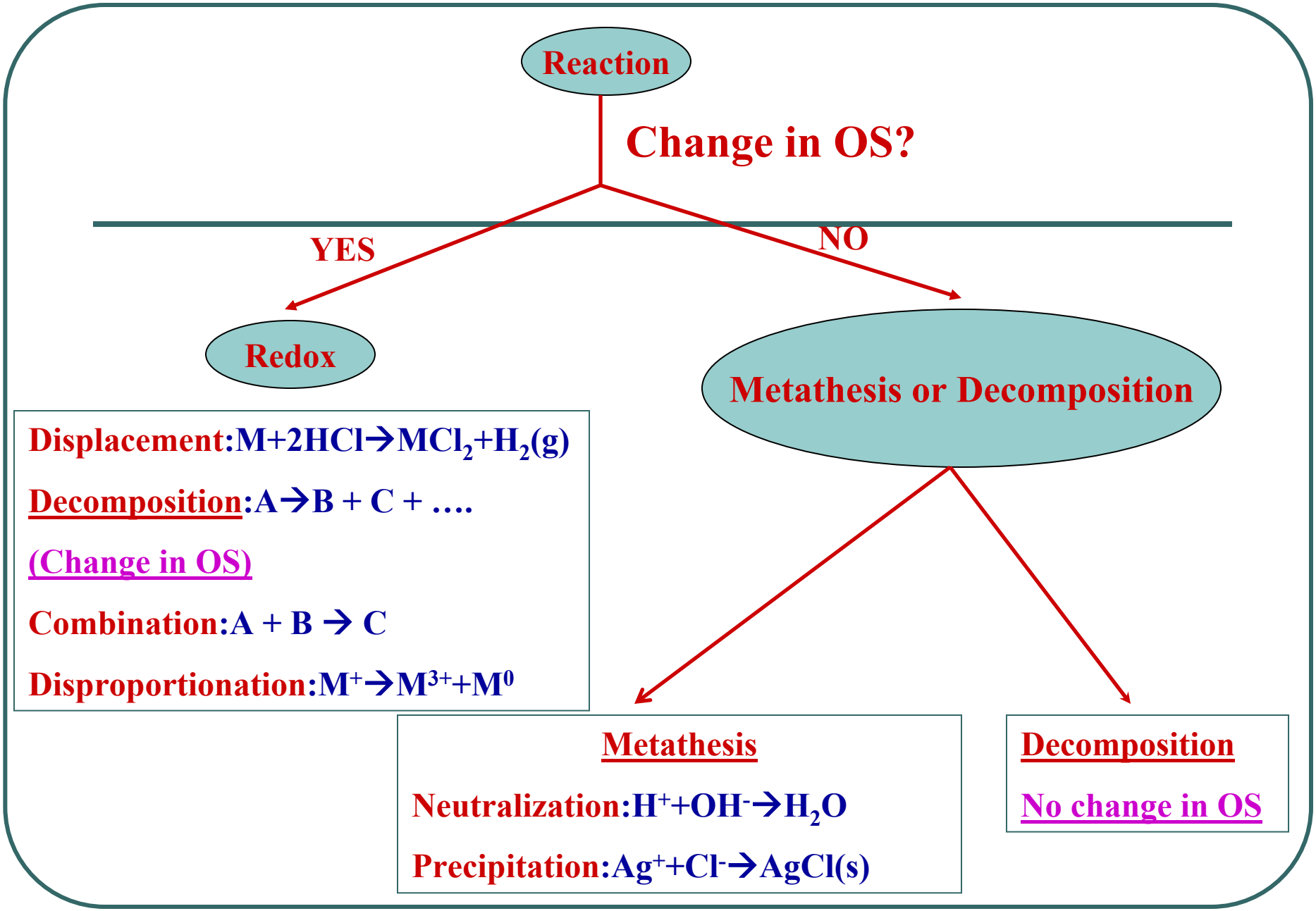
Classifying Chemical Reactions

- Oxidation-Reduction Reactions
- Combination Reactions
- Decomposition Reactions
- Displacement Reactions
- Metathesis Reactions
- Acid-Base (neutralization) Reactions
- Precipitation reactions


Reaction
Change in OS?
YES
NO
Redox
Metathesis or Decomposition
Displacement:M+2HCl→MCl2+H2(g)
Decomposition:A→B + C + ….
(Change in OS)
Combination:A + B → C
Disproportionation:M+→M3++M0
Metathesis
Neutralization:H++OH-→H2O
Precipitation:Ag++Cl-→AgCl(s)
Decomposition
No change in OS

Oxidation-Reduction Reactions

- Oxidation is an increase in the oxidation number.
  - Corresponds to the loss of electrons.
- Reduction is a decrease in the oxidation number.
  - Corresponds to the gain of electrons

Oxidation-Reduction Reactions

- Oxidizing agents are chemical species that:
  1. oxidize some other substance
  2. contain atoms that are reduced
  3. gain electrons
- Reducing agents are chemical species that:
  1. reduce some other substance
  2. contain atoms that are oxidized
  3. lose electrons

Combination Reactions

- **Combination reactions** occur when two or more substances combine to form a compound.
- There are three basic types of combination reactions.
  1. Two elements react to form a new compound
  2. An element and a compound react to form one new compound
  3. Two compounds react to form one compound

Combination Reactions

1. Element + Element → Compound
   - A. Metal + Nonmetal → Binary Ionic Compound

$$2\,Na_{(s)} + Cl_{2(g)} \rightarrow 2\,NaCl_{(s)}$$

$$2\,Mg_{(s)} + O_{2(g)} \rightarrow 2\,MgO_{(s)}$$

   - B. Nonmetal + Nonmetal → Covalent Binary Compound

$$P_{4(s)} + 5\,O_{2(g)} \rightarrow P_4O_{10(s)}$$

$$P_{4(s)} + 6\,Cl_{2(g)} \rightarrow 4\,PCl_{3(\ell)}$$

Combination Reactions

2. Compound + Element $\rightarrow$ Compound

$$AsCl_{3(s)} + Cl_{2(g)} \rightarrow AsCl_{5(s)}$$

$$SF_{4(s)} + F_{2(g)} \rightarrow SF_{6(g)}$$

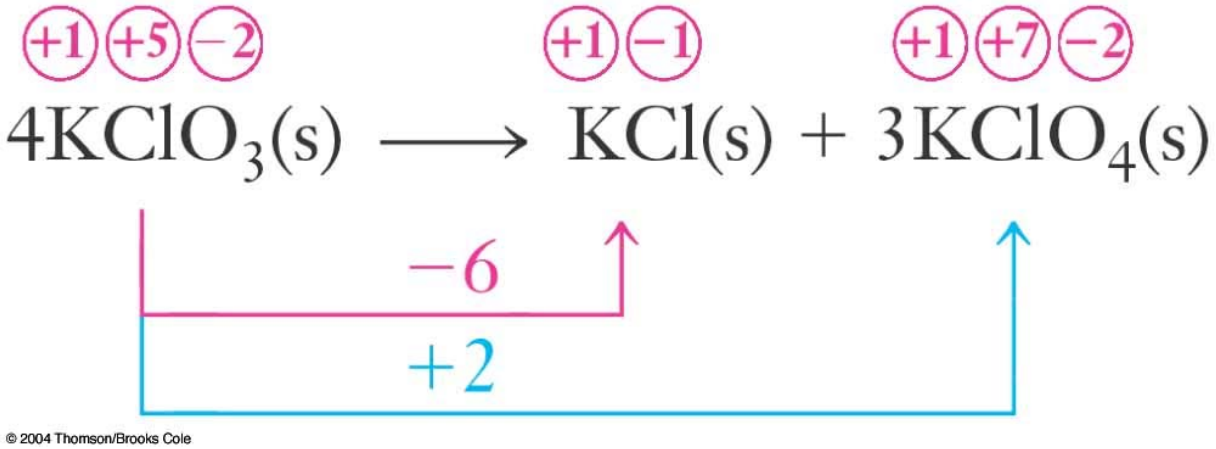
3. Compound + Compound $\rightarrow$ Compound

$$Li_2O + SO_2 \rightarrow Li_2SO_3$$

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

Disproportionation Reactions

Is a redox reaction in which the same element is oxidized and reduced.



Decomposition Reactions

- **Decomposition reactions** occur when one compound decomposes to form:
  1. Two elements
  2. One or more elements and one or more compounds
  3. Two or more compounds

Decomposition Reactions

1. Compound → Element + Element

$$2\,N_2O_{(g)} \xrightarrow{\Delta} 2\,N_{2(g)} + O_{2(g)}$$

2. Compound → Element + Compound(s)

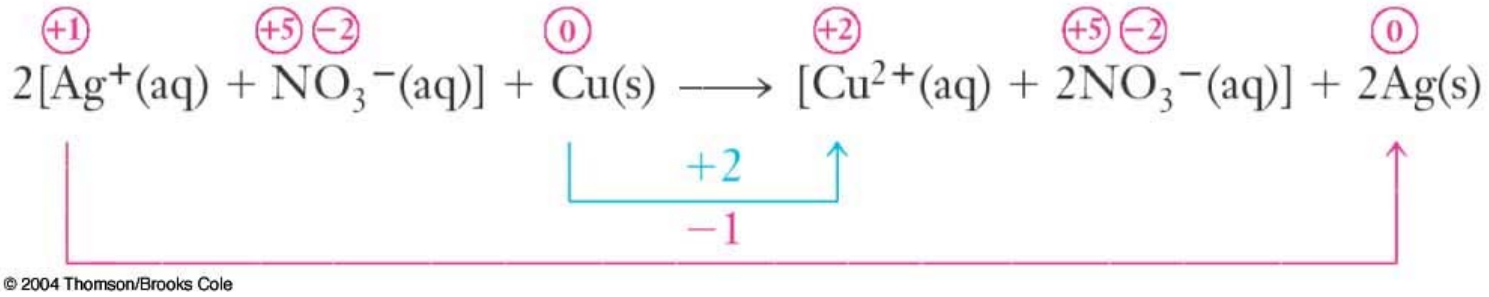
$$2\,H_2O_{2(aq)} \xrightarrow{h\nu \text{ or } Fe^{3+} \text{ or } Mn} 2\,H_2O_{(\ell)} + O_{2(g)}$$

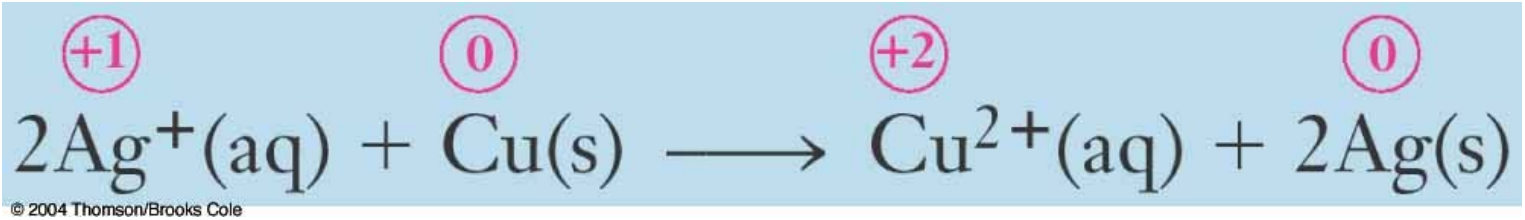
3. Compound → Compounds

$$NH_4HCO_{3(s)} \xrightarrow{\Delta} NH_{3(g)} + H_2O_{(g)} + CO_{2(g)}$$

Displacement Reactions

- **Displacement reactions** occur when one element displaces another element from a compound.





Displacement Reactions

- The following metals are active enough to displace hydrogen
  - K, Ca, Na, Mg, Al, Zn, Fe, Sn, & Pb

$$2\,Al_{(s)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 3\,H_{2(g)}$$

Displacement Reactions

- Each halogen will displace less active (heavier) halogens from their binary salts; that is, the order of decreasing activities is

$$F_2 > Cl_2 > Br_2 > I_2$$

$$Cl_{2(g)} + 2\ NaI_{(aq)} \rightarrow I_{2(s)} + 2\ NaCl_{(aq)}$$

Metathesis Reactions

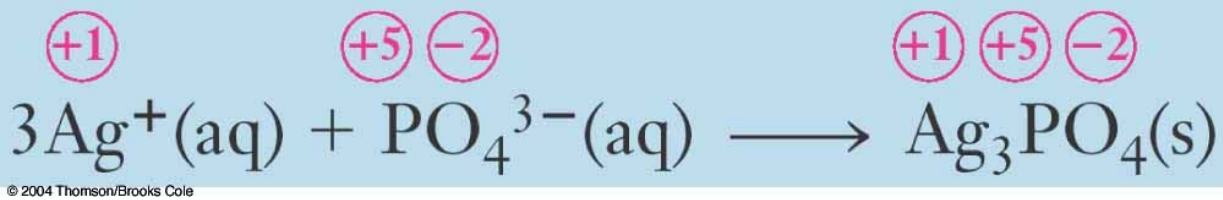
- **Metathesis reactions** occur when two ionic aqueous solutions are mixed and the ions switch partners.

$$AX + BY \rightarrow AY + BX$$

- Metathesis reactions remove ions from solution in two ways:
  1. form unionized molecules like H_2O
  2. form an insoluble solid
- Ion removal is the driving force of metathesis reactions.

Metathesis Reactions

1. **Acid-Base (neutralization) Reactions**
   - Formation of the nonelectrolyte H_2O
   - acid + base $\rightarrow$ salt + water
   - HCl + NaOH → NaCl + H_2O
2. **Precipitation reactions** are metathesis reactions in which an insoluble compound is formed.



c 115. Which of the following is a reduction-oxidation (redox) reaction?

$FeCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl(s) + Fe(NO_3)_2(aq)$

$AgNO_3(aq) + NaBr(aq) \rightarrow AgBr(s) + NaNO_3(aq)$

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$

$3HCl(aq) + Cr(OH)_3(s) \rightarrow CrCl_3(aq) + 3H_2O(l)$

b 85. Which of the following reactions is a combination reaction?

(a) $AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$

(b) $Na_2O(s) + CO_2(g) \rightarrow Na_2CO_3(s)$

(c) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

(d) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

(e) $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

Chapter 5
The Structure of Atoms

Outline

1. Fundamental Particles
2. The Discovery of Electrons
3. Canal Rays and Protons
4. Rutherford and the Nuclear Atom
5. Atomic Number
6. Neutrons
7. Mass Number and Isotopes
8. Mass spectrometry and Isotopic Abundance

Chapter Goals

9. The Atomic Weight Scale and Atomic Weights
10. Electromagnetic radiation
11. The Photoelectric Effect
12. Atomic Spectra and the Bohr Atom
13. The Wave Nature of the Electron
14. The Quantum Mechanical Picture of the Atom

Chapter Goals

15. Quantum Numbers
16. Atomic Orbitals
17. Electron Configurations
18. Paramagnetism and Diamagnetism
19. The Periodic Table and e Configurations

Reading Assignment

Please read 1-4.

Fundamental Particles

- Three fundamental particles make up atoms. The following table lists these particles together with their masses and their charges.

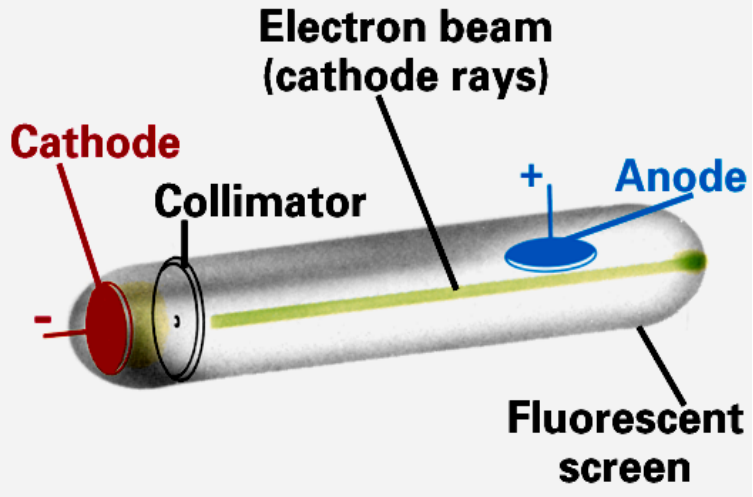
Particle	Mass (amu)	Charge
Electron (e^-)	0.00054858	-1
Proton (p, p^+)	1.0073	+1
Neutron (n, n^0)	1.0087	0

The Discovery of Electrons

- Humphrey Davy in the early 1800's passed electricity through compounds and noted:
  - that the compounds decomposed into elements.
  - Concluded that compounds are held together by electrical forces.
- Michael Faraday in 1832-1833 realized that the amount of reaction that occurs during electrolysis is proportional to the electrical current passed through the compounds.

The Discovery of Electrons

- Cathode Ray Tubes experiments performed in the late 1800's & early 1900's.
  - Consist of two electrodes sealed in a glass tube containing a gas at very low pressure.
  - When a voltage is applied to the cathodes a glow discharge is emitted.

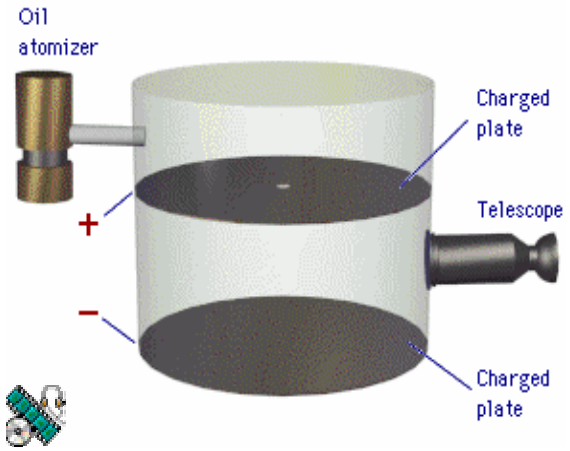


The Discovery of Electrons

- These “rays” are emitted from cathode (- end) and travel to anode (+ end).
  - Cathode Rays must be negatively charged!
- J.J. Thomson modified the cathode ray tube experiments in 1897 by adding two adjustable voltage electrodes.
  - Studied the amount that the cathode ray beam was deflected by additional electric field.

The Discovery of Electrons

- Robert A. Millikan won the 1st American Nobel Prize in 1923 for his famous oil-drop experiment.
- In 1909 Millikan determined the charge and mass of the electron.

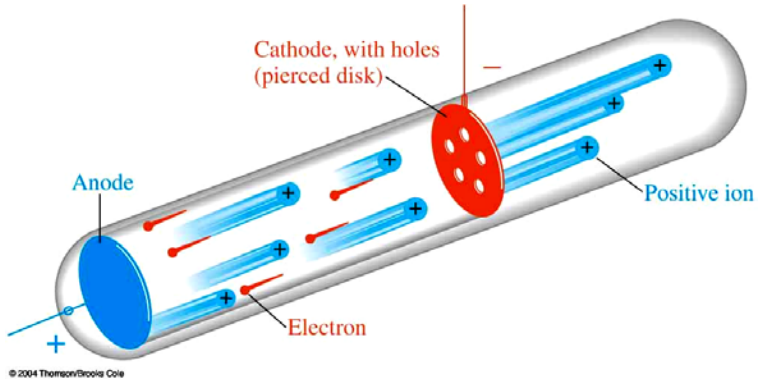


The Discovery of Electrons

- Millikan determined that the charge on a single electron = -1.60218×10^{-19} coulomb.
- Using Thomson's charge to mass ratio we get that the mass of one electron is 9.11×10^{-28} g.
  - e/m = -1.75881×10^{8} coulomb
  - e = -1.60218×10^{-19} coulomb
  - Thus m = 9.10940×10^{-28} g

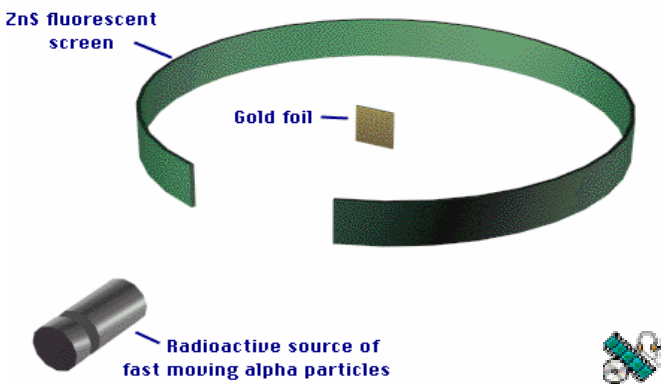
Canal Rays and Protons

- Eugene Goldstein noted streams of positively charged particles in cathode rays in 1886.
  - Particles move in opposite direction of cathode rays.
  - Called “Canal Rays” because they passed through holes (channels or canals) drilled through the negative electrode.
- Canal rays must be positive.
  - Goldstein postulated the existence of a positive fundamental particle called the “proton”.



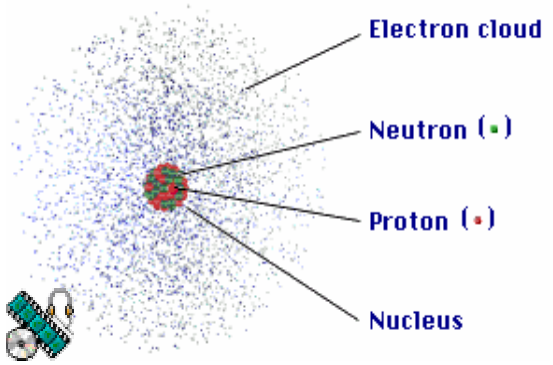
Rutherford and the Nuclear Atom

- Ernest Rutherford directed Hans Geiger and Ernst Marsden's experiment in 1910.
  - α- particle scattering from thin Au foils
  - Gave us the basic picture of the atom's structure.



Rutherford and the Nuclear Atom

- In 1912 Rutherford decoded the α-particle scattering information.
  - Explanation involved a nuclear atom with electrons surrounding the nucleus .



Rutherford and the Nuclear Atom

- Rutherford's major conclusions from the α-particle scattering experiment
  1. The atom is mostly empty space.
  2. It contains a very small, dense center called the nucleus.
  3. Nearly all of the atom's mass is in the nucleus.
  4. The nuclear diameter is 1/10,000 to 1/100,000 times less than atom's radius.

Rutherford and the Nuclear Atom

- Because the atom's mass is contained in such a small volume:
  - The nuclear density is 10^{15}g/mL.
  - This is equivalent to 3.72 x 10^{9} tons/in^{3}.
  - Density inside the nucleus is almost the same as a neutron star's density.