CHAPTER 2: Atoms, Molecules, and Ions

2.1 Dalton's Atomic Theory

Greeks (400 BC)
Aristotle - earth (cold, dry), air (wet, hot), fire (hot, dry), water (wet, cold)
Democritus - atomos
2000 years of alchemy and medicine based on Aristotelian theories

Dalton's Atomic Theory

1. Elements are made up of indivisible particles called atoms.
2. Atoms of the same element are identical, and atoms of different elements are different.
3. Atoms combine to form compounds in fixed integer ratios.
4. In chemical reactions, the atoms do not change.

Antoine Lavoisier, father of modern chemistry - proved combustion involved combination with oxygen. Proposed Law of Conservation of Mass - mass is neither created nor destroyed.

Joseph Proust - Law of Constant Composition - a compound always contains the same elements in the same proportion by mass.

John Dalton - Law of Multiple Proportions - when two elements combine to form more than one compound, the ratios of the masses of the second element that combine with 1 gram of the first element can always be reduced to small whole numbers.

Ferrous Chloride, 44.06% Fe, 55.94% Cl and Ferric Chloride 34.43% Fe, 65.57% Cl

$$\text{g Cl/1 g Fe} = \frac{55.94 \text{ g Cl}}{44.06 \text{ g Fe}} = 1.2696 \qquad \text{g Cl/1 g Fe} = \frac{65.57 \text{ g Cl}}{34.43 \text{ g Fe}} = 1.9044$$

$$\text{ratio of masses} = \frac{1.9044}{1.2696} = \frac{1.5}{1} = \frac{3}{2}$$

water, 11.11% H, 88.89% O and hydrogen peroxide, 5.88% H, 94.12%O

$$\text{g O/1 g H} = \frac{88.89 \text{ g O}}{11.11 \text{ g H}} = 8.00 \qquad \text{g O/1 g H} = \frac{94.12 \text{ g O}}{5.88 \text{ g H}} = 16.00$$

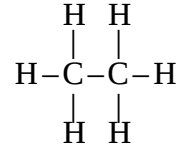
$$\text{ratio of masses} = \frac{16.000}{8.00} = \frac{2}{1}$$

Molecules

Molecule - cluster of 2 or more atoms held together by covalent bonds
Covalent bond - chemical bond caused by sharing electrons

The atoms can be the same O_2 or different H_2O

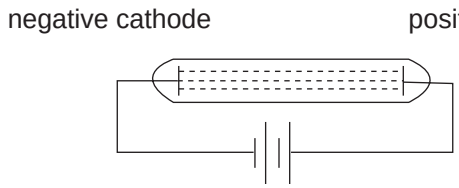
formulas: structural formula



molecular formula	C_2H_6
empirical formula	CH_3

CH_3CH_2OH and CH_3OCH_3 have the same molecular formula but different structural formulas. Sometimes condensed structural formulas are used.

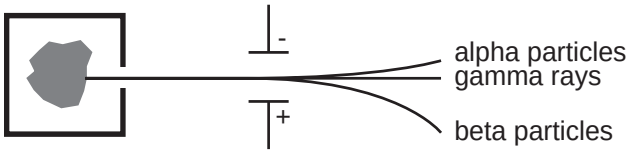
2.2 Structure of Atoms



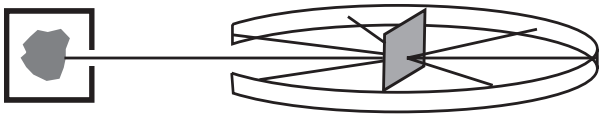
J.J. Thompson 1898-1903 - discovers electron - cathode ray tube.
Determined e/m = -1.76×10^{8} coulomb/g

Robert Millikan 1909 - oil drop experiment determined e = -1.60×10^{-19} coulombs, therefore m = 9.11×10^{-31} kg

Plum pudding model - atoms are positive stuff with negative electrons scattered throughout



β particles are high energy electrons
α particles are 7300 times the mass and have +2 charge relative to an electron
γ rays are high-energy electromagnetic radiation



Ernest Rutherford used α particles to probe the atom. He determined that most of the mas was concentrated in a nucleus 1/10,000 - 1/100,000 the diameter of the atom.

Nuclei are made up of protons and neutrons. The nucleus contains most of the mass and all of the positive charge of the atom. Electrons surround the nucleus and make up the volume of the atom.

particle	mass, kg	mass, amu	mass number	charge, coul.	relative charge
electron	9.11×10^{-31}	5.47×10^{-4}	0	-1.60×10^{-19}	-1
proton	1.67×10^{-27}	1.0073	1	$+1.60 \times 10^{-19}$	+1
neutron	1.67×10^{-27}	1.0087	1	0	0

James Chadwick discovered the neutron; Mosely discovered atomic numbers.
Atomic Number (Z) - number of protons. Determines the chemical identity of the atom.
Mass Number (A) - total number of protons and neutrons in nucleus.

Isotopes - elements of the same atom with different mass numbers.
mass number→ A
atomic number→ Z X ← symbol

examples: $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$ $^{12}_{6}C$, $^{13}_{6}C$, $^{14}_{6}C$

$^{17}_{8}O^{2-}$ has 8 protons, 9 neutrons and 10 electrons

2.3 Ionic Compounds

Ion - atom or cluster of atoms with charge
Cation - ion with positive charge (lost electrons)
Anion - ion with negative charge (extra electrons)

$Na \rightarrow Na^{+} + e^{-}$

$Cl + e^{-} \rightarrow Cl^{-}$

$Na^{+} + Cl^{-} \rightarrow NaCl$

Ionic bond - chemical bond caused by electrostatic attraction between oppositely charged ions

Ionic compounds have high melting points but melt to form conductive liquids. Molecular compounds usually have low melting points and are nonconductive

2.4 Chemical Nomenclature

Binary ionic compounds - monatomic cation, monatomic anion
1. cation named first, anion second
2. monatomic cation named same as metal
3. monatomic anion named by changing ending to -ide

for group 1 and 2 metals, charge is equal to the group number
for transition metals and some post-transition metals, more than one ion can form, i.e., Fe^{2+} and Fe^{3+}. These cations are named iron (II) and iron (III)
$FeCl_2$ is iron (II) chloride, $FeCl_3$ is iron (III) chloride

for nonmetals, charge is 8 - group number (or 18 - group number)

NaCl, MgO, K_2S, CaI_2

Polyatomic ions - pg. 65 NH_4^{+}, NO_3^{-}, SO_4^{-}, OH^{-}, CN^{-}, PO_4^{-}, CO_3^{-2}, ClO_3^{-}

Binary covalent compounds
1. more metallic element named first
2. second element named changing ending to -ide
3. numeric prefixes used; mono-, di-, tri-, tetra-, penta-, hexa-

carbon dioxide, sulfur trioxide, xenon tetrafloride, phosphorous pentachloride