Chapter 2. Atoms, Molecules, and Ions.

2.1. The Atomic Theory of Matter

- Greek philosophers; Can matter be subdivided into fundamental particles?
- Democritus (460-370 BC); All matter can be divided into indivisible atomos.
- Dalton (1808): Proposed atomic theory with the following postulates;
    - Elements are composed of atoms
    - All atoms of an element are identical
    - In chemical reactions atoms are not changed into different types of atoms. Atoms can neither be created nor destroyed.
    - Compounds are formed when atoms of element combine.

Atoms are the building blocks of matter.

Law of constant composition: the relative kinds and numbers of atoms are constant for a given compound.

Law of conservation of mass (matter): During a chemical reaction, the total mass before reaction is equal to the total mass after reaction.

For example: Metabolism of sugar

180 g glucose + 192 g oxygen gas ⟶ 264 g carbon dioxide + 108 g water

372 g material before change ⟶ 372 g material after change

Conservation means something can neither be created nor destroyed. It can be applied to both matter and energy.

Law of multiple proportions: if two elements A and B combine to form more than one compound, then the mass of B which combines with the mass A is a ratio of small whole number.

2.2. The Discovery of Atomic Structure

- By 1850 scientists knew that atoms consisted of charged particles
- Subatomic particles: those particles that make up the atom.

- Recall: The law of electrostatic attraction: like charges repel and opposite charges attract.

2.3. The Modern View of Atomic Structure

The atom consists of three fundamental subatomic particles, both electrically charged or uncharged. The particles are:

a) Protons (P+) positively charged
b) negative and neutral entities
c) negative and neutral entities (protons, electrons and neutrons).

The quantity 1.602 x 10^{-19} C is called electronic charge.

Masses are so small that we define the ***atomic mass unit***, amu.

1 amu = 1.66054 x 10^{-24} g. 1 g = 6.02214 x 10^{23} amu

The angstrom (A°) is convenient non-SI unit of length used to denote atomic dimensions

Since most atoms have radii around 1 x 10^{-10} m, we define 1 A° = 1 x 10^{-10} m.

Isotopes, Atomic Numbers, and Mass Numbers.

An atom of a specific isotope is called *nuclide.*

For example: Nuclides of hydrogen include

^{1}H = hydrogen (protium); ^{2}H = deuterium, ^{3}H = tritium; tritium is radioactive.

Radioactivity is the spontaneous emission of radiation.

Average Atomic Masses

We average the massed of isotopes to give relative atomic masses;

For example: Naturally occurring C (carbon) consists of 98.892% ^{12}C (12 amu) and 1.108 % ^{13}C (13.00335).

The average mass of C is: (0.98892)(12) + (0.01108)(13.00335) = 12.011 amu.

Atomic weight (AW) is also known as average atomic mass.

Atomic weight are listed on the periodic table.
A mass spectrometer is an instrument that allows for direct and accurate determination of atomic (and molecular) weights.

2.4. The Periodic Table

The periodic table is used to organize the elements is a meaningful way.

Metallic elements are located in the left-hand side of the periodic table. Most are metals. They tend to be malleable, ductile, and lustrous and are good thermal and electrical conductors.

Nonmetallic elements are located in the top right-hand side of the periodic table. They tend to be brittle as solids, dull in appearance, and do not conduct heat or electricity well.

Elements with properties similar to both metals and nonmetals are called *metalloids* and are located at the interface between metals and nonmetals. These include the elements B, Si, Ge, As, Sb and Te.

2.5. Molecules and Molecular Compounds

A molecule consists of two or more atoms bound together

Molecules and Chemical Formulas

Each molecule has a chemical formula.
The chemical formula indicates:

1. which atoms are found in the molecule, and
2. in what proportion they are found

A molecules made up of two atoms is called *diatomic molecule.*

Compounds composed of molecules are *molecular compounds*. These contain at least two types of atoms.

Molecular and Empirical Formulas

Molecular formulas: Give the actual numbers and types of atoms in a molecule. ***For example:*** H_2O, CO_2, CO, CH_4, H_2O_2, O_3, O_2, and C_2H_4.

Empirical formula: Give the relative number and types of atoms in a molecule (they give the lowest whole number ratio of atoms in a molecule). ***For example:*** H_2O, CO_2, CO, CH_4, HO, CH_2.

Picturing Molecules

Molecules occupy three-dimensional space.

The structural formula gives the connectivity between individual atoms in the molecule. Three models can be used

1- Perspective drawing use dashed lines and wedges to represent bonds receding and emerging from the plane of the paper
2- Ball-and-stick models show atoms as contracted spheres and the bonds as sticks. The angles are accurate.
3- Space-filling models give an accurate representation of the relative size of the atoms and the 3D shape of the molecule.

2.6. Ions and Ionic Compounds

If electrons are added to or removed from a neutral atom, an *ion* is formed

When an atom or molecule loses electrons it becomes positively charged

Positively charged ions are called *cations*. (e.g. Na^+)

When an atom or molecule gains electrons it becomes negatively charged

Negatively charged ions are called *anions*. (e.g. Cl^-)

In general, metal atoms tend to lose electrons and nonmetals atoms gain electrons.

When molecules lose electrons, *polyatomic ions* are formed (e.g.SO_4^{2-} , NO_3^-).

Predicting Ionic Charges

An atom or molecule can lose more than one electron.

Manu atoms gain or lose enough electrons to have the same number of electrons as the nearest noble gas (group 8A)

The number of electrons an atom loses is related to its position on the periodic table.

Ionic compounds

A great deal of chemistry involves the transfer of electrons between species

Example: Na^+ and Cl^- form the neutral ionic compound NaCl, Mg_3N_2 (3 Mg^{2+}, 2 N^{3-}).

Ionic compounds are named cation then anion. Calcium chloride, barium bromide.

Chemistry of life: Element Required by Living Organism.

Of the 114 elements known, only about 26 are required for life

Water accounts for more than 70% of the mass of the cell

Carbon is the most common solid constituent of cells.

The most important elements of life are H, C, N, O, P and S (red).

The most important ions are Na^+, Mg^{2+}, K^+, Ca^{2+}, and Cl^- (blue)

The other 15 elements are only needed in trace amounts (green).

2.7. Some Simple Organic Compounds.

Organic chemistry is the study of carbon-containing compounds.

Organic compounds are those that contain carbon and hydrogen, often in combination with other elements.

Alkanes are compounds containing only carbon and hydrogen, also called hydrocarbon.