CHAPTER I

FUNDAMENTAL CONCEPT

I-Introduction

the true impact of chemistry extends much farther than the products we use in daily life.

The most profound questions about health, climate change, even the origin of life, ultimately have chemical answers.

No matter what your reason for studying chemistry, this course will help you develop two mental skills. The first, common to all science courses, is the ability to solve problems systematically. The second is specific to chemistry, for as you comprehend its ideas, you begin to view a hidden reality filled with incredibly minute particles moving at fantastic speeds, colliding billions of times a second, and interacting in ways that determine how all the matter inside and outside of you behaves.

To study a course "the structure of matter", it is generally necessary to have a solid grounding in physics and a knowledge of mathematics, particularly differential and integral calculus,

A good place to begin our exploration of chemistry is to define it and a few central concepts.

Chemistry, is the study of matter and its properties, the changes that matter undergoes, and the energy associated with those changes.

Matter, is the "stuff " of the universe: air, glass, planets, students—anything that has mass and volume.

II-State and Macroscopic characteristics of states of matter

II-1-State of matter:

Matter comes in different forms called states of matter

The three states of matter are: solid, liquid and gas

Each state of matter has its own characteristics, such as:

- ✓ Solid state keeps a constant shape and volume, cannot be compressed and cannot drain.
- ✓ Liquid state takes the shape of the container, keeps the volume constant, cannot be compressed, can flow
- ✓ Gaseous state takes the shape and volume of the container, can be compressed and can flow.

Heat and cold play essential roles in the transition of a substance from one state to another depending on the temperature (T) and pressure (P):

States of Matter

Property	Solids	Liquids	Gases
Shape	Definite shape	No definite shape, takes shape of the container	No definite shape, takes shape of the container
Volume	Definite volume	Definite volume	No fixed volume
Particle Arrangement	Tightly packed Solid	Close together but can move Liquid	Far apart, can move Gas
Particle Motion	Vibrating in a fixed position	Flowing and sliding past each other	Moving rapidly and freely
Example	Ice, Wood, Stone	Water, Oil, Milk	Air, Oxygen, Nitrogen

Figure II-1: State of matter

II-2-Properties of matter

We can distinguish two properties of matter:

- *Physical properties*: a characteristic that can be observed or measured without changing the nature of matter.

Examples: mass, temperature, color

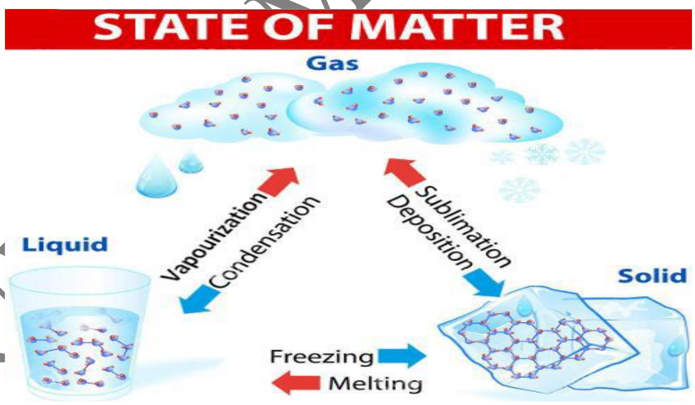

Figure II-2: Changes in the State of Matter

The physical quantities can be expressed by the 5 basic units defined by the international system (SI).

- *Chemical properties*: A chemical change is a transformation that alters the nature of a substance through a chemical reaction.

Examples:

- Corrosion: Iron rusts.
- Combustion: Wood burns to produce ash and gases.

- the reaction of zinc with hydrochloric acid gives hydrogen gas.

Chemical changes can be identified by certain indicators, such as:

- Formation of a gas;
- Formation of a precipitate;
- Change in color;
- Release of energy in the form of light and heat.

III- Notions of Atom, Molecule, Ion, Mole, and Avogadro's Number

III-1- Atom

An atom is the smallest unit of an element that can exist.

Atoms combine to form molecules.

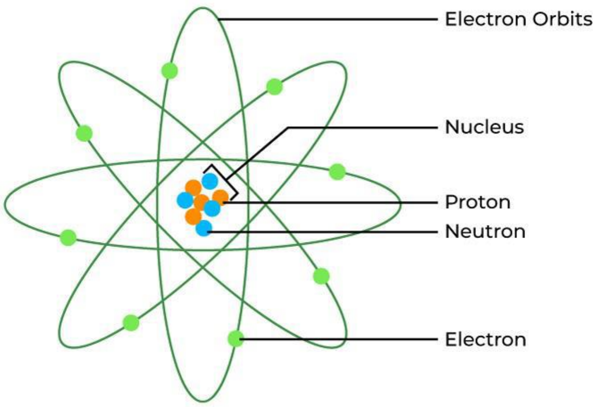

Figure III-1: Atom structure

III-2-Molecule

A molecule is the association of two or more atoms (e.g., NaCl, H_2O, O_2) bonded together by chemical bonds. It is the smallest part of a compound that retains its properties. A molecule is characterized by its molecular formula and its molecular molar mass.

Examples:

- H_2O (water);
- H_2 (hydrogen gas);
- HCl (hydrochloric acid);
- H_2SO_4 (sulfuric acid);

III-3- Ion

An ion is an atom or molecule charged positively (cation) or negatively (anion)

Examples:

- cation sodium (Na+);
- anion chloride (Cl^-);
- cation ammonium (NH_4^+)

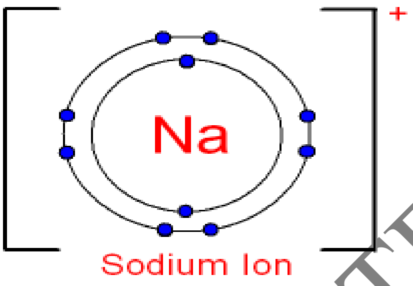

Figure III-3: Sodium ion

III-4-Mole and Avogadro's Number

The mole is a unit of measurement for the amount of substance in a system containing N identical entities. It is defined as the ratio between the mass of the sample (m), expressed in grams (g), and the molar mass (M), expressed in grams per mole (g/mol).

$$n = m / M$$

Where:

n is the number of moles.

m is the mass of the compound in grams (g).

M is the molar mass of the compound in grams per mole (g/mol).

IV-Concepts of Atomic Mass Unit, Atomic and Molecular Molar Mass, and Molar Volume

IV-1-Atomic Mass Unit (a.m.u)

The masses of particles such as electrons, protons, neutrons, etc., are not convenient to express in kilograms (Kg) due to their very small scale. Instead, a different unit of mass called the Atomic Mass Unit (a.m.u) or "u" is used.

One atomic mass unit is defined as one-twelfth the mass of a 12 C.

In other words, 1 u (AMU) is defined as 1/12th of the mass of one 12 C atom.

So: ***1amu= (1/12). 12/NA (g) = 1/ NA (g) =1.66.10^{-24} (g)* = 1.66. 10^{-27} Kg.**

IV-2- Atomic Molar Mass

Atomic molar mass is the mass of one mole of atoms.

Atomic molar mass = N_A x mass of a single atom (g/mol).

The molar mass of an element is the mass, in grams, of 6.023 x 10^{23} atoms of this element: It is the mass of 1 mol of this element

Example:

Molar mass of hydrogen (H): M(H)= $1.674.10^{-24}$g x N_A= 1.0079 g.mol^{-1};

IV-3- Molecular Molar Mass

The molecular molar mass of a molecular compound is the mass of one mole of molecules. It is equal to the sum of the molar masses of its constituent elements.

Examples:

Molar mass of CO_2: M(CO_2)= M(C) + 2.M(O)= 44 g/mol ;

Molar mass of H_2O: M(H_2O)= M(O) + 2.M(H)= 18.02 g/mol.

IV-4- Molar Volume

Under normal conditions of temperature and pressure (NTP: 0°C and 1 atm), one mole of gas molecules always occupies the same volume. This volume is the molar volume (MV):**MV = 22.4 mol/l**

Under these conditions, the number of moles can be calculated as follows:

$$n = V/MV = V/22.4$$

V- Law of Conservation of Mass (Lavoisier) in Chemical Reactions

the law of conservation of mass was discovered by Antoine Lavoisier in 1789 (French chemist), this law states that in chemical reactions the total mass of reagents equals the total mass of products. No atoms are lost or created during chemical reactions, only rearranged, maintaining a consistent mass throughout.

This law as stated, is: "In a chemical reaction, the total mass of the reactants is equal to the total mass of the products formed," which means that nothing is lost, nothing is created; everything is transformed.

VI- Qualitative Aspect of Matter

VI-1- Pure Substances, Homogeneous and Heterogeneous Mixtures

A pure substance is a substance composed of only one type of chemical entity (atom, ion, or molecule).

A pure substance can be either an element (simple pure substance, e.g., Cu, Fe, H_2, O_2...) or a compound (composed of multiple elements, e.g., pure water H_2O).

A mixture is a substance composed of several types of chemical entities mixed together. Mixtures can be either homogeneous (such as saltwater...) or heterogeneous (having two or more distinct phases, for example, water and oil...).

a) Heterogeneous mixtures:

It is a mixture for which we can distinguish at least 2 constituents (with the naked eye or under the microscope)

Examples: mixtures of sugar and sand, milk …

b) Homogeneous mixtures:

it is a mixture for which one does not distinguish the different constituents with the naked eye (and even with a microscope), These are mixtures made up of a single phase

Example: sugar water, salt water, syrup, honey, air, mixture of two gases etc.

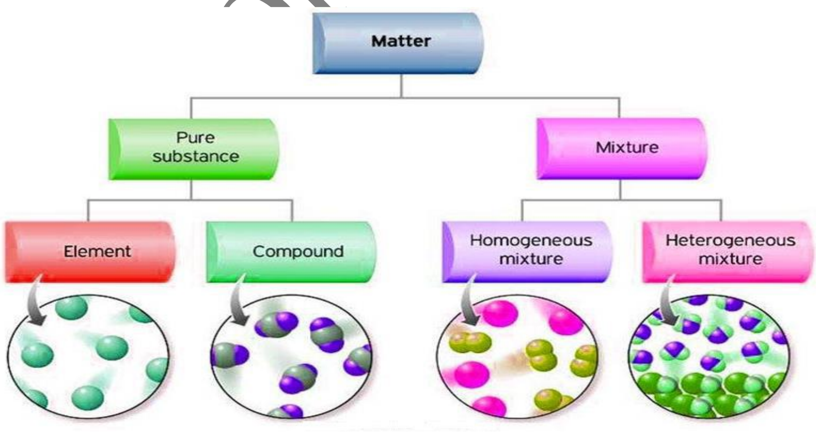

Figure VI: Classification of Matter

VII- Solutions, Solute, Solvent, Aqueous Solution and Dilution

A **solution** is a homogeneous mixture of two or more components, which can be in a liquid, gaseous, or solid phase.

The **solvent** is any liquid substance that has the ability to dissolve other substances.

The **solute** is a chemical species (molecular or ionic) that is dissolved in a solvent. The solvent is always present in a much larger quantity than the solute.

This homogeneous mixture (solvent + solute) is called an aqueous solution if the solvent is **water**.

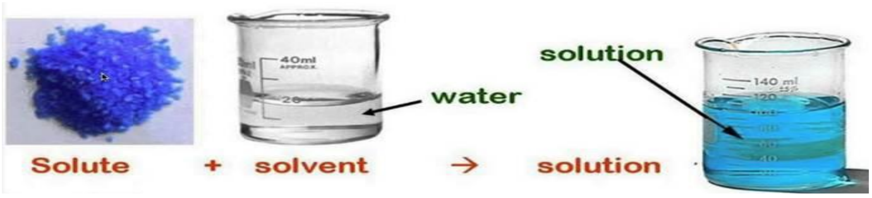

Figure VII: Solute, Solvent and Solution

Dilution is a process that involves obtaining a final solution with a lower concentration than the initial one, either by adding a solvent or by taking a portion of the solution and then adding solvent to maintain the same volume.
Dilution is characterized by its dilution factor.
This concept assumes that the substance being diluted is soluble in the chosen solvent.

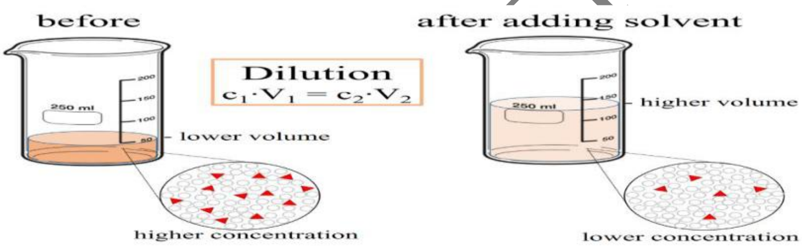

Figure VII-1: Dilution process

VII-Quantitative aspect of matter
In physical chemistry, certain quantities have a quantitative aspect of matter, such as density, different types of concentrations, and mass density
VII-1- Concentrations:
Concentrations are quantities with units used to determine the proportion of solutes to that of the solvent. Depending on the chosen unit, we distinguish:

a. Molarity (Molar Concentration) (MC) It expresses the number of moles of solute per liter of solution.

$$C_n = n/V$$

b. Mass Concentration: Mass concentration, also known as content, is the mass in grams of the solute per liter of solution. Its symbol is C_m, and its unit is grams per liter ($g \cdot L^{-1}$). It can be referred to as the partial mass density of a component of the solution:

$$C_m = m/V$$

There is a relationship between molar concentration and mass concentration:

$$C_m = C_n \times M$$

VII-2-Molality

Molality expresses the amount of solute contained in 1 kg of solvent:

molality = moles of solute / mass of solvent (kg)

VII-3-Normality (N)

Normality expresses the number of gram equivalent weights of solute per liter of solution (geq/L). The gram equivalent weight is the quantity of substance that contains one mole of the species in question (H^+, OH^-, e^-..).

$$N = g\text{eq} / V$$

Relationship between N: Normality and Cn: Molarity: **N = Cn x valence (Z)**

VII-4- Mass density

Density expresses the mass of a certain volume of a solution under specific temperature and pressure conditions. It is denoted as ρ, and its unit is g/L:

Mass density ρ = m/v

Example: Determine the density of ether, knowing that half a liter of ether weighs 358 g.
Solution: Mass density ρ = m/v = 358 g/0.5 L = 716 g/L.

VII-5- Density

a- Density of Solids and Liquids Relative to Water

Relative density (d) is the ratio of the density of a substance to the density of a reference substance. For solids and liquids, the reference substance is pure water, which has a density of 1 kg/liter.

The density of a liquid or solid is the ratio of the density of that liquid or solid to the density of water. In mathematical terms, it is expressed as:

d = ρ/ρwater

b- Density of Gases Relative to Air

The density of a gas relative to air is equal to the ratio of the mass (m) of a volume (v) of the gas to the mass m_{air} of the same volume of air (reference substance), with both masses measured under the same conditions of temperature and pressure.

This relationship is expressed as d = mass of the gas / mass of air = ρ x V / ρair x V, which simplifies to d = ρ / ρair.

If the volume considered is the molar volume, then m = M (molar mass), with the dry air density being equal to 1.293 g/L.

Therefore, mair = ρair x Vmol = 1.293 x 22.4 = 29 g.

Thus: d = mass of the gas / mass of air = $d = M/29$. Density has no unit.

VII-6- Mole Fraction (Xi)

The mole fraction (Xi) indicates the ratio of the number of moles of a specific component to the total number of moles in the solution. In a solution, you have:

Σ Xi = 1 (The sum of the mole fractions of all components of the solution is always equal to 1).