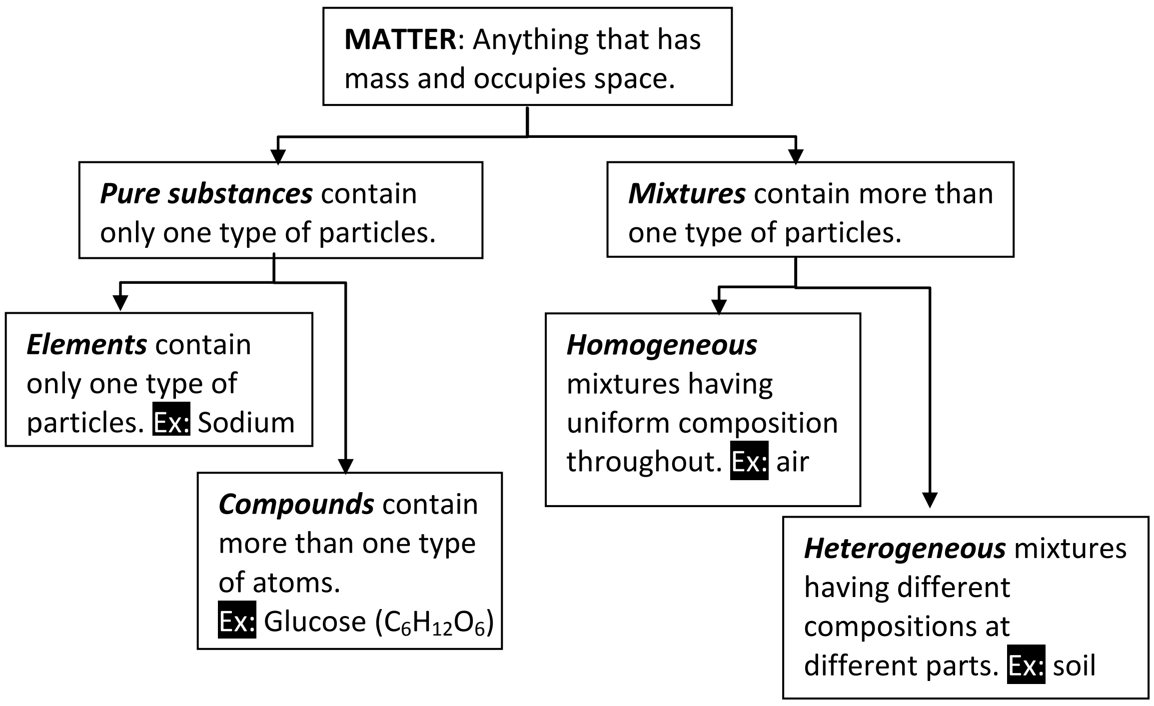
1. Some Basic Concepts of Chemistry

Chemistry is study of matter and its laws of combination and change.

CLASSIFICATION OF MATTER



MEASUREMENT OF MATTER

All substances contain matter which can exist in 3 states – solid, liquid or gas. When the properties of a substance are studied, measurement is essential. The measurement system accepted internationally is **SI units** (International System of Units).

Physical quantity (Symbol)	SI Unit (Symbol)
Length (*l*)	metre (m)
Mass (*m*)	kilogram (kg)
Time (*t*)	second (s)
Electric current (*I*)	ampere (A)
Temperature (*T*)	kelvin (K)
Amount of substance (n)	mole (mol)
Luminous intensity (I_v)	candela (cd)

UNCERTAINTY IN MEASUREMENT

Measurements involve recording of data which are always associated with a certain amount of uncertainty.

- The measurements of quantities in chemistry are spread over a wide range of 10^{-31} to 10^{+23}. Hence, a convenient system of expressing the numbers in scientific notation is used.
- The uncertainty is taken care of by specifying the number of **significant figures** (*meaningful digits which are known with certainty*) in which the observations are reported.
  The uncertainty is *indicated by writing the certain digits and the last uncertain digit.*

Rules for determining the number of significant figures:

(1) All non-zero digits are significant.
Ex: In 285 cm, there are three significant figures and in 0.25 mL, there are two significant figures.

(2) Zeros preceding to first non-zero digit are not significant.
Ex: In 0.03, there is only one significant figure and 0.0052 has two significant figures.

(3) Zeros between two non-zero digits are significant.
Ex: In 2.005, there are four significant figures.

(4) Zeros at the end or right of a number are significant if they are on the right side of the decimal point; otherwise, they are not significant.
Ex: In 0.200 g, there are three significant figures.

(5) Counting numbers have an infinite number of significant figures.
Ex: 2 balls or 20 eggs can be represented by writing infinite number of zeros after placing a decimal i.e., 2 = 2.000 or 20 = 20.0000

The **dimensional analysis** helps to express the measured quantities in different systems of units. Hence, it is possible to interconvert the results from one system of units to another.

Ex: There are 3 common scales to measure temperature — °C (degree celsius), °F (degree fahrenheit) and K (kelvin).

Degree Celsius and degree Fahrenheit are related as:

$$^{0}F = \frac{9}{5}(^{0}C) + 32$$

Degree celsius and Kelvin are related as:

$$K = {}^{0}C + 273.15$$

LAWS OF CHEMICAL COMBINATIONS

The combination of different atoms is governed by 5 basic laws–

1st Law **Law of Conservation of Mass** (by *Antoine Lavoisier*- 1789)
It states that *matter can neither be created nor destroyed*. Or, in a chemical reaction, the total mass of reactants is equal to the total mass of products.

2nd Law **Law of Definite Proportions** (by *Joseph Proust- 1799*)
It states that *a given compound always contains exactly the same proportion of elements by weight.*

3rd Law **Law of Multiple Proportions** (by *John Dalton*- 1803)
This law states that *if two elements can combine to form more than one compound, the different masses of one of the elements that combine with a fixed mass of the other element, are in small whole number ratio.*

4th Law **Law of Gaseous Volumes** (by *Gay Lussac*- 1808)
It states that *when gases combine to form gaseous products, their volumes are in simple whole number ratio at constant temperature and pressure*.

5th Law **Avogadro Law** (by *Amedeo Avogadro*- 1811)
It states that *equal volumes of all gases at the same temperature and pressure should contain equal number of molecules.*

All these laws led to the **Dalton's atomic theory** which states that *atoms are building blocks of matter*.

ATOMIC AND MOLECULAR MASSES

Atomic mass

- **Atomic mass** of an element is a number that expresses how many times the mass of an atom of the element is greater than 1/12th the mass of a C^{12} atom.

$$\text{Atomic mass} = \frac{\text{Mass of an atom of the element}}{1/12 \times \text{Mass of } C^{12} \text{ atom}}$$

- Usually, the atomic mass used for an element is the **average atomic mass** obtained by taking into account the natural abundance of different isotopes of that element.

Molecular mass

- The **molecular mass** of a molecule is obtained by taking sum of the atomic masses of different atoms present in a molecule.

MOLE CONCEPT AND MOLAR MASSES

- The numbers of atoms, molecules or any other particles present in a given system are expressed in the terms of **Avogadro constant** (6.022×10^{23}). This is known as **1 mol** of the respective particles or entities.
- **Molar mass:** The mass of one mole of a substance in gram.

PERCENTAGE COMPOSITION

$$\text{Percentage composition (mass \%) of an element} = \frac{\text{Mass of that element in the compound}}{\text{Molar mass of the compound}} \times 100$$

It is helpful in checking the purity of a given sample. Also by knowing the percentage composition, we can calculate the *empirical* and *molecular* formula of a compound.

➔ An **empirical formula** represents the simplest whole number ratio of various atoms present in a compound

➔ The **molecular formula** shows the exact number of different types of atoms present in a molecule of a compound.

e.g. the empirical formula of glucose is CH_2O but its molecular formula is $C_6H_{12}O_6$.

***Relationship between* the two formulae-**

Molecular formula = (***Empirical formula***) x *n*, where *n*= 1, 2, 3..

n can be calculated as-

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

STOICHIOMETRY AND STOICHIOMETRIC CALCULATIONS

- The quantitative study of the reactants required or the products formed is called **stoichiometry**.
  Using stoichiometric calculations, the amounts of one or more reactant(s) required to produce a particular amount of product can be determined and vice-versa.
- The **coefficients** indicate the molar ratios and the respective number of particles taking part in a particular reaction.

  Limiting reagent:
  - The reagent which limits a reaction or the reagent which is completely consumed in a chemical reaction is called limiting reagent.
- The amount of substance present in a given volume of a solution is expressed in number of ways, e.g., **mass per cent, mole fraction, molarity** and **molality.**

1. Mass percent

➔ It is the number of parts solute present in 100 parts by mass of solution.

$$\text{Mass \% of a component} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

2. Mole fraction

➔ It is the fraction of a particular component in the solution expressed in terms of mole.

$$\text{Mole fraction} = \frac{\text{Number of moles of the component}}{\text{Total number of moles of all the components}}$$

Ex: If a substance 'A' dissolves in substance 'B' and their number of moles are n_A and n_B respectively; then the mole fractionsof A and B are given as-

$$\text{Mole fraction of A} = \frac{\text{No. of moles of A}}{\text{No. of moles of solution}} = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B} = \frac{\text{No. of moles of B}}{\text{No. of moles of solution}} = \frac{n_B}{n_A + n_B}$$

3. Molarity

➔ It is defined as the number of moles of solute dissolved per litre of solution.

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute (n)}}{\text{Volume of solution in litre (V)}}$$

4. Molality

➔ It is defined as the number of moles of the solute present per kilogram (kg) of the solvent.

$$\text{Molality (m)} = \frac{\text{Moles of solute (n)}}{\text{Mass of solvent in kg}}$$

Some important Formulae

- Relationship between Molarity and Mass percentage

$$\text{Molarity} = \frac{\text{Mass \% x density x 10}}{\text{M. Mass}_{\text{(solute)}}}$$

- Relationship between Molality and Molarity

$$\text{Molality} = \frac{1000 \times \text{Molarity}}{(1000 \times \text{density}_{\text{(solute)}}) - (\text{Molarity} \times M_{\text{(solute)}})}$$

- Relationship between Molality and Mole fraction of solute (X_B)

$$X_B = \frac{m \times M_{\text{(solvent)}}}{1000 + m \times M_{\text{(solvent)}}}$$

$$\text{Also, } m = \frac{1000\, X_B}{X_A \times M_{\text{(solvent)}}} \qquad (X_A = \text{Mole fraction of solvent})$$

- Relationship between Molarity and Mole fraction of solute (X_B)

$$X_B = \frac{\text{Molarity} \times M_{\text{(solvent)}}}{\text{Molarity}\,(M_{\text{(solvent)}} - M_{\text{(solute)}}) + 1000 \times \text{density})}$$

$$\text{Also, } M = \frac{1000 \times d \times X_B}{X_A \times M_A + X_B \times M_B}$$