CHAPTER 1

Some Basic Concepts of Chemistry

SOME USEFUL CONVERSION FACTORS

$$1\ \text{Å} = 10^{-10}\text{m},\ 1\text{nm} = 10^{-9}\ \text{m}$$

$$1\ \text{pm} = 10^{-12}\text{m}$$

$$1\ \text{litre} = 10^{-3}\ \text{m}^3 = 1\ \text{dm}^3$$

$$1\ \text{atm} = 760\ \text{mm or torr}$$

$$= 101325\ \text{Pa or Nm}^{-2}$$

$$1\ \text{bar} = 10^5\ \text{Nm}^{-2} = 10^5\ \text{Pa}$$

$$1\ \text{calorie} = 4.184\ \text{J}$$

$$1\ \text{electron volt(eV)} = 1.6022 \times 10^{-19}\ \text{J}$$

$$(1\ \text{J} = 10^7\ \text{ergs})$$

$$(1\ \text{cal} > 1\ \text{J} > 1\ \text{erg} > 1\ \text{eV})$$

ATOMIC MASS OR MOLECULAR MASS

Mass of one atom or molecule in a.m.u.

$$C \rightarrow 12\ \text{amu}$$

$$NH_3 \rightarrow 17\ \text{amu}$$

Actual Mass

Mass of one atom or molecule in grams

$$C \rightarrow 12 \times 1.6 \times 10^{-24}\ \text{g}$$

$$CH_4 \rightarrow 16 \times 1.6 \times 10^{-24}\ \text{g}$$

Relative Atomic Mass or Relative Molecular Mass

Mass of one atom or molecule w.r.t. 1/12th of ^{12}C atom

$$C \rightarrow 12$$

$$CH_4 \rightarrow 16$$

It is unitless

GRAM ATOMIC MASS OR GRAM MOLECULAR MASS

Mass of one mole of atom or molecule

$$C \rightarrow 12\ g$$

$$CO_2 \rightarrow 44\ g$$

It is also called molar mass

DEFINITION OF MOLE

One mole is a collection of that many entities as there are number of atoms exactly in 12 gm of C-12 isotope.

The number of atoms present in exactly 12 gm of C-12 isotope is called Avogadro's number [$N_A = 6.022 \times 10^{23}$]

$$1u = 1amu = (1/12)^{th} \text{ of mass of 1 atom of } C^{12} = \frac{1g}{N_A}$$

$$= 1.66 \times 10^{-24}\ g$$

For Elements

- 1 g atom = 1 mole of atoms = N_A atoms
- g atomic mass (GAM) = mass of N_A atoms in g
- Mole of atoms = $\dfrac{\text{Mass }(g)}{\text{GAM or molar mass}}$

For Molecule

- 1g molecule = 1 mole of molecule = N_A molecule
- g molecular mass (GMM) = mass of N_A molecule in g.
- Mole of molecule = $\dfrac{\text{Mass }(g)}{\text{GMM or molar mass}}$

1 Mole of Substance

- Contains 6.022×10^{23} particles
- Weighs as much as molecular mass/ atomic mass/ionic mass in grams
- If it is a gas, one mole occupies a volume of 22.4 L at 1 atm & 273 K or 22.7 L at STP

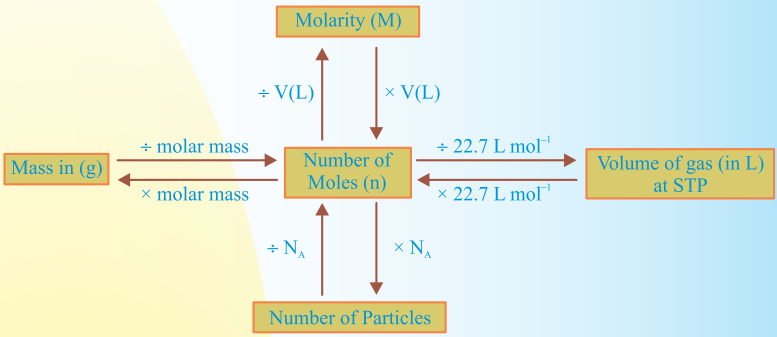
For Ionic Compounds

- 1 g formula unit = 1 mole of formula unit = N_A formula unit.
- g formula mass (GFM) = mass of N_A formula unit in g.
- Mole of formula unit = $\dfrac{\text{Mass }(g)}{\text{GMM or molar mass}}$

VAPOUR DENSITY

Ratio of density of vapour to the density of hydrogen at similar pressure and temperature.

$$\text{Vapour density} = \frac{\text{Molar mass}}{2}$$



STOICHIOMETRY BASED CONCEPT

$$aA + bB \longrightarrow cC + dD$$

- a,b,c,d, represents the ratios of moles, volumes [for gaseous] molecules in which the reactants react or products formed.
- a,b,c,d does not represent the ratio of masses.
- The stoichiometic amount of components may be related as

$$\frac{\text{Moles of A reacted}}{a} = \frac{\text{Moles of B reacted}}{b} = \frac{\text{Moles of C reacted}}{c} = \frac{\text{Moles of D reacted}}{d}$$

Concept of limiting reagent

If data of more than one reactant is given then first convert all the data into moles then divide the moles of reactants with their respective stoichiometric coefficient. The reactant having minimum ratio will be L.R. then find the moles of product formed or excess reagent left by comparing it with L.R. through stoichiometric concept.

Percentage Purity

The percentage of a specified compound or element in an impure sample may be given as

$$\%\text{purity} = \frac{\text{Actual mass of compound}}{\text{Total mass of sample}} \times 100$$

If impurity is unknown, it is always considered as inert (unreactive) material.

EMPIRICAL AND MOLECULAR FORMULA

- **Empirical formula:** Formula depicting constituent atoms in their simplest ratio.
- **Molecular formula:** Formula depicting actual number of atoms in one molecule of the compound.
- The molecular formula is generally an integral multiple of the empirical formula.

  i.e. molecular formula = empirical formula × n

  $$\text{where } n = \frac{\text{molecular formula mass}}{\text{empirical formula mass}}$$

- **For determination of atomic mass:**

  Dulong's & Petit's Law:

  ***Atomic weight of metal* × *specific heat capacity* (*cal/gm-°C*) ≈ 6.4.**

  It should be remembered that this law is an empirical observation and this gives an approximate value of atomic weight. This law gives better result for heavier solid elements, at high temperature conditions.

CONCENTRATION TERMS

Concentration Type	Mathematical Formula	Concept
Percentage by mass	$\%\left(\frac{w}{w}\right) = \frac{\text{Mass of solute} \times 100}{\text{Mass of solution}}$	Mass of solute (in gm) present in 100 gm of solution.
Volume percentage	$\%\left(\frac{v}{v}\right) = \frac{\text{Volume of solute} \times 100}{\text{Volume of solution}}$	Volume of solute (in cm^3) present in 100 cm^3 of solution.
Mass-volume percentage	$\%\left(\frac{w}{v}\right) = \frac{\text{Mass of solute} \times 100}{\text{Volume of solution}}$	Mass of solute (in gm) present in 100 cm^3 of solution.
Parts per million	$\text{ppm} = \frac{\text{Mass of solute} \times 10^6}{\text{Mass of solution}}$	Parts by mass of solute per million parts by mass of the solution

Concentration Type	Mathematical Formula	Concept
Mole fraction	$X_A = \frac{\text{Mole of A}}{\text{Mole of A} + \text{Mole of B} + \text{Mole of C} + \ldots}$ $X_B = \frac{\text{Mole of B}}{\text{Mole of A} + \text{Mole of B} + \text{Mole of C} + \ldots}$	Ratio of number of moles of one component to the total number of moles.
Molarity	$M = \frac{\text{Mole of solute}}{\text{Volume of solution (in L)}}$	Moles of solute in one liter of solution.
Molality	$m = \frac{\text{Mole of solute}}{\text{Mass of solvent (Kg)}}$	Moles of solute in one kg of solvent

MIXING OF SOLUTIONS

It is based on law of conservation of moles.

(i) Two solutions having same solute:

$$\text{Final molarity} = \frac{\text{Total moles}}{\text{Total volume}} = \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$$

(ii) Dilution Effect: Final molarity, $M_2 = \frac{M_1V_1}{V_1 + V_2}$

Volume Strenght of H_2O_2 Solutions

Labelled as 'volume H_2O_2' means volume of O_2 (in litre) at 1 bar & 273 K that can be obtained from 1 litre of such a sample when it decomposes according to

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

- Volume Strenght of H_2O_2 solution = 11.35 × molarity

PERCENTAGE LABELLING OF OLEUM

Labelled as '% oleum' means maximum amount of H_2SO_4 that can be obtained from 100 gm of such oleum (mixture of H_2SO_4 and SO_3) by adding sufficient water. For example, 109% oleum sample means, with the addition of sufficient water to 100 gm oleum sample 109 gm H_2SO_4 is obtained.

% labelling of oleum sample = (100 + x)%

x = mass of H_2O required for the complete conversion of SO_3 in H_2SO_4

- % of free SO_3 in oleum = $\left(\frac{40}{9} \times x\right)\%$

EUDIOMETRY

Some basic assumptions related with calculations are:

1. Gay-Lussac's law of volume combination holds good. According to this law, the volumes of gaseous reactants reacted and the volumes of gaseous products formed, all measured at the same temperature and pressure, bear a simple ratio.

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

   1 vol. 3 vol. 2 vol.

   Problem may be solved directly is terms of volume, in place of mole.

   The stoichiometric coefficients of a balacned chemical reactions gives the ratio of volumes in which gaseous substances are reacting and products are formed at same temperature and pressure.

2. The volumes of solids or liquids is considered to be negligible in comparison to the volume of gas. It is due to the fact that the volume occupied by any substance in gaseous state is even more than thousand times the volume occupied by the same substance in solid or liquid states.

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

   2 mole 1 mole 2 mole

   2 vol. 1 vol. 0 vol.

3. Air is considered as a mixture of oxygen and nitrogen gases only. It is due to the fact that about 99% volume of air is composed of oxygen and nitrogen gases only.
4. Nitrogen gas is considered as an non-reactive gas.
5. The volume of gases produced is often given by certain solvent which absorb contain gases.

Solvent	Gases absorb
KOH	CO_2, SO_2, Cl_2
Ammonical Cu_2Cl_2	CO
Turpentine oil	O_3
Alkaline pyrogallol	O_2
water	NH_3, HCl
$CuSO_4$/$CaCl_2$	H_2O

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