Mole Concept and Stoichiometry – Summary Notes

Gases have some properties which differentiate them from other states of the matter, i.e., solids and liquids. The distance between the molecules of a gas is far larger than solids and liquids which results in weaker force of attraction between these molecules. The collision between the gas molecules is random and, hence, gas molecules move in all directions, that too, in a straight line.

Characteristics of Gases

- Gases have no fixed shape or volume.
- They exert equal pressure in all directions.
- They are highly compressible.
- They can expand on decreasing pressure or increasing temperature.
- They have low density.
- They have large intermolecular spaces and kinetic energy, so they diffuse easily.

- Factors causing variations in the properties of a gas are pressure, temperature and volume of the gas.
- Gay Lussac's law of combining volumes states that under similar conditions of temperature and pressure whenever gases react together, the volumes of the reacting gases as well as the gaseous products bear a simple whole number ratio.
- Avogadro's law states that equal volumes of all gases contain the same number of molecules under similar conditions of temperature and pressure.
- The number of atoms present in 12 g (gram atomic weight) of carbon $\left(C^{12}\right)$ is called Avogadro's number or Avogadro's constant. It is represented by N_A.

  $$N_A = 6.023 \times 10^{23}$$
- **Atomicity:** It is the number of atoms present in one molecule of an element.
  - Elements containing one atom in their molecules are called monoatomic, for example, helium (He), neon (Ne) and argon (Ar).
  - Elements containing two atoms in their molecules are called diatomic, for example, oxygen $\left(O_2\right)$, nitrogen $\left(N_2\right)$ and chlorine $\left(Cl_2\right)$.
  - Elements containing more than two atoms in their molecules are called polyatomic, for example, ozone $\left(O_3\right)$, phosphorus $\left(P_4\right)$ and sulphur $\left(S_8\right)$.
- **Applications of Avogadro's Law**
  - To determine the atomicity of elementary gases like H_2, O_2, Cl_2 and N_2.
  - To explain Gay Lussac's law of combining volumes.
  - To relate gram molecular mass and gram molar volume of the gas at STP

    i.e., Molar Volume $= \dfrac{\text{GMM}}{\text{Mass per gas at STP}}$
  - To relate molecular mass and vapour density
  - To determine the molecular formula of a gas

- **Atomic Weight or Relative Atomic Mass**

  Hydrogen scale: It is the number of times an atom of an element is heavier than an atom of hydrogen.

  $$\text{Relative atomic mass} = \frac{\text{Mass of one atom of an element}}{\text{Mass of one atom of hydrogen}}$$

  Carbon scale: It is the average relative mass of an atom of an element as compared to the mass of an atom of carbon $\left(C^{12}\right)$ taken as 12.

  $$\text{Relative atomic mass} = \frac{\text{Mass of one atom of an element}}{(1/12)\times \text{Mass of one atom of carbon } \left(C^{12}\right)}$$

- **Gram Atomic Mass (GAM):** It is the atomic mass of an element expressed in grams.
  Gram atomic mass = Gram atoms

Molecular Weight or Relative Molecular Mass

Hydrogen scale: It is the number of times a molecule of a substance is heavier than an atom of hydrogen.

$$\text{Molecular weight} = \frac{\text{Mass of one molecule of a substance}}{\text{Mass of one atom of hydrogen}}$$

Carbon scale: It is the average relative mass of a molecule of a substance as compared to the mass of an atom of carbon $\left(C^{12}\right)$ taken as 12.

$$\text{Molecular weight} = \frac{\text{Mass of one molecule of a substance}}{(1/12)\times \text{Mass of one atom of carbon } (C^{12})}$$

- **Molar mass or Gram Molecular Mass (GMM):**
  It is the molecular mass of a substance expressed in grams.
  Gram molecular mass = Gram molecules
  Gram molecular mass of all gases contains 6.023×10^{23} number of molecules at STP.
- **Molar Volume or Gram Molecular Volume:** It is the volume occupied by one mole of a gas at STP and is equal to 22.4 litres. Gram molecular mass of all gases occupy a volume of 22.4 litres at STP.

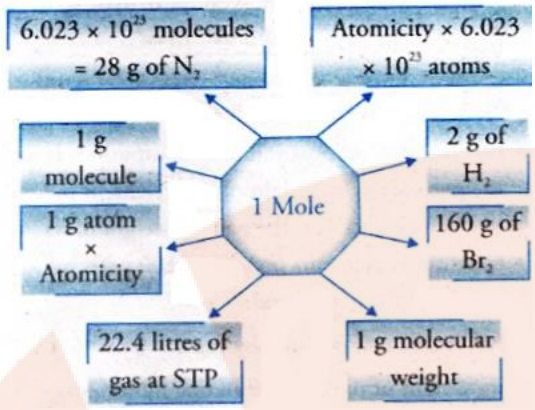
  $$\text{Molar Volume} = \frac{\text{Gram molecular mass}}{\text{Mass per litre of gas at STP}}$$

- Mole: It is the amount of a substance which contains the same number of elementary particles (atoms, molecules or ions) as the number of atoms present in 12 g of carbon $\left(C^{12}\right)$.

  $$1 \text{ mole} = 6.023\times10^{23} \text{ particles}$$

- $$\text{Moles of an element} = \frac{\text{Mass of the element}}{\text{Atomic mass or GAW}}$$
- $$\text{Moles of a compound} = \frac{\text{Mass of the compound}}{\text{Molecular mass or GAW}}$$

- 1 mole can be depicted diagrammatically as:



- **Applications of Mole Concept**

  The mole concept helps in the chemical calculations in a number of ways as follows:

  - To calculate the actual mass of atoms

    $$\text{Mass of one atom} = \frac{\text{Atomic mass or GAW}}{6.023\times10^{23}}$$

  - To calculate the actual mass of molecules

    $$\text{Mass of one molecule} = \frac{\text{Molecular mass or GAW}}{6.023\times10^{23}}$$

  - To calculate the number of atoms

    $$= \text{Moles}\times6.023\times10^{23}$$

    $$= \frac{\text{Mass of substance in grams}\times6.023\times10^{23}}{\text{Gram molecular mass}}$$

  - To calculate the number of molecules

    $$= \text{Moles}\times6.023\times10^{23}$$

    $$= \frac{\text{Molecular mass or GMW}}{6.023\times10^{23}}$$

  - To determine the number of particles present in V litres of a gas at NTP

    Number of molecules present in V litres of gas at NTP

    $$= \frac{\text{Volume of the gas in litres}\times6.023\times10^{23}}{22.4\,\text{litres}}$$

- **Vapour Density:** It is the ratio of the mass of a certain volume of a gas (or vapour) to the mass of the same volume of hydrogen under similar conditions of temperature and pressure.

  $$\text{Vapour Density [VD]} = \frac{\text{Mass of a certain volume of a or vapour}}{\text{Mass of the same volume of hydrogen}}$$

  $$\text{Vapour Density} = \frac{\text{Molecular Mass}}{2}$$

  or $$\text{Molecular Mass} = 2\times\text{VD}$$

- **Percentage Composition of a Compound:** It is the percentage by weight of each element present in a compound. It is the part by weight of its constituent elements present in 100 parts by weight of the compound.
  Percentage composition by mass
  $$= \frac{\text{Weight of the element in one molecule of a compound}}{\text{GMW of the compound}} \times 100$$
- **Empirical Formula:** It is the simplest formula of a compound which gives the simple whole number ratio of various elements present in one molecule of the compound.
- **Determining the Empirical Formula:** The following steps are involved in the calculation of the empirical formula.
  - **Step 1:** Write down the percentage composition by weight and the atomic weight of each element in the given compound.
  - **Step 2:** Divide the percentage composition of each element by its atomic weight to get the relative number of atoms in the compound.
  - **Step 3:** Select the smallest relative number and divide the remaining relative numbers by it to find the simplest ratio of atoms present in the compound.
  - **Step 4:** In case the simplest ratio is not a whole number, multiply each ratio by the smallest suitable integer so that a whole number ratio is obtained.
  - **Step 5:** Write the empirical formula showing the atoms in the proper simple ratio of whole number.
- **Molecular Formula:** It is a chemical formula which gives the actual number of atoms of various elements in one molecule of a compound.
  Molecular Formula $= [\text{Empirical Formula}]_n$
- Relationship between Empirical Formula Weight and Molecular Formula Weight
  $$n = \frac{\text{Molecular formula weight}}{\text{Empirical formula weight}}$$
  Where $n = \text{Simple whole number}$
- **Stoichiometry:** It is the study of the quantitative relationship conveyed by a chemical equation.
- **Chemical Equation:** It gives the composition and identity of the elements, or compounds, which take part as the remains and are formed as the products.
- **Information Conveyed by the Chemical Equation**
  - The chemical equation gives information about moles and masses of various reactants and products.
  - It gives information about volumes of gaseous reactants and products measured at STP.
- **Calculations Based on Chemical Equations**
  - The equation must be balanced.
  - The molecular weight of the required substance is calculated and should be written below the formula of the substance.
  - The volume of a gas in litres is indicated by multiplying the number of molecules of the gas with 22.4.