CHAPTER-5
MOLE CONCEPT AND STOICHIOMETRY

Topic-1 Gay Lussac's Law

Concepts covered: • *Gay Lussac's law of combining volumes*

Revision Notes

➢ **Gay Lussac's law of combining volumes :**

- It states that whenever gases react, they always do so in volumes which bear a simple whole number ratio to one another and to the volumes of gaseous products. All volumes being measured under similar conditions of

temperature and pressure. In simple words, it states that, "for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature."

- Gay Lussac's Law is valid only for gases and the volumes of solids and liquids are considered to be zero. It expresses the relationship between pressure and temperature.

➢ **Example of Gay Lussac's Law :**

Hydrogen chloride : One volume of hydrogen mixed with one volume of chlorine gives two volumes of hydrogen chloride gas.

$$\underset{1\text{ Vol.}}{H_2} + \underset{1\text{ Vol.}}{Cl_2} \rightarrow \underset{2\text{ Vol.}}{2HCl}$$

(At same temperature and pressure)

Simple ratio is 1: 1: 2

➢ **Avogadro's law explains Gay-Lussac's Law**

Avogadro's law states that, under the same conditions of temperature and pressure, equal volume of different gases have the same number of molecules. As substance reacts in simple ratio by the number of molecules, volumes of gaseous reactants and products will also bear a simple ratio. This is the statement of Gay-Lussac's law.

$$\underset{\text{1 vol}}{H_2} + \underset{\text{1 vol}}{Cl_2} \rightarrow \underset{\text{2 vol}}{2HCl}$$

[by Gay-Lussac's law] [by Avogadro's law]

Mnemonics

1. Concept : Gas Laws

Mnemonics :

Can These **G**uys **P**ossibly **B**e **V**ictorious?

C—Charles

T—Temperature

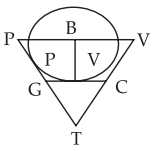
G—Gay Lussac's Law

P—Pressure

B—Boyles

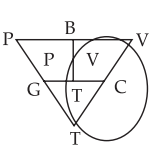
V—Volume

Interpretation :



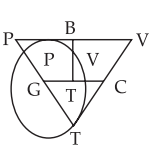
Boyle's Law

$= P_1V_1 = P_2V_2$



Charles Law:

$= \frac{V_1}{T_1} = \frac{V_2}{T_2}$



Gay Lussacs Law

$= \frac{P_1}{T_1} = \frac{P_2}{T_2}$

Key Words

- **Absolute Scale or Kelvin Scale :** A temperature scale with absolute zero (Zero Kelvin) as the starting point is called the absolute scale or Kelvin scale.
- **Limiting reagent or reactant :** The reactant which is completely used up in a reaction is called limiting reagent or limiting reactant.
- **Stoichiometry :** It measures quantitative relationship which is used to determine the amount of products or reactants that are produced or required in a given reaction.
- **Atom :** It is the smallest particle of an element that can take part in a chemical reaction. It may or may not exist independently.
- **Molecule :** It is the smallest particle of an element or a compound that can exist by itself. It never breaks up except for taking part in a chemical reaction.

Key Terms

- Since the volume of a gas changes remarkably with change of temperature and pressure, it becomes necessary to choose standard values of temperature and pressure to which gas volumes can be referred.
- **Standard values :**
  - 0°C or 273 K for temperature
  - 1 atmospheric pressure or 760 mm or 76 cm of Hg for pressure.
- Absolute zero = 0K = – 273°C
- Gay-Lussac's Law is valid only for gases. The volume of solids and liquids are considered to be zero.
- The relative atomic mass of any element is the weighted average of the relative atomic masses of its natural isotopes. For example, chlorine consists of a mixture of two isotopes of masses 35 and 37 in the ratio of 3 : 1.
- Atomicity $= \frac{\text{Molecular Mass}}{\text{Atomic Mass}}$

Topic-2 Relative Molecular Mass and Mole Concept

Concepts covered: • *Relative molecular mass*, • *Vapour density*, • *Mole concept*

Revision Notes

- The relative molecular mass of an element or a compound is the mass of one molecule of an element or compound compared with the mass of an atom of carbon - 12, which is arbitrarily assigned a value of 12.00.
- Relative molecular mass is a number dealing with a molecule.
- Gram molecular mass is the mass of one mole of a substance.
  For example,
  (i) Gram molecular mass of oxygen gas = 32 g
  (ii) Gram molecular mass of nitric acid = 63 g.
- The relative molecular mass of a gas or vapour is twice its vapour density (V.D.).
- Relative molecular mass of a gas = 2×VD.
- The molar mass of any gas is its relative molecular mass expressed in g (grams).
- The molar volume of any gas at STP is equal to 22.4 dm^3.
- The volume of a gas, which contains 6.023×10^{23} molecules is always 22.4 dm^3 at STP.
- The number of molecules contained in one mole of any substance is equal to 6.023×10^{23}.
- Mole is the mass of a substance containing 6.023×10^{23} particles. The particles may be atoms, molecules, ions, electrons, etc.
  Thus, the mole of substance is related to
  (a) the mass of a substance,
  (b) particles contained in a substance.

$$\text{Number of moles of a substance} = \frac{\text{Mass of the substance}}{\text{Gram molecular mass of the substance}}$$

$$= \frac{\text{Number of particles in the substance}}{6.023\times10^{23}}$$

- **Mole Concept :** Mole is simply like a dozen or a gross. A dozen is a collection of 12 objects, a gross is a collection of 144 objects, similarly a mole is a collection of 6.023×10^{23} (Avogadro's number) elementary particles (atoms or ions or molecules).
- **Mole :** A mole is defined as the amount of a substance containing elementary particles like atoms, molecules or ions in 12 g of carbon (C-12).
- **Mole of Atoms (Relating Mole and Atomic Mass) :** One mole of atoms contain 6.023×10^{23} atoms having mass equal to its gram atomic mass. One mole of oxygen atoms contains 6.023×10^{23} atoms of oxygen and weights 16 g.
- **Mole of Molecules (Relating Mole and Molecular Mass) :** One mole contains 6.023×10^{23} molecules and is equivalent to the given molecular mass of any given substance. For example, 1 mole of O_2 contain, 6.023×10^{23} molecules and weights 32 g.
- **Mole and Molar volume :** One mole of any gaseous molecule occupy 22.4 (dm^3) litre or 22400 cm^3 (mL) at STP. This volume is known as **molar volume**. The molar volume of a gas can be defined as the volume occupied by one mole of a gas at STP.

$$\text{Gram molecular volume (Molar volume)} = \frac{\text{Gram molecular weight}}{\text{Weight per litre of gas at STP}}$$

For example :
1 mole of H_2SO_4 = $(2\times1) + 32 + (4\times16) = 98g = 6.022\times10^{23}$ molecules of H_2SO_4
1 mole of NH_3 = $14+(3\times1) = 17g = 6.022\times10^{23}$ molecules of NH_3
1 mole of Na = $23g = 6.023\times10^{23}$ atoms of Na.
Volume occupied by 1 mole of NH_3 = 22.4 litres at STP
Volume occupied by 1 mode of O_2 = 22.4 litres at STP

- **Relative Vapour Density :** The relative vapour density of a gas is the ratio between the masses of equal volumes of gas (or vapour) and hydrogen under the same conditions of temperature and pressure.

$$\text{Relative VD} = \frac{\text{Mass of volume V of the gas under similar condition}}{\text{Mass of volume V of hydrogen gas under similar condition}}$$

- According to Avogadro's law, volume at the same temperature and pressure may be substituted by molecules.

- 2 × Relative vapour density (VD) = Relative molecular mass of a gas. The relative molecular mass of gas or vapour is twice its vapour density.

Mnemonics

Concept : Relation in molecular mass and vapour density

Mnemonics :

My **M**om is equal to **2 v**estern **D**ancer

Interpretation :
M—molecular
M—mass
2—2
V—vapour
D—density
Molecular mass = 2 x Vapour density

Key Words

- **Relative Atomic mass :** The relative atomic mass or atomic weight of an element is the number of times one atom of the element is heavier than 1/12 time of the mass of an atom of C-12.
- **Atomic mass unit :** It is defined as 1/12 the mass of carbon atom C-12.
- **Relative molecular mass :** The relative molecular mass or molecular weight of an element or a compound is the number that represents how many times one molecule of the substance is heavier than 1/12 of the mass of an atom of carbon-12.
- **Gram Atomic Mass :** It is defined as the atomic mass of an element expressed in grams.
- **One Gram Atom :** The quantity of the element which weighs equal to its gram atomic mass is known as one gram atom of that element.
- **Gram Molecular mass :** It is defined as the molecular mass of a substance expressed in grams.
- **Avogadro's Number :** It is defined as the number of atoms present in 12 g (gram atomic mass) of C-12 isotope i.e., 6.023×10^{23} atoms.

Key Terms

- One mole of oxygen atoms contain 6.023×10^{23} atoms of oxygen and weighs 16 g.
- 1 G.M.M. of the substance = 1 mole of that substance = 6.02×10^{23} molecules of that substance = 22.4 L at S.T.P.
- The relative vapour density of a gas (or a vapour) is the ratio between the masses of equal volumes of gas (or vapour) and hydrogen under the same conditions of temperature and pressure.
- The relative molecular mass of a gas or vapour is twice its vapour density.
- Mass of one atom = $\frac{\text{Atomic mass}}{6.023 \times 10^{23}}$
- Mass of one molecule = $\frac{\text{Molecular mass}}{6.023 \times 10^{23}}$
- Number of molecules = moles × 6.023×10^{23}
- Number of atoms = moles × 6.023×10^{23}

Topic-3

Percentage Composition, Empirical and Molecular Formula

Concepts covered: • *Molecular formula,* • *Empirical formula,* • *To calculate percentage of element in a compound,* • *Relationship between molecular formula and empirical formula*

Revision Notes

- **Molecular Formula :** It is the symbolic representation of a molecule of a substance which indicates the actual number of atoms of various elements present in one molecule of it.
  For example, Molecular formula of benzene = C_6H_6.

➢ **To Calculate Percentage of an Element in a Compound :**

Percentage of an element in a compound $= \frac{\text{Total mass of the element}}{\text{Molecular mass of the compound}} \times 100$

➢ **To Calculate Percentage Composition of a compound :**

- In order to calculate the percentage composition of a compound we have to calculate the percentage of each element in the compound.

➢ **Empirical Formula :** Empirical formula of a compound gives us the simplest whole number ratio between the atoms of various elements present in one molecule of it.

- Empirical formula of benzene = C_1H_1
- Empirical formula of glucose = $C_1H_2O_1$

➢ **Relationship between Empirical and Molecular formula :**

- Molecular formula of a compound is a simple whole number multiple of its empirical formula.

  Molecular formula = n × empirical formula

  Where n is a simple whole number

  or $n = \frac{\text{Molecular formula}}{\text{Empirical formula}}$ or $n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}}$

  $= \frac{2 \times \text{Vapour density of a gas or vapour}}{\text{Empirical formula mass}}$

(Note : Molecular and unit less)

Mnemonics

Concept : Relation between molecular formula and empirical formula
Mnemonics:
MF Tyres **N**ot **E**asy To **F**ail
M—Molecular
F—Formula
N—n
E—empirical
F—Formula
Interpretation : Molecular Formula = $n \times E F$

Key Terms

➢ Molecular formula of Blue vitriol is $CuSO_4 \cdot 5H_2O$.

➢ The empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O. It indicates that the ratio of C, H and O atoms in a molecule of glucose is 1 : 2 : 1.

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