CHEMISTRY

CLASS NOTES FOR CBSE

Chapter 05 States of Matter

01. Measurable Properties of Gases

Mass : The mass of gas is generally used in the form of number of moles which is related as

(i) $\text{no. of moles} = \dfrac{\text{wt. in gm}}{\text{molecular mass of gases}} \left(n = \dfrac{w}{M}\right)$

Two other useful formulae to calculate number of moles of gas are–

(ii) $\text{no. of moles} = \dfrac{\text{no. of molecules of given gas}}{\text{Avogadro's number of molecules}} \left(n = \dfrac{N}{N_A}\right)$

(iii) $\text{no. of moles} = \dfrac{\text{volume of given gas in litre at STP}}{22.4\ \text{L}} \left(n = \dfrac{N}{N_A}\right)$

Volume : Volume of gas is volume of the container in which it is present, i.e., space which the gas molecules can occupy.

Temperature : Degree of hotness or coldness of a body is measured by temperature.

$$\frac{C}{100} = \frac{K-273}{100} = \frac{F-32}{180}$$

C – Celcius scale, K – Kelvin scale, F – Fahrenheit scale

> ***NOTE*** ☞ *In all the problems of gaseous state (i.e. in all gas law equations), temperature must be expressed in kelvin scale. i.e.,* ***t°C+273.15 = TK***

Pressure : Pressure of gas is defined as the force exerted by the gas on the walls of its container. It is often assumed that pressure is isotopic, i.e. it is the same in all the three directions.

02. Measurement of Pressure

Barometer : The instrument used for the measurement of atmospheric pressure is called Barometer. It consists inverted a tube filled with mercury in a dish of mercury. The height of the mercury column is a measure of the atmospheric pressure at that place.

vol. of Hg = Area$\times$Height = A$\times$h

Mass of Hg = Volume & Density = A$\times$h$\times$d

Force of mercury = Mass$\times$g = A$\times$h$\times$d$\times$g

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{A \times h \times d \times g}{A} = hdg$$

$$P = hdg$$

$$h = \frac{P}{dg}$$

$P = 1$ atm $= 1.01325 \times 10^5$ Pascal.

Manometer : The instrument used for the measurement of the pressure of a gas called a manometer. It simply consists of a U shaped tube containing mercury usually. One limb of the tube is longer than the other. Two types of manometer are used. These are

(I) Open Manometer

(i) If level of Hg in the two limbs is same then $P_{gas} = P_{atm}$

(ii) If level of Hg is shorter limb is higher than that of longer limb

$P_{atm} = P_{gas} + hdg$

$P_{gas} = P_{atm} - hdg$

(iii) If level of Hg in longer limb is higher than that of shorter limb

$P_{gas} = P_{atm} + hdg$

(II) Closed Manometer-

(i) If level of mercury in longer limb is higher than that of shorter limb

$P_{gas1} = P_{gas2} + hdg$

(ii) If level of mercury in longer limb is lower than that of shorter limb

$P_{gas1} + hdg = P_{gas2}$

03. Gas Laws

Boyle's Law

It relates the volume and the pressure of a given mass of a gas at constant temperature. Boyle's law states that, "at constant temperature, the volume of a sample of a gas varies inversely with the pressure"

$\therefore \quad P \propto \frac{1}{V}$ (when temperature and number of moles are kept constant)

The proportionality can be changed into an equality by introducing a constant k, i.e.,

$P = \frac{K}{V}$ or $PV = k$

Charle's Law

It states "at constant pressure, the volume of a given mass of a gas, increases or decrease by $\frac{1}{273.15}$th of its volume at 0°C for every rise or fall of one degree in temperature".

$$\frac{V_t}{V_0} = 1 + \frac{t}{273.15}t \quad \text{(constant n and P)}$$

or $\quad V_t = V_0\left(1 + \frac{t}{273.15}\right) \quad$ or $\quad V_t = \frac{V_0(273.15 + t)}{273.15}$

0°C on the Celsius scale is equal to 273.15 K at the Kelvin or absolute scale.
i.e. T_t (Temperature in Kelvin scale) = 273.15 + t

Gay-Lussac's Law

(i) It states that at constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

(ii) Mathematically – $P \propto T$ (at constant volume)

Where P = Pressure of gas
T = Absolute temperature

$$P = KT$$

$$\text{or} \quad \frac{P}{T} = K$$

Hence, if the pressure of a gas is P_1 at temperature T_1 changes to P_2 at T_2, volume remaining constant.

$$\text{then} \quad \frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$$

$$\log P - \log T = \text{constant.}$$

(iii) $P_t = P_o\left(1 + \frac{t}{273.15}\right)$

where P_t = Pressure of gas at t °C
P_o = Pressure of gas at 0 °C
t = Temperature in °C.

Avagadro's Law

(i) According to this law under the same condition of temperature and pressure, equal volumes of all gas contains equal no. of molecules.

$V \propto n$ (At constant temperature & pressure)

Where V = volume
n = no of molecules

(ii) Molar Volume or gram molecular volume is 22.4 litres or 22400ml of every ideal gas at NTP is the volume occupied by its one gram mole and it is called molar volume or gram molecular volume.

04. Ideal Gas Equation

For 1 mole of the gas n = 1

$$PV = RT$$

So $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = R$ or $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Where P_1, V_1, T_1 are the initial pressure, volume and temperature and P_2, V_2, T_2 are final values. The above equation is called as ideal gas equation.

Ideal gas equation in terms of density

Let w and M be the mass and molecular mass of a gas; then

$$n = \frac{w}{M}$$

Hence, eq. (1) becomes $PV = \frac{w}{M} RT$

or $P = \frac{w}{M} \cdot \frac{RT}{V}$ $\left[\frac{w}{V} = \frac{\text{mass}}{\text{Volume}} = \text{Density}(d)\right]$

or $P = \frac{d}{M} RT$

05. Dalton's Law of Partial Pressures

Dalton's law of partial pressure states "at a given temperature, the total pressure exerted by two or more non reacting gases occupying a definite volume is equal to the sum of the partial pressures of the component gases.

$P_{total} = P_1 + P_2 + P_3 + ...$(at constant V and T)

$$= \left(\frac{n_1}{V} + \frac{n_2}{V} + \frac{n_3}{V} + ...\right) RT = (n_1 + n_2 + n_3 + ...) \frac{RT}{V} = \frac{nRT}{V}$$

where $n = n_1 + n_2 + n_3 + ... =$ Total volume

$$P_{total} = \sum p_i = \frac{RT}{V} \sum n_i$$

06. Graham's Law of Diffusion

Effusion is the process of gas molecules coming out of container through a small orifice, due to presence of difference between container and surrounding atmosphere. The process of effusion is similar to diffusion and same formula are applicable with the only difference that effusion occurs due to presence difference.

According to Graham, the rate of diffusion (or effusion) of a gas at constant pressure and temperature is inversely proportional to the square root of its molecular mass.

$$r \propto \sqrt{\frac{1}{M}}, \text{ at constant P and T}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}, \text{ at constant P and T}$$

07. Kinetic Theory of Gases

The theoretical model for all the experimental gas laws can be analysed with the help of kinetic theory of gases which is based on following assumptions:

(i) All the gases consists of very small molecules or atoms whose volume is negligible compared to volume of container.

(ii) There is no interaction between gaseous particles (the interaction maybe appreciably affected under certain conditions of temperature and pressure).

(iii) The gaseous molecules are under a state of continuous motion which is unaffected by gravity (the random straight line motion is known as Brownian motion).

(iv) Due to the continuous motion, collision between gaseous molecules with the wall of container occurs. The collision with the walls of container are responsible for pressure exerted by the gas on the wall of container.

08. Equation for Kinetic Molecular Theory

$$PV = \frac{1}{3} mN_0 U_1^2 = \frac{1}{3} MU^2$$

mN_0 = M (molar mass)

N_0 = Avogadro's number

U = root mean square velocity (U_{rms})

Translation kinetic energy of n mole

$$\frac{1}{2} Mu^2 = \frac{3}{2} PV = \frac{3}{2} nRT$$

Average translational kinetic energy per molecule

$$= \frac{3}{2} \frac{RT}{N_0} = \frac{3}{2} KT$$

Where $K\left(\frac{R}{N_0}\right)$ is called Boltzmann's constant.

09. Different Types of Molecular Velocities

(i) **Root mean square velocity (U_{rms})**

$$U_{rms} = \sqrt{\frac{U_1^2 + U_2^2 + \dots U_n^2}{N}}$$

(ii) **Average velocity (U_{av})**

$$U_{av} = \frac{U_1 + U_2 + \dots U_n}{n}$$

$$U_{av} (\text{average velocity}) = \sqrt{\frac{8RT}{\pi M}}$$