STATES OF MATTER

Short Answer Questions:

1) State and explain Graham's law of diffusion?

Ans. Graham's law is stated as, at constant temperature and pressure, the rate of diffusion of a gas is inversely proportional to square root of its density.

The rate of diffusion (r) is related to the density (d) of gas by the equation -

$$r \propto \frac{1}{\sqrt{d}}$$

As Density is directly proportional to the molecular weight (M) or vapour density (VD) of gas. Graham's law is also stated as; the rate of diffusion of gas is inversely proportional to the square root of its molecular weight or vapour density.

$$r \propto \frac{1}{\sqrt{M}} (or) \frac{1}{\sqrt{VD}}$$

The ratio of rates of diffusion of two gases under identical conditions of temperature and pressure is given as -

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{VD_2}{VD_1}}$$

The ratio of rates of diffusion of two gases is also related as - $\frac{r_1}{r_2} = \frac{V_1 t_2}{V_2 t_1}$

i. If volumes of two gases diffused are same, the ratio of times (t) taken for diffusion is given as - $\frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$

ii. If times taken for the diffusion of two gases are same, the ratio of volumes (V) is given as -

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}}$$

Applications

1). Ansil alarm in coal mines for the detection of marsh gas is based on diffusion.

2). Atmolysis, a process of separation of uranium isotopes (U235 & U^{238}) is also based on diffusion, where the isotopes are converted to volatile uranium hexaflourides

3). Useful in the calculation of molecular weights and density of gases and vapours.

2) Write the postulates of kinetic theory of gases?

Ans. The postulates of the kinetic gas theory

1. Gases are made up of many small, tiny and discrete particles, called molecules.

2. Molecules of a gas are well separated from each other. The volume occupied by molecules of a gas is negligible compared to the volume of gas. The mean free path is very high compared to the diameter of the molecule.

3. Molecules of a gas are electrically neutral and they do not have attractions and repulsions between them.

4. Gas molecules move rapidly and randomly in all the directions with high velocities.

5. Motion of gas molecules is not affected by the gravitational force.

6. Pressure exerted by a gas is due to collisions of molecules made on the inner walls of the vessel. Pressure number of collisions on the inner walls.

7. During collisions there can be transfer of energy among the molecules, but the average kinetic energy of gas is constant. Hence Collisions among gas molecules are perfectly elastic.

8. The average kinetic energy of gas molecules is directly proportional to absolute temperature of the gas.

Kinetic energy $\propto$ absolute temperature.

3. State and explain Dalton's law of Partial Pressures?

Ans. Dalton's Law Of Partial Pressures:- 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.

Mathematically $P = P_1 + P_2 + p_3$ ..... *(T, V constant)*

Where P1, P2 and P3are the partial pressures of the component gases respectively. In a mixture the pressure exerted by the individual gas is known as its partial pressure

Partial pressure in terms of mole fraction :- Let n_1, n_2 be the no. of moles of two non -reacting gases A and B filled in a vessel of volume V at temperature T,

Total pressure in the vessel P may be calculated as $PV = (n_1 + n_2)RT$ .... (1)

Partial pressures may be calculated as $P_A V = n_1 RT$ ....(2)

$P_B V = n_2 RT$ ....(3)

Adding equation 2 & 3, we get $(P_A + P_B)V = (n_1 + n_2)RT$........(4)

Comparing equation (1) and (4), we get. $P = P_A + P_B$

Dividing equation (2) and (1), we get $\frac{P_A}{P} = \frac{n_1}{n_1 + n_2} = X_A \Rightarrow P_A = P_{total}.X_A$

Similarly dividing equation (3) and (1), we get $\Rightarrow P_B = P_{total}.X_B$

Hence partial pressure of a component = mole fraction x total pressure.

Applications of Dalton's Partial Pressure Law:-

I. Water insoluble gases like N_2, O_2, He, H_2 etc are collected over water. When a gas is collected over water the observed pressure of the gas is equal to the sum of the pressures dry gas and pressure of water vapour.

$$P_{moist\ gas} = P_{dry\ gas} + P_{water Vapour}$$

$$\Rightarrow P_{dry\ gas} = P_{moist\ gas} - Aqueous\ tension$$

4. Deduce a). Boyle"s Law and b). Charle's Law from kinetic gas equation?

Ans. a) **Boyle's Law**

It states that at constant temperature, the volume of certain mass of a gas is inversely proportional to its pressure.

The kinetic gas equation $PV = \frac{1}{3}mnC^2$ (or) $PV = \frac{2}{3}\left(\frac{1}{2}mnC^2\right)$

Kinetic energy of 'n' molecules of a gas is $(1/2)mnC^2$ and is directly proportional to the absolute temperature, $\frac{1}{2}mnC^2 = K.T$

Where K is constant. $\therefore PV = K.T$

If temperature is constant then PV = constant

This is Boyle's law

b). **Charle's Law:** It states that**,** at constant pressure the volume of certain mass of a gas is directly proportional to its absolute temperature.

The kinetic gas equation $PV = \frac{1}{3}mnc^2$

$$\mathbf{PV} = \frac{2}{3}\left(\frac{1}{2}mnC^2\right) \quad \textbf{or} \quad \mathbf{PV} = \frac{2}{3}\mathbf{K.T}$$

Since kinetic energy of n molecules of a gas is $(1/2)mnC^2$ and is directly proportional to absolute temperature.

$\mathbf{V} = \frac{2}{3}\frac{K.T}{P}$, if pressure (P) is constant, then

$\mathbf{V}$ = constant × T (or) $V \propto T$

This is Charles' law

5. Deduce a) Graham's law and b) Dalton's law from kinetic gas equation?

Ans. a) Graham's Law:

The kinetic gas equation $PV = \frac{1}{3} mnC^2$

For one mole of a gas, with Avogadro number of molecules, the mass 'mn' becomes equal to gram molecular weight, M.

$PV = \frac{1}{3} MC^2$ (or) $C = \sqrt{\frac{3PV}{M}}$ or $C = \sqrt{\frac{3P}{d}}$

Where density (d) is mass per volume.

The RMS velocity is a measure of rate of diffusion of gas.

At constant pressure, rate of diffusion is $r \propto \frac{1}{\sqrt{d}}$

This is Graham's law of diffusion.

b) Dalton's Law:

Consider a gas in a vessel of volume V. If the vessel contains n_1 molecules of a gas with mass of each molecule m_1 and RMS velocity C_1, the pressure (P_1) is given from kinetic gas equation-

$$P_1 = \frac{1}{3} \frac{m_1 n_1 C_1^2}{V}$$

If the gas in the vessel is replaced by another gas, the pressure (P_2) is given in terms of n_2 molecules of mass m_2 each with RMS velocity C_2 as -

$$P_2 = \frac{1}{3} \frac{m_2 n_2 C_2^2}{V}$$

Suppose two gases are taken in the same vessel, with pressure of the mixture (P)

$$\mathbf{PV} = \frac{1}{3} m_1 n_1 C_1^2 + \frac{1}{3} m_2 n_2 C_2^2$$

Re-writing this

$$\mathbf{P} = \frac{1}{3} \frac{m_1 n_1 C_1^2}{V} + \frac{1}{3} \frac{m_2 n_2 C_2^2}{V}$$

$P = P_1 + P_2$

This is Dalton's law of partial pressures.

6. Define a) RMS b) average and c) most probable speeds of gas molecules. Give their interrelation ship?

Ans. RMS velocity

It is the square root of mean of squares of velocities of molecules present in the gas. **It is denoted by C. It is given by**

$$C = \sqrt{\frac{c_1^2 + c_2^2 + c_3^2 + ... + c_n^2}{n}} \quad \textbf{Or} \quad C = \sqrt{\frac{3RT}{M}}$$

Average velocity

It is the ratio of sum of the velocities of all gas molecules to the total number of molecules.

It is also called mean velocity. It is denoted by -

$$\bar{C} = \frac{c_1 + c_2 + c_3 + ... + c_n}{n} \quad \textbf{Or} \quad \bar{C} = \sqrt{\frac{8RT}{\pi M}}$$

Most probable velocity

It is the velocity possessed by maximum number of molecules present in a given amount of gas. **It is denoted by C_p.**

$$C_p = \sqrt{\frac{2RT}{M}}$$

The ratio of three types of molecular velocities of a gas is given as,

$$C_p : \bar{C} : C = \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}} \qquad \textbf{(Or)} \quad C_p : \bar{C} : C = 1 : 1.128 : 1.224.$$

$C = \bar{C} \times 1.128$ and $C = 1.224 \times C_p$.

7. What is vapour pressure of liquids? How the vapour of a liquid is related to its boiling point?

Ans. The pressure exerted by vapour molecules of a liquid in equilibrium, on the surface of the liquid at a given temperature is called vapour pressure of the liquid.

Generally, the vapour pressure of a liquid is more, if the rate of evaporation is more. Vapour pressure of a liquid depends up on: nature of liquid, temperature and purity of the liquid.

With increase in the temperature the vapour pressure of a liquid increases exponentially but not linearly. The temperature at which the vapour pressure of the liquid becomes equal to one bar pressure is called standard boiling point of the liquid.

8). Calculate the RMS velocity, average velocity and most probable velocity of CO_2 at 27^0C?

Solution: Absolute temperature = T = 300 K

Gram molecular weight = M = 44 g mol^{-1}

Gas constant = R = 8.314×10^7 erg k^{-1} mol^{-1}

RMS velocity (C) = $\sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.314 \times 300 \times 10^7}{44}} = 4.12 \times 10^4 cm\ s^{-1}$ =412 ms^{-1}

Most probable velocity (C_p) = 0.8166 × C = 0.8166 × 412 = 336 ms^{-1}

Average velocity = = 0.9213 x 412 = 381 ms^{-1}

9. 300cc of methane diffused through a porous membrane in 15min. Under identical conditions 120cc of gas 'X' diffused in 10 min. Calculate the molecular weight of 'X'?

Solution:

Rate of diffusion of methane = 300 / 15 = 20 cc m^{-1},

Rate of diffusion of gas 'X' = 120 / 12 = 10 cc m^{-1}

Ratio of rates of diffusion is given as

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} = \frac{20}{10}. \quad \sqrt{\frac{M_2}{M_1}} \Rightarrow 2 = \sqrt{\frac{M_2}{16}}$$

Molecular weight of 'X' = $2^2 \times 16 = 64$

Very Short Answer Questions

1. What is an absolute Temperature?

Ans. Temperature expressed in kelvin scale is called absolute temperature. This is denoted by T.

T (in K) = (t°C + 273) K.

2). Why is gas constant (R) called universal gas constant?

Ans. 'R' is called universal gas constant as its value is same for all gases at S.T.P

3. What is an ideal gas?

Ans. The Gas which obeys Boyle's law, Charle's law and Avogadro's law is called an ideal gas.

4.What are standard temperature and pressure conditions? What is the volume of one mole of an ideal gas under these conditions?

Ans. The temperature 273.15K (0^oC) and the pressure 1 bar i.e., exactly 10^5 Pascals are called **standard** temperature and pressure conditions. At STP conditions the molar volume is 22.711 lit. mol^{-1}

5). Which gas diffuses faster among N_2, O_2, CH_4 gases? Why?

Ans. CH_4 diffuses faster as its molecular weight is lower than reaming two gases. $r \propto \frac{1}{\sqrt{M}}$

6. How many times methane diffuses faster than sulphur dioxide?

Ans. $\frac{r_{CH_4}}{r_{SO_2}} = \sqrt{\frac{M_{SO_2}}{M_{CH_4}}} = \sqrt{\frac{64}{16}} = 2$. Methane diffuses 2 times faster than sulphur dioxide

7. Give the relation between partial pressure and mole fraction of a gas?

Ans. Partial pressure = Total pressure X Mole-fraction

8.What is Boltzmann constant? Write its value?

Ans. Boltzmann constant is the gas constant per one molecule. It is given as the ratio of Universal gas constant and Avogadro number.

$k = \frac{R}{N_0}$ the value of Boltzmann constant, $k = 1.38 \times 10^{-23} J\ K^{-1}\ molecule^{-1}$

9. Find the kinetic energy of 2 moles of an ideal gas in calories at 27°C?

Ans. Kinetic energy is given as (K.E.) = $\frac{3}{2}$ nRT

$$= \frac{3}{2} x2x2x300 = 1800 calories.$$

10. Why RMS velocity is used in the derivation of kinetic gas equation?

Ans. RMS velocity is used in the derivation of kinetic gas equation as it is the most accurate velocity among the three types of velocities of a gas and it represents the velocity of all gas molecules

11. What is Boyle Temperature?

Ans. The temperature at which real gas behaves like ideal gas and obeys the gas laws over a wide range of pressure is called Boyle temperature or **Boyle** point and is denoted by 'T_b'

12. What is compressibility factor?

Ans. The ratio of real volume of a gas to that of its ideal volume is called compressibility factor. It is a measure to deviation from ideal gas behavior.

Compressibility factor (Z) = $\frac{molar\ volume\ of\ the\ gas (V)}{molar\ volume\ of\ perfect\ gas (V_{perfect})}$

Or Z = PV / nRT (per n moles of gas)

13. What is critical temperature? What is the critical temperature of the CO_2 gas?

Ans. The temperature above which the gas can't be liquefied by the application of pressure is called critical temperature **(**T_C). For CO_2 gas critical temperature is 31.1^0C.

14. What are critical pressure and critical volume?

Ans. The pressure of a gas at its critical temperature is called critical pressure (P_C).

The Volume of one mole of gas at critical temperature (T_C) and critical pressure (P_C) is called critical volume (V_C)

15. What is coefficient of viscosity? Give its units?

Ans. Viscosity coefficient is defined as the force when velocity gradient and area of contact each is unity. It is a measure of viscosity. Its units $dynes.cm^{-2}.\sec org.cm^{-1}.\sec^{-1} =$ **1 poise.**

16. Calculate the kinetic energy of 5 moles of Nitrogen at 27°C?

Ans. Kinetic energy is given as (K.E.) = $\frac{3}{2}$ nRT= $\frac{3}{2}$x5x8.314 x300 = 18706.5 J.

17. Calculate the kinetic energy (in S.I units) of 4 gm of methane at -73°C?

Ans. No. of moles of methane, n=4/16=0.25

Kinetic energy is given as (K.E.) = $\frac{3}{2}$ nRT

= $\frac{3}{2}$x0.25x8.314 x200 = 623.6 J.