Long Answer Type Questions

Q. 1. (a) Find the pressure of 4 g of O_2 and 2 g of H_2 confined in a bulb of 1 liter at 0ºC.

(b) What is the molar volume of a gas at SATP conditions?
(c) Define and explain Gay Lussac's law. [DDE, 2017-18]

Ans. (a) Number of moles of O_2

$$= \frac{\text{Mass of } O_2}{\text{Molar mass of } O_2} = \frac{4}{32} = 0.125$$

$$= \frac{\text{Mass of } H_2}{\text{Molar mass of } H_2} = \frac{2}{2} = 1$$

Total moles = 0.125 + 1 = 1.125

According to ideal gas equation, -

PV = nRT

[V = 1 L, n = 1.125 moles, T = 0 + 273 = 273 K, P =?]

$$\therefore\ P = \frac{nRT}{V}$$

$$= \frac{1.125 \text{ moles } \times\ 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}\ \times 273 \text{ K}}{1\ L}$$

= 25.215 atm

(b) At SATP, the molar volume of a gas is 24.789 L mol^{-1}

(c) Gay Lussac's Law: According to this law, "At constant volume, pressure of a fixed amount of a gas varies directly with the temperature." Mathematically, $P \propto T$

Or $\frac{P}{T} = \text{constant} = \text{K}$

Q. 2. (a) For Dalton's law of partial pressure, derive the expression $P_{gas} = X_{gas} . P_{total}$

(b) A 2 L flask contains 1.6 g of methane and 0.5 g of hydrogen at 27°C. Calculate the partial pressure of each gas in the mixture and hence, calculate the total pressure. [DDE, 2017-18]

Ans. (a) Suppose, at temperature T, these gases, enclosed in the volume V, exert partial pressure P_1, P_2 and P_3, respectively. Then,

$$P_1 = \frac{n_1\ RT}{V} \qquad ...(i)$$

$$P_2 = \frac{n_2\ RT}{V} \qquad \ldots (ii)$$

$$P_3 = \frac{n_3\ RT}{V} \qquad \ldots (iii)$$

Where, n_1, n_2 and n_3 = Number of moles of these gases

∴ Total pressure $P_{total} = P_1 + P_2 + P_3$

$$= n_1 \frac{RT}{V} + n_2 \frac{RT}{V} + n_3 \frac{RT}{V}$$

$$= (n_1 + n_2 + n_3) \frac{RT}{V} \qquad \ldots (iv)$$

On dividing P_1 by P_{total}, we get,

$$\frac{P_1}{P_{total}} = \left(\frac{n_1}{n_1 + n_2 + n_3}\right) \frac{RTV}{RTV}$$

$$= \frac{n_1}{n_1 + n_2 + n_3} = \frac{n_1}{n} = X_1$$

Where X_1 = mole fraction of first gas

∴ $P_1 = X_1 P_{total}$

Similarly, for other two gases

$P_2 = X_2 P_{total}$

$P_3 = X_3 P_{total}$

General equation can be written as:

$$\boxed{P_{gas} = X_{gas} . P_{total}}$$

(b) V = 2L, T = 27 + 273 = 300K

Number of moles of CH_4

$$= \frac{\text{Mass of CH}_4}{\text{Molar mass of CH}_4}$$

$$= \frac{1.6}{16} = 0.1\ mol$$

Number of moles of H_2

$$= \frac{\text{Mass of H}_2}{\text{Molar mass of H}_2}$$

According to ideal gas equation,

PV = nRT

Partial pressure of CH_4 (P_{CH4}) = $\frac{nRT}{V}$

$$= \frac{0.1 \text{ mol } \times 0.0821 \text{ L atm } K^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{2\, L}$$

= 1.23 atm

Partial pressure of H_2 (P_{H2}) = $\frac{nRT}{V}$

$$= \frac{0.25 \text{ mol } \times 0.0821 \text{ L atm } K^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{2\, L}$$

= 3.079 atm

Total pressure = 1.23 + 3.079 = 4.31 atm

Q. 3. Mention the intermolecular forces present between

(a) H_2O and alcohol
(b) Cl_2 and CCl_4
(c) He and He atoms
(d) Na^+ ion and H_2O
(e) HBr and HBr [DDE, 2017-18]

Ans. (a) H_2O and alcohol - Hydrogen bonding

(b) Cl_2 and CCl_4,- London forces

(c) He and He atoms - van der Waals forces

(d) Na^+ ion and H_2O Dipole-dipole forces

(e) HBr and HBr- Dipole - dipole forces

Q. 4. A gaseous molecule has radius of about 0.4 nm. Assuming that this molecule is spherical in shape, calculate.

(i) Volume of single molecule of gas
(ii) The percentage of empty space in one mole of gas at STP.

Ans. (i) Radius (r) = 0.4 nm

= 0.4×10^{-9} m = 0.4×10^{-7} cm

= 4×10^{-8} cm

∴ Volume of a sphere = $\frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times \frac{22}{7} \times (4 \times 10^{-8})^3 cm^3$$

$= 2.68 \times 10^{-22}$ cm^3

(ii) Volume of 6.022×10^{23} molecules of gas = $268 \times 10^{-22} \times 6.022 \times 10^{23}$ = 161.39 cm^3

∴ Volume occupied by 1 mole of gas at STP

= 22.4 L = 22400 cm^3

Empty volume = Total volume of gas –

Volume occupied by molecules

= 22400 - 161.39 = 22238.61 cm^3

∴ Percentage empty space

$$= \frac{\text{empty space}}{\text{total volume}} \times 100$$

$$= \frac{22238.61}{22400} \times 100 = 99.28\%$$

Hence, 99.28% of space of 1 mole of gas at STP in empty.

Q. 5. Why at extremely low pressures, the real gases obey the ideal gas equation?

Ans. At low pressures, volume V is very large and hence the correction term b (volume correction term) can be neglected in comparison to very large value of V. Thus, the van der Waals equation for 1 mole of a real gas.

$\left(p + \frac{a}{V^2}\right)(V - b)$ RT may be written as

$$\left(p + \frac{a}{V^2}\right)(V) = RT$$

Or PV + $\frac{a}{V}$ = RT

PV = RT – $\frac{a}{V}$

For large V (at very low pressure), $\frac{a}{V}$ is very small and can be ignored.

∴ PV becomes RT at very low pressure. That is why at very low pressure, real gases obey ideal gas equation.

Q. 6. Using the Kinetic gas equation show that the average kinetic energy per mole of gas is given by $\frac{3}{2}$ RT.

Ans. From the Kinetic model for gases

PV = $\frac{1}{3}$ mN c^{-2}

For 1 mole of the gas

PVm = $\frac{1}{3}$ mNA c^{-2}

$= \frac{1}{3}$ m c^{-2}

For ideal gas PVm = RT

$\frac{1}{3}$ mc^{-2} = RT

$$\frac{2}{3} \cdot \frac{1}{2} mc^{-2} = RT$$

$$\frac{1}{2} mc^{-2} = \frac{3}{2} RT$$

But $\frac{1}{2}$ mc^{-2} Average kinetic energy per mole gas (K.E).

Hence K.E = $\frac{3}{2} RT$

Q. 7. What are the postulates of Kinetic theory of gases?

Ans. The important postulates of Kinetic theory of gases are:

(i) All gases are made up of a very large number of minute particles called molecules.

(ii) The molecules are separated from one another by large distances. The empty spaces among the molecules are so large that the actual volume of the molecules is negligible as compared to the total volume of the gas.

(iii) The molecules are in a state of constant rapid motion in all the directions. During their motion, they keep on colliding with one another and also with the walls of the container and thus, change their directions.

(iv) Molecular collisions are perfectly elastic, i.e., no loss of energy occurs when the molecules collide with one another or with the walls of the container. However, there may be redistribution of energy during the collisions.

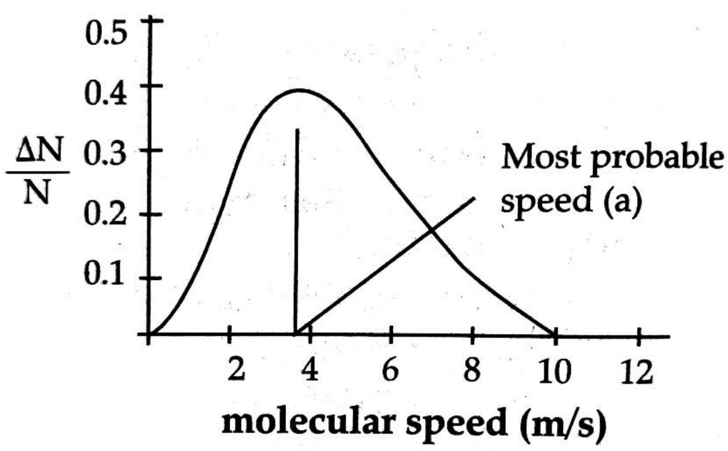
(v) There are no forces of interaction (attractive or repulsive) between molecules. They move completely independent of one another.

(vi) The pressure exerted by the gas is due to the bombardment of its molecules on the walls of the container per unit area.

(vii) The average kinetic energy of the gas molecules is directly proportional to the absolute temperature.

Q. 8. What is the concept of Maxwell: Boltzmann distribution of molecular speeds, at a given temperature in a gas sample?

Ans. A gas consists of tiny particles (atoms or molecules) separated from one another by large spaces. These particles are constantly moving in all directions. During their motion, they collide with one another and also with the walls of the container. As a result of collisions, the speed and the direction of the molecules keep on changing. Thus, all the molecules present in given sample of a gas do not possess the same speed. The speeds of individual molecules are different and are distributed over a wide range. The speeds of different molecules keep on changing However, the distribution of speed among different molecules remains the same at particular temperature although the individual speeds of the molecules may change. The distribution of molecules between different possible speeds was given by Maxwell and Boltzmann. He plotted the fraction of molecules, i.e., (along y-axis) having different speeds against the speeds of the molecules (along x-axis). The curve so obtained is shown in figure below and is known as Maxwell's distribution curve.



The important features of Maxwell's distribution curve can be summarized as follows:

(i) The fraction of molecules with very low or very high speeds is very small.

(ii) The fraction of molecules possessing higher and higher speeds goes on increasing till it reaches the peak and then it starts decreasing.

(iii) The maximum fraction of molecules possesses a speed corresponding to the peak in the curve. The speed corresponding to the peak in the curve is referred to as most probable speed.

Q. 9. (a) What is the reason of cleaning action of soap and detergents?

(b) Define boiling point of a liquid.
(c) Which will have higher viscosity: Glycerol or Ethylene glycol?
(d) Surface tension of a liquid ………… with increase in the magnitude of

intermolecular forces.
(e) Liquids are much less compressible than gases. Why?

Ans. (a) Cleaning action of soap and detergents is due to lowering of surface tension between water and greasy substances.

(b) The temperature at which vapour pressure of liquid becomes equal to the external pressure is known as boiling point of a liquid.

(c) Glycerol has higher viscosity because glycerol has more extent of hydrogen bonding than ethylene glycol.

(d) Surface tension of a liquid increases with increase in the magnitude of intermolecular forces.

(e) Liquids are much less compressible than gases because the intermolecular distances of separation are much smaller in liquids than in gases.