

## Solved Examples

### JEE Main/Boards

**Example 1:** At 27°C, volume of 95 mL of N<sub>2</sub>O is collected in a graduated tube over mercury, the level of mercury inside the tube being 60 mm above the outside mercury level when barometer reads 750 mm.

(a) What is the volume of the same mass at STP?

(b) What volume would the same mass of a gas occupy at 40°C when the barometer pressure is 745 mm and the level of mercury inside the tube is 25 mm below the outside level?

**Sol:** Use the combined gas law equation.

(a) Given, T = 300 K

At STP,

$$V = (95/1000) \text{ mL}; V = ?$$

$$P = (750 - 60) \text{ mm} = 690 \text{ mm}, P = 1 \text{ atm} \\ = (690/760) \text{ atm}, T = 273 \text{ K}$$

$$\therefore \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \\ \frac{690 \times 95}{760 \times 300 \times 1000} = \frac{1 \times V}{273}$$

$$V = 0.07848 \text{ L} = 78.48 \text{ mL}$$

(b) At T = (40 + 273) K = 313 K [case (a) data]

$$P = (745 + 25) \text{ mm} = 770 \text{ mm}, T = 300 \text{ K}$$

$$= \frac{770}{760} \text{ atm} \quad P = \frac{690}{760} \text{ atm}$$

$$V = ? \quad V = \left( \frac{95}{1000} \right) \text{ L}$$

$$\therefore \text{Using } \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \\ \frac{770 \times V}{760 \times 313} = \frac{690 \times 95}{760 \times 1000 \times 300}$$

$$V = 0.0888 \text{ L} = 88.8 \text{ mL}$$

**Example 2:** At 27°C, an open flask contains air. Determine the temperature at which it should be heated so that:

(a) 1/3rd of the air measured at 27°C escapes out.

(b) 1/3rd of the air measured at the final temperature escapes out.

**Sol:** (a) Suppose initial moles of gas = n at temperature = 300 K. The gas on heating to TK lose (n/3) moles  
∴ Moles of the gas left at temperature T = n - (n/3)  
= (2n/3)

At constant P and V,  $n_1 T_1 = n_2 T_2$

$$n \times 300 = (2n/3)T$$

$$\therefore T = 450 \text{ K} = 177^\circ\text{C}$$

(b) Suppose moles present at TK = n

Moles coming out at TK = n/3

Hence, moles at 300 K should be

$$n + (n/3) = 4n/3$$

Therefore,  $n_1 T_1 = n_2 T_2$

$$n \times T = (4n/3) \times 300 \quad \therefore T = 400 \text{ K} = 127^\circ\text{C}$$

**Example 3:** Calculate the final pressure of O<sub>2</sub> in the following experiment: a collapsed polythene bag of 30 L capacity is partially blown up by the addition of 10 L of N<sub>2</sub> at 0.965 atm at 298 K. Subsequently, enough O<sub>2</sub> is pumped into the bag so that at the temperature of 298 K and external pressure of 0.990 atm, the bag contains a volume of 30 L.

**Sol:** Initial condition,  $P_{N_2} = 0.965 \text{ atm}$ ,

$$V = 10 \text{ L}, T = 298 \text{ K}$$

O<sub>2</sub> is now introduced to expand the bag fully to 30 L. N<sub>2</sub> also occupies a volume of 30 L at 298 K.

∴ For N<sub>2</sub> alone, new pressure has to be calculated by the following equation:

$$P_1 V_1 = P_2 V_2$$

$$0.965 \times 10 = P_{N_2} \times 30$$

$$\therefore P_{N_2} = 0.322 \text{ atm (at 30-L volume)}$$

$$\text{Total pressure} = P_{O_2} + P_{N_2}$$

$$\therefore P_{O_2} = P_T - P_{N_2} = 0.990 - 0.322 = 0.668 \text{ atm}$$

**Example 4:** Two bulbs A and B having equal capacity are filled with He and SO<sub>2</sub>, respectively, at the same temperature.

(i) If the pressure in the two bulbs is the same, what will be the ratio of rms speed of the molecules of the two

gases?

- (ii) At what temperature, the speed of  $\text{SO}_2$  molecules becomes half of the speed of He
- (iii) How does the speed change if the volume of B becomes 4 times that of A at the same temperature?
- (iv) How does the speed change if half of the molecules of  $\text{SO}_2$  are removed from B?

**Sol:** (i) For He:  $u_{\text{rms}} = \sqrt{[(3RT)/M]} = \sqrt{[(3RT)/4]}$

For  $\text{SO}_2$ :  $u_{\text{rms}} = \sqrt{[(3RT)/M]} = \sqrt{[(3RT)/64]}$

$$\frac{u_{\text{rms}} \text{ of He}}{u_{\text{rms}} \text{ of SO}_2} = 4$$

(ii) Given,  $u_{\text{rms}}$  of  $\text{SO}_2 = \left(\frac{1}{2}\right) u_{\text{rms}}$  of He at  $27^\circ\text{C}$

$$\therefore \sqrt{\frac{3RT}{64}} = \frac{1}{2} \sqrt{\frac{3R \times 300}{4}} \quad \therefore T = 1200 \text{ K}$$

(iii)  $u_{\text{rms}} = \sqrt{[(3RT)/M]}$  and, thus, independent of P and V terms. Thus, there is no change in  $u_{\text{rms}}$  on changing the volume.

(iv)  $u_{\text{rms}} = \sqrt{[(3RT)/M]}$  and, thus, independent of the number of molecules and therefore no change in  $u_{\text{rms}}$  by the changing molecules

**Example 5:** A liquefied petroleum gas (LPG) cylinder weighs 14.8 kg when empty. When full, it weighs 29.0 kg and has a pressure of 2.5 atm. At  $27^\circ\text{C}$ , the weight of the full cylinder in the course of its use reduces to 23.2 kg. Calculate the volume of the gas in cubic meters used up under the normal usage conditions and the final pressure inside the cylinder. Assume LPG to be n-butane with a normal boiling point of  $0^\circ\text{C}$ .

**Sol:** Calculate the decrease in the amount which can be used to find the volume.

Decrease in the amount of

$$\text{LPG} = 29.0 - 23.2 = 5.8 \text{ kg} = \text{moles } \frac{5800}{58} = 100 \text{ moles}$$

Volume of 100 moles at a pressure of 1 atm and at a temperature of 300 K =  $\frac{nRT}{p}$

$$= \frac{100 \text{ moles} \times 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{1 \text{ atm}}$$

$$= 2463 \text{ L} = 2463 \times 10^{-3} \text{ m}^3 = 2.463 \text{ m}^3$$

Final pressure inside the cylinder

As the cylinder contains LPG in equilibrium with its vapors, as long as the temperature remains constant and some LPG is present, pressure will remain constant. As the cylinder still contains  $\text{LPG} = 23.2 - 14.8 = 8.4 \text{ kg}$ , the pressure inside the cylinder will be the same, i.e. 2.5 atm.

**Example 6:** What is the pressure exerted by 1 mole of  $\text{CO}_2$  gas at a temperature of 273 K if the van der Waals' constant 'a' =  $3.592 \text{ dm}^6 \text{ atm mol}^2$ . Assume that the volume occupied by the  $\text{CO}_2$  molecules is negligible.

**Sol:** According to the van der Waals' equation:

$$P + (a/V^2)[V - b] = RT \quad (\text{for 1 mole})$$

If b is negligible, then  $[P + (a/V^2)][V] = RT$

$$\text{or } PV = RT - (a/V) \text{ or } P = \frac{RT}{V} - \frac{a}{V^2}$$

$$\text{or } V^2P - RTV + a = 0$$

$$\text{or } V = \frac{+RT \pm \sqrt{(-RT)^2 - 4Pa}}{2P}$$

As the volume of gas is constant at constant P and T, V can have only one value or discriminant, i.e. 0

$$\text{or } R^2T^2 - 4Pa = 0$$

$$\text{or } P = \frac{R^2T^2}{4a} = \frac{(0.0821)^2 \times (273)^2}{4 \times 3.592} = 34.98 \text{ atm}$$

**Example 7:** A mixture of ethane ( $\text{C}_2\text{H}_6$ ) and ethene ( $\text{C}_2\text{H}_4$ ) occupies a volume of 40 L at 1.00 atm and 400 K. The mixture reacts completely with 130 g of  $\text{O}_2$ , producing  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . Assuming the ideal gas behavior, calculate the mole fractions of  $\text{C}_2\text{H}_4$  and  $\text{C}_2\text{H}_6$  in the mixture.

**Sol:** Combustion reactions of ethane and ethene with the calculation of no. of moles by using ideal gas equation is done.

For a gaseous mixture of  $\text{C}_2\text{H}_6$  and  $\text{C}_2\text{H}_4$

$$PV = nRT$$

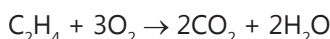
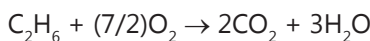
$$\therefore 1 \times 40 = n \times 0.082 \times 400$$

$$\therefore n = 1.2195$$

$$\therefore \text{Total moles of } \text{C}_2\text{H}_6 + \text{C}_2\text{H}_4 = 1.2195$$

Let moles of  $\text{C}_2\text{H}_6$  and  $\text{C}_2\text{H}_4$  be a and b, respectively

$$a + b = 1.2195 \quad \dots (i)$$



$\therefore$  Moles of  $\text{O}_2$  needed for complete reaction of the mixture =  $(7a/2) + 3b$

$$\therefore \frac{7a}{2} + 3b = \left(\frac{130}{32}\right) \quad \dots \text{(ii)}$$

From equations (i) and (ii),  $a = 0.808$ ,  $b = 0.4115$

$$\therefore \text{Mole fraction of } C_2H_6 = 0.808/1.2195 = 0.66$$

$$\text{Mole fraction of } C_2H_4 = 0.34$$

**Example 8:** The pressure in a bulb dropped from 2000 to 1500 mm of Hg in 47 minutes when the contained  $O_2$  leaked through a small hole. Then, the bulb was completely evacuated. A mixture of  $O_2$  and another gas of molecular weight of 79 in the molar ratio of 1:1 at a total pressure of 4000 mm of Hg was introduced. Calculate the mole ratio of the two gases remaining in the bulb after a period of 74 minutes.

**Sol:** Pressure of  $O_2$  (at  $t = 0$ ) = 2000 mm

Let  $n_1$  moles be taken initially

Pressure of  $O_2$  (at 47 min) = 1500 mm

Let  $n_2$  moles be left after 47 min

$$\therefore \text{For pure } O_2: \frac{P_1}{P_2} = \frac{n_1}{n_2}$$

$$\therefore \frac{n_1}{n_2} = \frac{2000}{1500} = \frac{4}{3} \quad \therefore n_2 = \left(\frac{3}{4}\right)n_1$$

$\therefore$  Moles of  $O_2$  diffused in 47 min

$$= n_1 - (3n_1/4) = (n_1/4)$$

$\therefore$  Mole of  $O_2$  will diffuse in 74 min

$$= \frac{n_1}{4} \times \frac{74}{47} = \frac{74}{188} n_1 = 0.3936 \text{ (assume } n_1 = 1)$$

Now, diffusion of  $O_2$  in the mixture also occurs at partial pressure of 2000 mm (the ratio of gas and  $O_2$  being 1: 1)

When both  $O_2$  and the gas diffuse simultaneously at

$$2000 \text{ mm pressure, then for 74 min, } \frac{n_{O_2}}{74} \times \frac{74}{n_g} = \sqrt{\frac{79}{32}}$$

$$\therefore n_g = n_{O_2} \times \sqrt{(32/79)}$$

$$= 0.3936 \times \sqrt{(32/79)} = 0.249$$

$\therefore$  Moles of  $O_2$  left after 74 min

$$= 1 - 0.3936 = 0.6064$$

Moreover, moles of the gas left after 74 min

$$= 1 - 0.249 = 0.7510$$

$$\therefore n_{O_2} : n_g = 0.6064 : 0.7510 : 1 : 1.236$$

**Example 9:** A long rectangular box is filled with  $Cl_2$  (atomic weight 35.45), which is known to contain only  $Cl^{35}$  and  $Cl^{37}$ . If the box can be divided by a partition and the two types of chlorine molecules put into the two compartments, respectively, determine where should be the partition made if the pressure on both the sides is to be same. Is this pressure the same as the original pressure?

**Sol:** At constant P and T, the volume of a gas  $\propto$  the number of moles, i.e. the mole ratio yields the volume ratio. Thus, the partition should be made in the volume ratio of 3.44: 1. Moreover, pressure at this condition is same as at the original condition since the volume of the box and number of moles along with temperature are constant. Suppose  $n_1$  and  $n_2$  be moles of  $Cl^{35}$  and  $Cl^{37}$  in the mixture, respectively

$$\text{Average molecular weight} = \frac{35 \times n_1 + 37 \times n_2}{n_1 + n_2}$$

$$\therefore 35.45 = \frac{35n_1 + 37n_2}{n_1 + n_2} \text{ or } \frac{n_1}{n_2} = 3.44$$

$$\therefore PV_1 = n_1RT; PV_2 = n_2RT$$

$$\therefore \frac{V_1}{V_2} = \frac{n_1}{n_2}$$

**Example 10:** Determine the critical constants of a gas whose van der Waals' constants are

$$a = 0.751 \text{ L}^2 \text{ atm mol}^{-2} \text{ and}$$

$$b = 0.0226 \text{ L mol}^{-1}.$$

**Sol:** Refer the formulae sheet.

$$P_c = \frac{a}{27b^2} = \frac{0.751 \text{ L}^2 \text{ atm mol}^{-2}}{27 \times (0.0226 \text{ L mol}^{-1})^2} = 54.5 \text{ atm}$$

$$T_c = \frac{8a}{27Rb} = \frac{8 \times 0.75 \text{ L}^2 \text{ atm mol}^{-2}}{27 \times 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 0.0226 \text{ L mol}^{-1}}$$

$$= 120 \text{ K}$$

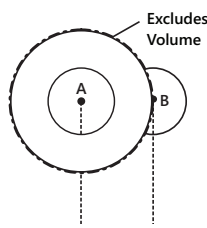
$$V_c = 3b = 3 \times 0.0226 \text{ L mol}^{-1} = 0.0678 \text{ L mol}^{-1}$$

## JEE Advanced/Boards

**Example 1:** Prove that the excluded volume 'b' is four times the actual volume of gas molecules.

**Sol:** Let us consider two molecules A and B. Taking the molecules to be spherical, if  $r$  is the radius of the molecules, then the distance of the closest approach

between the two molecules =  $2r$  (as shown in Fig.), which is the distance between the centers of their nuclei. As the molecules cannot come closer than the distance  $2r$ , the excluded volume for a pair of molecules = Volume of sphere of radius  $2r$ .



$$= \frac{4}{3} \pi (2r)^3 = 8 \times \frac{4}{3} \pi r^3$$

$\therefore$  The excluded volume per molecule (b)

$$= \frac{1}{2} \left( 8 \times \frac{4}{3} \pi r^3 \right) = 4 \times \frac{4}{3} \pi r^3$$

But  $\frac{4}{3} \pi r^3 = v_m$ , i.e. the actual volume of the gas molecule

$$\therefore b = 4v_m$$

**Example 2:** At  $27^\circ\text{C}$ , an open vessel is heated until  $\frac{3}{5}$  parts of the air in it has been expelled. Assuming that the volume of the vessel remains constant, determine the temperature to which the vessel has been heated.

**Sol:** Since the vessel is open, pressure and volume remain constant. Therefore, if  $n_1$  moles are present at  $T_1$  and  $n_2$  moles are present at  $T_2$ , we can write  $PV = n_1RT_1$  and also  $PV = n_2RT_2$

$$\text{Thus, } n_1RT_1 = n_2RT_2 \text{ or } n_1T_1 = n_2T_2$$

$$\text{or } \frac{n_1}{n_2} = \frac{T_1}{T_2} \quad \dots\dots (i)$$

Let us suppose the number of moles of air originally present =  $n$

After heating, the number of moles of air expelled =  $\frac{3}{5}n$

$\therefore$  The number of moles left after heating

$$= n - \frac{3}{5}n = \frac{2}{5}n$$

$$\text{Hence, } n_1 = n, T_1 = 300 \text{ K; } n_2 = \frac{2}{5}n, T_2 = ?$$

Substituting in equation (i), we get

$$\frac{n}{\frac{2}{5}n} = \frac{T_2}{300} \text{ or } \frac{5}{2} = \frac{T_2}{300} \text{ or } T_2 = 750 \text{ K}$$

Alternatively, let the volume of the vessel be  $V$ , i.e. volume of air initially at  $27^\circ\text{C} = V$

$$\text{Volume of air expelled} = \frac{3}{5}V$$

$$\therefore \text{The volume of air left at } 27^\circ\text{C} = \frac{2}{5}V$$

On heating to  $T^\circ\text{K}$ , it would become =  $V$

As the pressure remains constant, (vessel being open),

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}, \text{ i.e., } \frac{2/5V}{300\text{K}} = \frac{V}{T_2} \text{ or } T_2 = 750 \text{ K}$$

**Example 3:** A perfectly elastic spherical balloon having a diameter of  $0.2 \text{ m}$  was filled with hydrogen at sea level. Calculate its diameter when it has risen to an altitude where the pressure is  $0.65 \text{ atm}$ . (Assume that there is no change in temperature and atmospheric pressure at sea level.)

**Sol:** If  $r_1$  is the radius of the balloon at sea level, volume

$$\text{of the balloon at sea level} = \frac{4}{3} \pi r_1^3 = \frac{4}{3} \pi (0.1 \text{ m})^3 \text{ i.e. the}$$

$$\text{volume of the gas at sea level } (V_1) = \frac{4}{3} \pi (0.1 \text{ m})^3$$

Pressure at the sea level ( $P_1$ ) =  $1 \text{ atm}$

Let the radius of the balloon at altitude be  $r_2$

$$\text{Volume of the balloon at altitude } (V_2) = \frac{4}{3} \pi r_2^3$$

Pressure at the altitude ( $P_2$ ) =  $0.65 \text{ atm}$  (given)

As the temperature remains constant, applying Boyle's

$$\text{law } P_1V_1 = P_2V_2$$

(At sea level) (At altitude)

$$1 \text{ atm} \times \frac{4}{3} \pi (0.1 \text{ m})^3 = 0.65 \text{ atm} \times \frac{4}{3} \pi r_2^3 \quad \text{or}$$

$$r_2^3 = \frac{(0.1\text{m})^3}{0.65} = 1.54 \times 10^{-3} \text{ m}^3$$

$$\therefore r_2 = (1.54 \times 10^{-3})^{1/3} \text{ m} = 0.1154 \text{ m}$$

$$\therefore \text{The diameter of the balloon at altitude} = 2 \times 0.1154 \text{ m} = 0.2308 \text{ m}$$

**Example 4:** Assuming oxygen molecule to be spherical in shape, find out the volume of a single molecule of oxygen if its radius is  $150 \text{ pm}$ . Calculate the percentage of empty space in one mole of the gas at STP.

**Sol:** As oxygen molecule is spherical, volume of one

$$\text{molecule} = \frac{4}{3} \pi r^3 = \frac{4}{3} \times \frac{22}{7} (150 \times 10^{-10} \text{ cm})^3$$

$$= 1.41 \times 10^{-23} \text{ cm}^3$$

To calculate the empty space in 1 mole of  $\text{O}_2$  molecules, let us first calculate the volume occupied by 1 mole of the molecules, i.e.  $6.022 \times 10^{23}$  molecules, which will be

$$= (6.022 \times 10^{23}) \times (1.41 \times 10^{-23} \text{ cm}^3) = 8.49 \text{ cm}^3.$$

Volume occupied by 1 mole of molecules at STP = 22,400 cm<sup>3</sup>

$$\therefore \text{Empty space} = 22400 - 8.49 \text{ cm}^3 = 22391.51 \text{ cm}^3$$

$$\% \text{ of empty space} = \frac{22391.51}{22400} \times 100 = 96.96\%$$

**Example 5:** A spherical balloon having a diameter of 21 cm is to be filled with hydrogen at NTP from a cylinder containing the gas at 20 atm at 27°C. If the cylinder can hold 2.82 L of water, then calculate the number of balloons that can be filled up.

**Sol:** To find the no. of balloons, volume of one balloon can be equated with the available gas to be filled.

Volume of the balloon

$$= \frac{4}{3} \pi r^3 = \frac{4}{3} \times \frac{22}{7} \times \left(\frac{21}{2}\right)^3 = 4851 \text{ cm}^3$$

$$\text{Volume of the cylinder} = 2.82 \text{ L} = 2820 \text{ cm}^3$$

Pressure = 20 atm

Temperature = 300 K

Converting this to the volume at NTP, we get

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \therefore \frac{20 \times 2820}{300} = \frac{1 \times V_2}{273}$$

$$\text{or } V_2 = 51324 \text{ cm}^3$$

When the pressure in the cylinder is reduced to 1 atm, no more H<sub>2</sub> will be released and thus 2820 cm<sup>3</sup> of H<sub>2</sub> will be left in it. Therefore, the volume of H<sub>2</sub> used in filling the balloons

$$= 51324 - 2820 \text{ cm}^3$$

$$= 48504 \text{ cm}^3$$

$$\text{Number of balloons filled} = 48504/4851 = 10$$

**Example 6:** A liquefied petroleum gas (LPG) cylinder weighs 14.8 kg when empty. When full, it weights 29.0 kg and has a pressure of 2.5 atm. At 27°C, the weight of the full cylinder in the course of its use has reduced to 23.2 kg. Calculate the volume of the gas in cubic meters used up under the normal usage conditions and the final pressure inside the cylinder. Assume LPG to be n-butane with a normal boiling point of 0°C.

**Sol:** Weight of butane in the cylinder

$$= 29.0 - 14.8 = 14.2 \text{ kg} = 14.2 \times 10^3 \text{ g}$$

P = 2.5 atm, T = 300 K, molecular weight of butane = 58

$$\therefore PV = \frac{w}{m} RT$$

$$2.5 \times V = \frac{14.2 \times 10^3}{58} \times 0.0821 \times 300$$

$$V = 2.4120 \times 10^3 \text{ L} = 2.4120 \text{ m}^3$$

This is the volume of the cylinder or the volume of the gas.

Now, the weight of the gas left after use = 23.2 – 14.8

$$= 8.4 \text{ kg} = 8.4 \times 10^3 \text{ g}$$

Volume remains constant

Using PV = (w/m) RT

$$P \times 2.412 \times 10^3 = \frac{8.4 \times 10^3}{58} \times 0.0821 \times 300$$

$$\therefore \text{Pressure (P) of the gas left in cylinder} = 1.48 \text{ atm}$$

Now, pressure of the gas given out = 1 atm

Weight of the gas given out = (29.0 – 23.2) kg

$$= 5.8 \text{ kg} = 5.8 \times 10^3 \text{ g}$$

Therefore, the volume of gas given out under these conditions is given by the following equation:

$$\therefore 1 \times V = \frac{5.8 \times 10^3}{58} \times 0.0821 \times 300$$

$$\therefore V = 2463 \text{ L} = 2.463 \text{ m}^3$$

**Example 7:** If the volume occupied by CO<sub>2</sub> molecules is negligible, then find out the pressure exerted by 1 mole of CO<sub>2</sub> gas at 273 K (a = 3.592 atm L<sup>2</sup> mol<sup>-2</sup>)

**Sol:** Using Vander Waal's equation, get a quadratic equation from which the pressure can be found.

$$\text{For 1 mole, } \left(P + \frac{a}{V^2}\right) (V - b) = RT$$

$$\text{If } b \text{ is negligible, then } \left(P + \frac{a}{V^2}\right) V = RT$$

$$\text{or } P = \frac{RT}{V} - \frac{a}{V^2} \text{ or } PV^2 - RTV + as = 0$$

This equation is found to be quadratic in V. Thus,

$$V = \frac{+RT \pm \sqrt{R^2 T^2 - 4aP}}{2P}$$

As V can have only one value at P and T, we must have

$$R^2 T^2 - 4aP = 0 \text{ or } R^2 T^2 = 4aP$$

$$\text{or } P = \frac{R^2 T^2}{4a}$$

$$= \frac{(0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1})^2 (273\text{K})^2}{4 \times 3.592 \text{ atm L}^{-2} \text{ mol}^{-2}} = 34.96 \text{ atm}$$

**Example 8:** (i) When a pressure deodorant can is used for a few seconds, the can tends to become cooler. Why?

(ii) When the ping pong ball, used as a toy by children, gets dented without being punctured, what do we do to regain the original shape and why?

(iii) Bottles and beer or soda cans have a label on them stating 'Store in a cool, dry place.' Why?

(iv) In winter, inflated football gets deflated. Why?

If you live in a centrally heated apartment and on a chilly winter day, you inflate a football inside your apartment and then go out to play, the football seems deflated. Why?

(v) Why hot air is filled in balloons for meteorological observations?

**Sol:** (i) On spraying the can, the liquid spray of the can is released. Thus, the pressure inside decreases a bit. As the can's volume does not change, the temperature falls.

(ii) We place the dented ping-pong ball in warm water to regain the original shape. As the temperature inside increases (i.e. air inside gets warmer), the pressure inside also increases. As a result, the dent gets removed.

(iii) The reason is that these cans have a lot of artificial pressure stored inside them. When exposed to direct sunlight/heat, the pressure inside the cans rises because the volume remains constant. The can explodes when the pressure exceeds a particular limit.

(iv) When the ball is brought outside, the temperature drops. As a result, the pressure of the air inside the football also drops, making the ball look deflated.

(v) When air is heated, it expands, resulting in the decrease of its density. Hence, hot air is lighter than atmospheric air, which helps the balloon to rise up.

**Example 9:** (i) The magnitude of surface tension of a liquid depends on the attractive forces between the molecules. Arrange the following in the increasing order of surface tension:

Water, alcohol ( $\text{C}_2\text{H}_5\text{OH}$ ) and hexane [ $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$ ].

(ii) The van der Waals' constants for two gases are as follows:

Gas	a (atm L <sup>2</sup> mol <sup>-2</sup> )	b (L mol <sup>-1</sup> )
X	1.39	0.0391
Y	3.59	0.0427

Which of the gases is more easily liquefiable and which has a greater molecular size?

(iii) At the same temperature, liquid is transferred from a smaller vessel to a bigger vessel. Determine the effect on the vapor pressure?

**Sol:** (i) In hexane, attractive forces are minimum (only London forces). Hydrogen bonding in  $\text{H}_2\text{O}$  is stronger as compared with the hydrogen bonding in  $\text{C}_2\text{H}_5\text{OH}$ . Thus, the order of surface tension is hexane < alcohol < water.

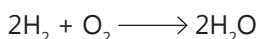
(ii) Greater the value of 'a,' more easily the gas gets liquefied. Also, greater the value of 'b,' greater is the molecular size. Thus, gas Y will be more easily liquefiable and will have a greater molecular size.

(iii) No effect since it depends only on the nature of the liquid and temperature.

**Example 10:** At NTP, a mixture of 1 L of  $\text{O}_2$  and 1 L of  $\text{H}_2$  is taken in a vessel of 2-L capacity. The gases are allowed to combine to form water. Determine (a) the moles and weight of water formed, (b) the amount of gas left in the vessel, (c) the total pressure if the vessel is heated to  $100^\circ\text{C}$  and (d) mole of  $\text{O}_2$  used for the formation of water.

**Sol:** Frame the reaction and lay down the values of the individual reacting species. Apply ideal gas equation to find out moles and to solve the volume of the species.

The given reaction is as follows:



Volume before    1    1    0

the reaction (in liters)

Volume after    0    0.5    1

the reaction (liters)

(a) At NTP, moles of  $\text{H}_2\text{O}$  formed = Moles of  $\text{H}_2$  used

$$= \frac{PV}{RT} = \frac{1 \times 1}{0.0821 \times 273} = 4.46 \times 10^{-2}$$

$\therefore$  The weight of  $\text{H}_2\text{O}$  formed

$$= 4.46 \times 10^{-2} \times 18 = 8.03 \times 10^{-1} \text{ g}$$

$$(b) \text{ Total moles of } \text{O}_2 \text{ left} = \frac{1 \times 0.5}{0.0821 \times 273} = 2.23 \times 10^{-2}$$

$\therefore$  The weight of  $\text{O}_2$  left =  $2.23 \times 10^{-2} \times 32 = 0.7136 \text{ g}$

(c) On heating to a temperature of  $100^\circ\text{C}$ ,  $\text{H}_2\text{O}$  exists as vapor

$\therefore$  Total moles present at a temperature of  $100^\circ\text{C}$

$$= \text{Moles of } \text{H}_2\text{O} + \text{Moles of } \text{O}_2$$

$$= 4.46 \times 10^{-2} + 2.23 \times 10^{-2}$$

$$= 6.69 \times 10^{-2} \text{ K}$$

Volume of the vessel = 2 L, T = 373 K

$$\therefore P = \frac{nRT}{V} = \frac{6.69 \times 10^{-2} \times 0.0821 \times 373}{2} = 1.02 \text{ atm}$$

(d) Volume of  $O_2$  used for the formation of  $H_2O$  = 0.5 L

$\therefore$  Moles of  $O_2$  used for the formation of  $H_2O$  at

$$NTP = \frac{0.5}{22.4} = 2.23 \times 10^{-2}$$

## JEE Main/Boards

### Exercise 1

**Q.1** Calculate the Kinetic energy in joules of the molecules in 8.0 g of methane gas at 27°C.

**Q.2** 3.7 g of a gas at 25°C occupied the same volume as 0.184 g of hydrogen at 17°C and at the same pressure. What is the molecular weight of the gas?

**Q.3** Calculate the density of  $NH_3$  gas at 30°C and 5 atmosphere pressure.

**Q.4** A desiccator of internal volume of 1 litre and containing nitrogen at 1 atmosphere pressure is partially evacuated to a final pressure of 7.6 mm of Hg, while the temperature remains constant what is the volume of the gas at this stage.

**Q.5** Calculate the volume of 6.0 g of hydrogen at 1.5 atmosphere and 273°C

**Q.6** When 3.2 g of sulphur is vaporized at 450°C and 723 mm pressure the vapour occupies a volume of 780 mL. What is the molecular formula of sulphur vapour under these condition?

**Q.7** The ratio of rates of diffusion of gases A and B is 1:4. If the ratio of their masses present in the mixture is 2:3 calculate the ratio of their mole fractions.

**Q.8** Calculate the volume occupied by 5 g of acetylene gas at 50°C and 740 mm pressure.

**Q.9** 1 molar mixture of He and  $CH_4$  is contained in a vessel at 20 bar pressure. Due to a hole in the vessel the gas mixture leaks out. What is the composition of the mixture effusing out initially?

**Q.10** The composition of equilibrium mixture ( $Cl_2 - 2Cl$ ) which is attained at 1200°C, is determined by measuring

the rate of effusion through a pinhole. It is observed that at 1.8 mm. Hg pressure, the mixture effuses 1.16 times as fast as Krypton effuses under the same condition. Calculate the fraction of chlorine molecules dissociated into atoms (At. wt. of Kr = 84).

**Q.11** 20 dm<sup>3</sup> of  $SO_2$  diffuse through a porous partition in 60 seconds. What volume of  $O_2$  will diffuse under similar condition in 30 seconds?

**Q.12** Calculate the root mean square speed of ozone kept in a closed vessel at 20°C and 82 cm mercury pressure.

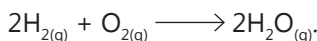
**Q.13** Oxygen is present in a 1.0 litre flask at pressure  $7.6 \times 10^{-10}$  mm Hg. Calculate the no. of oxygen molecules in the flask at 0°C.

**Q.14** Calculate the volume occupied at 27°C and 2 atmosphere of the gas evolved from 2 mL of solid carbon dioxide. Given that the density of solid carbon dioxide is 1.53 g/mL.

**Q.15** Calculate the relative rate of diffusion for  $^{235}UF_6$  and  $^{238}UF_6$  gaseous form.

**Q.16** The pressure exerted by 12 g of an ideal gas at temperature t°C in a vessel of volume V litres is one atmosphere. When the temperature is increased by 10° at the same volume, the pressure increased by 10%. Calculate the temperature t and volume V. (Molecular weight of the gas is 120).

**Q.17** A mixture in which the mole ratio of  $H_2$  and  $O_2$  is 2:1 is used to prepare water by the reaction



The total pressure in the container is 0.8 atmosphere at 20°C before the reaction. Determine the final pressure at 120°C after the reaction assuming 80% yield of water.

**Q.18** An open vessel at 27°C is heated until 3/5 of the air in it has been expelled. Assuming the volume of the vessel to be constant find the temperature to which the vessel was heat.

**Q.19** When 2 g of a gaseous substance (A) is introduced into an initially evacuated flask at 25°C, the pressure is found to be 1 atmosphere. 3.0 g of another gas (B) is then added to it at the same temperature and pressure. The final pressure is found to be 1.5 atmosphere. Assuming ideal gas behaviour calculate the ratio of molecular weights of (A) and (B).

**Q.20** At room temperature ammonia gas at one atmospheric pressure and hydrogen chloride at P atmosphere are allowed to effuse through identical pinholes from opposite ends of a glass tube of 1 meter length and of uniform cross-section.  $\text{NH}_4\text{Cl}$  is first formed at a distance of 60 cm from the end through which HCl gas is seat in. Find out the value of P

**Q.21** A plant virus is found to consist of uniform cylindrical particles of 150 Å m diameter and 500 Å long. The specific volume of virus is  $0.75 \text{ cm}^3/\text{g}$ . If the virus is considered to be a single particle find its molecular weight.

**Q.22** The mass of molecule A is twice the mass of molecule B. The r.m.s. speed of A is twice the r.m.s. speed of B. If two samples of A and B contain same no of molecules. What will be the ratio of P of two samples?

**Q.23** Two glass bulbs of equal volume are connected by a narrow tube and filled with a gas at 0°C and pressure of 76 cm of Hg. One of the bulb is then placed in a water bath maintained at 62°C. What is the new value of the pressure inside the bulbs the volume of the connecting tube is negligible.

**Q.24** A column of Hg of 10 cm in length is contained in the middle of a narrow 1 m long tube which is closed at both ends. Both the halves of the tube contained air at a pressure of 76 cm of Hg. By what distance will the column of Hg be displaced if the tube is held vertical?

**Q.25** Using Vander Waal's equation, calculate the constant 'a' when two moles of a gas confined in a four litre flask exerts a pressure of 11.0 atmosphere at a temperature of 300 K. The value of b is  $0.05 \text{ litre mol}^{-1}$ .

**Q.26** An evacuated glass vessel weighs 50.0 g when empty 148.0 g when filled with a liquid of density  $0.98 \text{ gmL}^{-1}$  and 50.5 g when filled with an ideal gas at 760 mm Hg at 300 K. Determine the molecular weight of the gas.

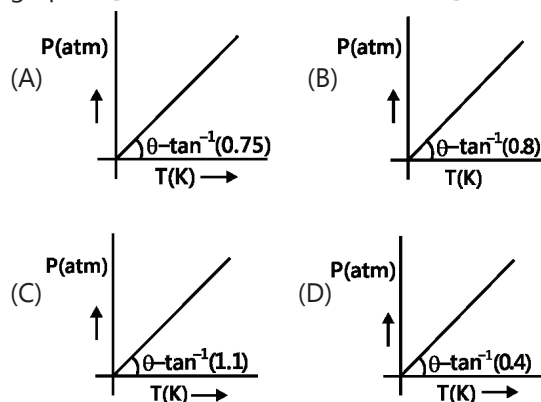
**Q.27** Calculate the total pressure in a 10 litre cylinder which contains 0.4 g of helium, 1.6 g of oxygen and 1.4 g of nitrogen at 27°C. Also calculate the partial pressure of helium gas in the cylinder. Assume ideal behaviour for gases.

## Exercise 2

### Single Correct Choice Type

**Q.1** Gas A(1 mol) dissociates in a closed rigid container of volume 0.16 lit. as per following reaction  $2\text{A}(\text{g}) \longrightarrow 3\text{B}(\text{g}) + 2\text{C}(\text{g})$

If degree of dissociation of A is 0.4 and remains constant in entire range of temperature, then the correct P vs T graph is [Given  $R = 0.08 \text{ lit-atm mol/K}$ ]



**Q.2** Calculate the ratio of rate of effusion of  $\text{O}_2$  and  $\text{H}_2$  from a container containing 16 gm  $\text{O}_2$  and 2gm  $\text{H}_2$ :

- (A) 1: 8      (B) 8: 1      (C) 1: 4      (D) 4: 1

**Q.3** Kinetic energy of one mole of  $\text{CO}_2$  at 'T' K is:

- (A) 3 RT      (B) 2/3 RT  
(C) 3/2 RT      (D) None of these

**Q.4** The mean kinetic energy of 1 mole of  $\text{CO}_2$  at 300 K is E. The average kinetic energy at 1500 K will be:

- (A) E/5      (B) 5 E      (C) 3/5 E      (D) E

**Q.5** At what temperature the RMS velocity of oxygen molecules is equal to that of  $\text{SO}_2$  at 300 K?

- (A) +123°C      (B) -123°C  
(C) 27°C      (D) 600 K



**Q.6** Temperature at which most probable speed of  $O_2$  becomes equal to root mean square speed of  $N_2$  is [Given:  $N_2$  at  $427^\circ C$ ]:

- (A) 732 K (B) 1200 K  
(C) 927 K (D) 800 K

**Q.7** A rigid container containing 10 gm gas at some pressure and temperature. The gas has been allowed to escape (do not consider any effusion or diffusion) from the container due to which pressure of the gas becomes half of its initial pressure and temperature become  $(2/3)^{rd}$  of its initial. The mass of gas (in gms) escaped is:

- (A) 7.5 (B) 1.5 (C) 2.5 (D) 3.5

**Q.8** If the absolute temperature and pressure of a gas are doubled, its volume would become:

- (A) Doubled  
(B) Halve  
(C) Increases four times  
(D) Remains the same

**Q.9** Two gases contained separately in flasks of equal pressures of 1 atmosphere each. What will be the resultant pressure if the flasks are connected?

- (A) 2 atmosphere (B)  $1/2$  atmosphere  
(C) 1 atmosphere (D) None of these

**Q.10** At very low pressure, the Vander Waal's equation for one mole is written is:

- (A)  $PV - pb = RT$  (B)  $PV + a = RT$   
(C)  $PV = RT$  (D)  $(P + a/V^2)(V) = RT$

**Q.11** A gas cylinder contains 0.3 mol of  $N_2$ , 0.2 mol of  $O_2$  and 0.5 mol of helium. If the total pressure is P atmospheres, what will be the partial pressure of nitrogen?

- (A)  $P/5$  atm (B)  $0.3 \times P \times 760$  mm  
(C)  $\frac{P}{0.3} \times 760$  mm (D)  $\frac{P}{0.3} \times$  atm

**Q.12** 10 g each of sulphur dioxide, phosphine and hydrogen are kept in three flasks. Decreasing order of number of atoms is:

- (A) Phosphine, sulphur dioxide, hydrogen  
(B) Hydrogen, phosphine, sulphur dioxide  
(C) Sulphur dioxide, phosphine, hydrogen  
(D) Hydrogen, sulphur dioxide, phosphine

**Q.13** Pressure of a real gas is less than that of ideal gas due to:

- (A) Increase in the number of collisions  
(B) Intermolecular forces of attractions  
(C) Increase in the kinetic energy of molecules  
(D) Finite size of the molecules

**Q.14** Values of Vander Waal's constant 'a' for three gases A, B and C are 5.6, 3.6 and 2.4 respectively. The increasing order of their ease of liquefaction will be:

- (A) A, B, C (B) C, B, A (C) B, A, C (D) B, C, A

**Q.15** The volume of 6 g hydrogen at 1.5 atm and  $273^\circ C$  is:

- (A) 89.65 mL (B) 0.895 mL  
(C) 8.95 mL (D) None of these

**Q.16** A gas cylinder containing cooking gas can withstand a pressure at 14.9 atm. The pressure gauge of the cylinder indicates 12 atm. at  $27^\circ C$ . Due to a sudden fire in the building its temperature starts rising. At what temperature will be cylinder explode?

- (A) 372.5 K (B) 3.725 K  
(C) 37.25 K (D) None of these

**Q.17** When 2 g of a gas A is introduced into an evacuated flask kept at  $25^\circ C$ , the pressure is found to be one atmosphere. If 3 g of another gas B is then added to the same flask, the total pressure becomes 1.5 atmosphere. Assuming ideal gas behaviour, calculate the ratio of molecular wt. MA: MB.

- (A) 3: 1 (B) 1: 4 (C) 1: 3 (D) None of these

**Q.18** Two vessels of the same capacity and at the same temperature are filled with 44 g of hydrogen gas in one and 44 g of  $CO_2$  in the other. If the pressure of  $CO_2$  in the second container is 1 atm that of hydrogen in the first container would be -

- (A) 1 atm (B) 22 atm (C) 10 atm (D) 44 atm

**Q.19** Select the correct option(s) for an ideal gas:

- (A) Most probable speed increases with increase in temperature  
(B) Fraction of particles moving with most probable speed increases with increase in temperature  
(C) Fraction of particles moving with most probable speed are more for  $Cl_2$  than  $H_2$  under similar condition of T, P & V  
(D) Most probable speed is more for  $Cl_2$  than  $H_2$  at same temperature

## Previous Years' Questions

**Q.1** A mono-atomic ideal gas undergoes a process in which the ratio of P to V at any instant is constant and equals to 1. What is the molar heat capacity of the gas? (2006)

- (A)  $\frac{4R}{2}$       (B)  $\frac{3R}{2}$       (C)  $\frac{5R}{2}$       (D) 0

**Q.2** For an ideal gas number of moles per litre in terms of pressure is P gas constant R and temperature T is: (2006)

- (A) PT/R      (B) PRT      (C) P/RT      (D) RT/P

**Q.3** An ideal gas is allowed to expand both reversibly and irreversibly in an isolated system. If  $T_i$  is the initial temperature and  $T_f$  is the final temperature, which of the following statements is correct: (1992)

- (A)  $(T_f)_{\text{irrev}} > (T_f)_{\text{rev}}$   
 (B)  $T_f > T_i$  for reversible process but  $T_f = T_i$  for irreversible process  
 (C)  $(T_f)_{\text{irrev}} = (T_f)_{\text{rev}}$   
 (D)  $T_f = T_i$  for both reversible and irreversible processes

**Q.4** X mL of  $H_2$  gas effuses through a hole in a container in 5 seconds. The time taken for the effusion of the same volume of the gas specified below under identical condition is: (2006)

- (A) 10 seconds: He      (B) 20 seconds:  $O_2$   
 (C) 25 seconds: CO      (D) 55 seconds:  $CO_2$

**Q.5** Equal masses of methane and oxygen are mixed in an empty container at  $25^\circ\text{C}$ . The fraction of the total pressure exerted by oxygen is: (2007)

- (A)  $\frac{2}{3}$       (B)  $\frac{1}{3} \times \frac{273}{298}$       (C)  $\frac{1}{3}$       (D)  $\frac{1}{2}$

**Q.6** If  $10^{-4} \text{ dm}^3$  of water is introduced into a  $1.0 \text{ dm}^3$  flask at 300 K, how many moles of water are in the vapour phase when equilibrium is established:

(Given: Vapour pressure of  $H_2O$  at 300 K is 3170 Pa;  $R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}$ ) (2010)

- (A)  $1.27 \times 10^{-3} \text{ mol}$       (B)  $5.56 \times 10^{-3} \text{ mol}$   
 (C)  $1.53 \times 10^{-2} \text{ mol}$       (D)  $4.46 \times 10^{-2} \text{ mol}$

**Q.7** At constant volume, for a fixed number of moles of a gas, the pressure of the gas increases with increase in temperature due to: (1992)

- (A) Increase in the average molecular speed  
 (B) Increased rate of collision amongst molecules  
 (C) Increase in molecular attraction  
 (D) Decrease in mean free path

**Q.8** The ratio between the root mean square velocity of  $H_2$  at 50 K and that of  $O_2$  at 800 K is: (1996; 2006)

- (A) 4      (B) 2      (C) 1      (D)  $\frac{1}{4}$

**Q.9** Which one of the following statements is NOT true about the effect of an increase in temperature on the distribution of molecular speeds in a gas (2005)

- (A) The most probable speed increases  
 (B) The fraction of the molecules with the most probable speed increases  
 (C) The distribution becomes broader  
 (D) The area under the distribution curve remains the same as under the lower temperature.

**Q.10** Vander Waal's equation of state for a non-ideal gas, the term that accounts for intermolecular forces is: (1998; 1990)

- (A)  $(V - b)$       (B)  $(RT)^{-1}$       (C)  $\left(P + \frac{a}{V^2}\right)$       (D) RT

**Q.11** When an ideal gas undergoes unrestrained expansion, no cooling occurs because the molecules: (1984, 89)

- (A) Are above the inversion temperature  
 (B) Exert no attractive force on each other  
 (C) Do work equal to loss in kinetic energy  
 (D) Collide without loss of energy

**Q.12** In Vander Waal's equation of state of the gas law, the constant 'b' is a measure of: (2004)

- (A) Volume occupied by the molecules  
 (B) Intermolecular attraction  
 (C) Intermolecular repulsions  
 (D) Intermolecular collisions per unit volume

**Q.13** The compression factor (compressibility factor) for 1 mole of a Vander Waal's gas at  $0^\circ\text{C}$  and 100 atm pressure is found to be 0.5. Assuming that the volume of a gas molecule is negligible, calculate the Vander Waal's constant 'a': (2004)

- (A)  $0.253 \text{ L}^2 \text{ mol}^{-2} \text{ atm}$  (B)  $0.53 \text{ L}^2 \text{ mol}^{-2} \text{ atm}$   
 (C)  $1.83 \text{ L}^2 \text{ mol}^{-2} \text{ atm}$  (D)  $1.253 \text{ L}^2 \text{ mol}^{-2} \text{ atm}$

**Q.14** As the temperature is raised from  $20^\circ\text{C}$  to  $40^\circ\text{C}$  the average kinetic energy of neon atoms changes by a factor of which of the following (2004)

- (A)  $313/293$  (B)  $\sqrt{(313/293)}$   
 (C)  $1/2$  (D)  $2$

**Q.15** If  $C_1, C_2, C_3, \dots$  represent the speeds of  $n_1, n_2, n_3, \dots$  molecules, then the root mean square speed is (1993)

- (A)  $\left( \frac{n_1 C_1^2 + n_2 C_2^2 + n_3 C_3^2 + \dots}{n_1 + n_2 + n_3 + \dots} \right)^{1/2}$   
 (B)  $\frac{(n_1 C_1^2 + n_2 C_2^2 + n_3 C_3^2 + \dots)^{1/2}}{n_1 + n_2 + n_3 + \dots}$   
 (C)  $\frac{(n_1 C_1^2)^{1/2}}{n_1} + \frac{(n_2 C_2^2)^{1/2}}{n_2} + \frac{(n_3 C_3^2)^{1/2}}{n_3} + \dots$   
 (D)  $\left[ \frac{(n_1 C_1 + n_2 C_2 + n_3 C_3 + \dots)^2}{(n_1 + n_2 + n_3 + \dots)} \right]^{1/2}$

**Q.16** 'a' and 'b' are van der Waals' constants for gases. Chlorine is more easily liquefied than ethane because (2011)

- (A) a and b for  $\text{Cl}_2 < a$  and b for  $\text{C}_2\text{H}_6$   
 (B) a for  $\text{Cl}_2 < a$  for  $\text{C}_2\text{H}_6$  but b for  $\text{Cl}_2 > b$  for  $\text{C}_2\text{H}_6$   
 (C) a for  $\text{Cl}_2 > a$  for  $\text{C}_2\text{H}_6$  but b for  $\text{Cl}_2 < b$  for  $\text{C}_2\text{H}_6$   
 (D) a and b for  $\text{Cl}_2 > a$  and b for  $\text{C}_2\text{H}_6$

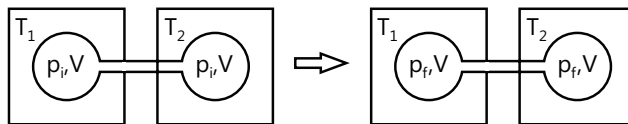
**Q.17** For gaseous state, if most probable speed is denoted by  $C^*$ , average speed by  $\bar{C}$  and mean square speed by  $C$ , then for a large number of molecules the ratios of these speeds are: (2013)

- (A)  $C^* : \bar{C} : C = 1.225 : 1.128 : 1$   
 (B)  $C^* : \bar{C} : C = 1.128 : 1.225 : 1$   
 (C)  $C^* : \bar{C} : C = 1 : 1.128 : 1.225$   
 (D)  $C^* : \bar{C} : C = 1 : 1.225 : 1.128$

**Q.18** If  $Z$  is a compressibility factor, van der Waals equation at low pressure can be written as (2014)

- (A)  $Z = 1 + \frac{RT}{Pb}$  (B)  $Z = 1 - \frac{a}{VRT}$   
 (C)  $Z = 1 - \frac{Pb}{RT}$  (D)  $Z = 1 + \frac{Pb}{RT}$

**Q.19** Two closed bulbs of equal volume ( $V$ ) containing an ideal gas initially at pressure  $p_i$  and temperature  $T_1$  are connected through a narrow tube of negligible volume as shown in the figure below. The temperature of one of the bulbs is then raised to  $T_2$ . The final pressure  $p_f$  is: (2016)



## JEE Advanced/Boards

### Exercise 1

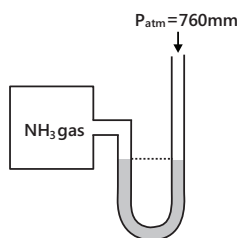
**Q.1** Automobile air bags are inflated with  $\text{N}_2$  gas which is formed by the decomposition of solid sodium azide ( $\text{NaN}_3$ ). The other product is Na-metal. Calculate the volume of  $\text{N}_2$  gas at  $27^\circ\text{C}$  and 756 Torr formed by the decomposing of 125 gm of soda azide.

**Q.2** 3.6 gm of an ideal gas was injected into a bulb of internal volume of 8L at pressure  $P$  atmp and temp  $T$ -K. The bulb was then placed in a thermostat maintained at  $(T+15)$  K 0.6 gm of the gas was let off to keep the original pressure. Find  $P$  and  $T$  if mol weight of gas is 44.

**Q.3** While resting, the average human male use  $0.2 \text{ dm}^3$  of  $\text{O}_2$  per hour at 1 atm & 273 K for each kg of body mass. Assume that all this  $\text{O}_2$  is used to produce energy by oxidizing glucose in the body. What is the mass of glucose required per hour by a resting male having mass 60 kg. What volume, at 1 atm & 273 K of  $\text{CO}_2$  would be produced.

**Q.4** An ideal gas is at a temperature of 200 K & at a pressure of 8.21 atm. It is subjected to change in volume by changing amount of the gas & a graph of  $n_2$  vs  $V_2$  (litre) is plotted Is slope constant? If yes, calculate its value else justify why is not constant.

**Q.5** A manometer attached to a flask contains,  $\text{NH}_3$  gas have no difference in mercury level initially as shown in diagram After the sparking into the flask, it have difference of 19 cm in mercury level in two columns. Calculate % dissociation.



**Q.6**  $1.0 \times 10^{-2}$  kg of hydrogen and  $6.4 \times 10^{-2}$  kg of oxygen are contained in a  $10 \times 10^{-3}$  m<sup>3</sup> flask at 473 K. Calculate the total pressure of the mixture. If a spark ignites the mixture. What will be the final pressure?

**Q.7** Calculate relative rate of effusion of  $\text{SO}_2$  to  $\text{CH}_4$  under given condition

- Under similar condition of pressure & temperature
- Through a container containing  $\text{SO}_2$  and  $\text{CH}_4$  in 3: 2 mass ratio
- If the mixture obtained by effusing out a mixture ( $n_{\text{SO}_2} / n_{\text{CH}_4} = 8 / 1$ ) for three effusing steps.

**Q.8** Pure  $\text{O}_2$  diffuses through an aperture in 224 sec, whereas mixture of  $\text{O}_2$  and another gas containing 80%  $\text{O}_2$  takes 234 sec to effuse out same volume what is the molecular weight of the gas?

**Q.9** Find the number of diffusion steps required to separate the isotopic mixture initially containing some amount of  $\text{H}_2$  gas and 1 mol of  $\text{D}_2$  gas in a container of 3 lit capacity maintained at 24.6 atm & 27°C to the final

$$\text{mass ratio. } \left( \frac{W_{\text{D}_2}}{W_{\text{H}_2}} \right) \text{ Equal to } \frac{1}{4}$$

**Q.10** An iron cylinder contains helium at a pressure of 250 k pa and 27°C. The cylinder can withstand a pressure of  $1 \times 10^4$  pa. The room in which cylinder is placed catches fire. Predict whether the cylinder will blow up before it melts or not. [Melting point of cylinder = 1800 k]

**Q.11** Calculate U of molecules of  $\text{H}_2$  at 1 atm if density of  $\text{H}_2$  is 0.00009 g/cc.

**Q.12** A bulb of capacity 1 dm<sup>3</sup> contains  $1.03 \times 10^{23}$   $\text{H}_2$  molecules & external pressure exerted by these molecules is 101.325 k Pa. Calculate the average square molecular speed and the temperature.

**Q.13** The density of CO at 273 K and 1 atm is 1.2504 kg m<sup>-3</sup>. Calculate (a) root mean square speed (b) the average speed and (c) most probable speed.

**Q.14** Calculate the fraction of  $\text{N}_2$  molecules at 101.325 k Pa and 300 K whose speeds are in the range of  $u_{\text{mp}} - 0.005 u_{\text{mp}}$  to  $u_{\text{mp}} + 0.005 u_{\text{mp}}$ .

**Q.15** What is the ratio of the number of molecules having speeds in the range of  $2u_{\text{mp}}$  and  $2u_{\text{mp}} + du$  to the number of molecules having speeds in the range of  $u_{\text{mp}}$  and  $u_{\text{mp}} + du$ ?

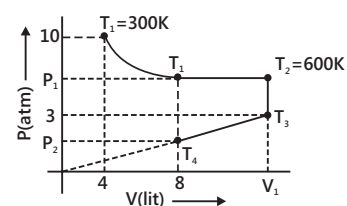
**Q.16**  $\text{H}_2$  gas is kept inside a container A and container B each having volume 2 litre under different conditions which are described below. Determine the missing values with proper unit. [ $R = 8 \text{ J mol}^{-1} \text{ K}^{-1}$  and  $N_A = 6 \times 10^{23}$ , N = No. of molecules]

Parameter	Container A	Container B
P	(i) -----	1 atm
T	300 K	600 K
N	$6 \times 10^{23}$	(ii) -----
Total Average KB	(iii) -----	(iv) -----
Ratio $U_{\text{mp}}$	(v) -----	
Ratio $Z_n$	(vi) -----	

**Q.17** A mixture of hydrogen and helium is prepared such that the number of wall collisions per unit time by molecules of each gas is the same. Which gas has a higher concentration?

**Q.18** The mean free path of the molecule of a certain gas at 300 K is  $2.6 \times 10^{-5}$  m . The collision diameter of the molecule is 0.26 mm. Calculate (a) pressure of the gas, and (b) number of molecules per unit volume of the gas.

**Q.19** Fixed mass of a gas is subjected to the changes as shown in diagram, calculate  $T_3$ ,  $T_4$ ,  $T_1$ ,  $P_2$  and  $V_1$  as shown is diagram. Considering gas obeys  $PV = nRT$  equation.



**Q.20** A balloon containing 1 mole of air at 1 atm initially is filled further with air till pressure increases to 3 atm. The initial diameter of the balloon is 1 m and the pressure at each state is proportion to diameter of the balloon. Calculate-

- No. of moles of air added to change the pressure from 1 atm to 3 atm.
- Balloon will burst if either pressure increases to 7 atm or volume increases to  $36 \pi \text{ m}^3$ . Calculate the number of moles of air that must be added after initial condition to burst the balloon.

**Q.21** One mole of  $\text{NH}_4\text{Cl(s)}$  is kept in an open container & then covered with a lid. The container is now heated to 600 K where all  $\text{NH}_4\text{Cl(s)}$  dissociates into  $\text{NH}_3$  &  $\text{HCl(g)}$ . If volume of the container is 24.63 litres, calculate what will be the final pressure of gases inside the container. Also find whether the lid would stay or bounce off if it can withstand a pressure difference of 5.5 atm. Assume that outside air is at 300 K and 1 atm pressure.

**Q.22** Calculate the value of  $\sigma$ ,  $\lambda$ ,  $z_1$  and  $z_{11}$  for nitrogen molecules at 25°C and at pressure of  $10^{-3}$  mm Hg. Given that  $b$  for nitrogen is  $39.1 \text{ cm}^3 \text{ mol}^{-1}$

**Q.23** A gas present in a container connected to frictionless, weightless piston operating always at one atmosphere pressure such that it permits flow of gas outside (with no adding of gas.). The graph of  $n$  vs  $T$  (Kelvin) was plotted & was found to be a straight line with Co-ordinates of extreme points as (300, 2) & (200, 3). Calculate

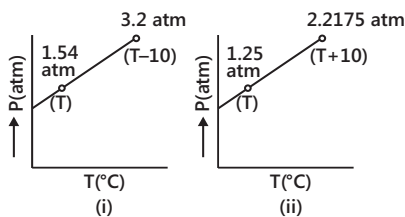
- Relationship between  $n$  &  $T$
- Relationship between  $V$  &  $T$
- Maxima or minima value of ' $V$ '

**Q.24** A compound exists in the gaseous state both as a monomer (A) and dimer ( $A_2$ ). The molecular weight of the monomer is 48. In an experiment, 96 g of the compound was confined in a vessel of volume 33.6 litres and heated to 273°C. Calculate the pressure developed, if the compound exists as a dimer to the extent of 50 per cent by weight, under these conditions, ( $R = 0.082$ )

**Q.25** A closed vertical cylinder is divided into two parts by a frictionless piston, each part contains 1 mole of air. At 27°C the volume of the upper part is 4 times than that of the lower part. Calculate the temperature when volume of the upper part will be three times than that of the lower part.

**Q.26** You are told to prepare a closed experimental environment (a box) for student mice. The box volume will be 294 liters (about  $10 \text{ ft}^3$ ) and the entire air volume will be changed every minute. The relative humidity of the air entering the box is to be controlled at 40% at 21°C. What weight of  $\text{H}_2\text{O}$  must be added to the flow of dry air per minute? (Equilibrium vapour pressure for  $\text{H}_2\text{O}$  at 21°C  $\cong 19$  torr). ( $R = 0.082 \text{ liter atm mole}^{-1} \text{ deg}^{-1}$  Mol wt:  $\text{H}_2\text{O} = 18$ )

**Q.27** A closed vessel of known volume containing known amount of ideal gaseous substance 'A' was observed for variation of pressure with temperature. The expected graph was to be like as in



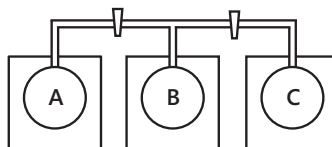
(i) However actual observations revealed the graph to be like. (ii) The deviation was attributed to polymerisation of gas molecules as  $nA(g) \rightarrow A_n(g)$ . If it known that the above reaction gives only 50% yield

- Calculate the ratio of  $\frac{n_{\text{experiment}}}{n_{\text{theoretical}}}$  (where  $n_{\text{exp.}} =$  Total no. of gaseous mole actually present  $n_{\text{theoretical}} =$  Total no. of mole original taken,
- Find the value of  $n$  to which the gas A is being polymerized into

**Q.28** A mixture of  $\text{CH}_4$  &  $\text{O}_2$  is used as an optimal fuel if  $\text{O}_2$  is present in thrice the amount required theoretically for combustion of  $\text{CH}_4$ . Calculate number of effusions steps required to convert a mixture containing 1 part of  $\text{CH}_4$  in 193 parts mixture (parts by volume). If calorific value (heat evolved when 1 mole is burnt) of  $\text{CH}_4$  is 100 cal/mole & if after each effusion 90% of  $\text{CH}_4$  is collected, find out what initial mole of each gas in initial mixture required for producing 1000 cal of energy after processing. [Given  $(0.9)^5 = 0.6$ ]

**Q.29** A 50 litre vessel is equally divided into three parts with the help of two stationary semi permeable membrane (SPM). The vessel contains 60 g  $\text{H}_2$  gas in the left chamber 160g  $\text{O}_2$  in the middle & 140 g  $\text{N}_2$  in the right one. The left SPM allows transfer of only  $\text{H}_2$  gas while the right one allows the transfer of both  $\text{H}_2$  &  $\text{N}_2$ . Calculate the final ratio of pressure in the three chambers.

**Q.30** The apparatus shown consists of three temperature jacketed 1 litre bulbs connected by stop cocks. Bulb A contains a mixture of  $\text{H}_2\text{O(g)}$ ,  $\text{CO}_2(g)$  and  $\text{N}_2(g)$  at 27°C and a total pressure of 547.2 mm Hg. Bulb B is empty and is held at a temperature  $-23^\circ\text{C}$ . Bulb C is also empty and is held at a temperature of  $173^\circ\text{C}$ . The stopcocks are closed and the volumes of limes connecting the bulbs is zero. Given.  $\text{CO}_2(g)$  converted into  $\text{CO}_2(s)$  at  $-78^\circ$ ,  $\text{N(g)}$  converted into  $\text{N(s)}$  at  $-196^\circ\text{C}$  &  $\text{H}_2\text{O(g)}$  converted into  $\text{H}_2\text{O(s)}$  at  $0^\circ\text{C}$ .



[Use  $R = 0.08 \text{ atm-litre/mole. K}$ ]

- (a) The stopcock between A & B is opened and the system is allowed to come to equilibrium. The pressure in A & B is now 228 mmHg. What do bulbs A & B contain?
- (b) How many moles of  $\text{H}_2\text{O}$  are in system?
- (c) Both stopcocks are opened and the system is again allowed to equilibrium. The pressure throughout the system is 45.6 mmHg. What do bulbs A, B and C contain?

## Exercise 2

### Single Correct Choice Type

**Q.1** The number of effusion steps required to convert a mixture of  $\text{H}_2$  and  $\text{O}_2$  from 240: 1600 (by mass) to 3072: 20 (by mass) is:

- (A) 2 (B) 4 (C) 5 (D) 6

**Q.2** Consider the following pairs of gases A and B.

	A	B
(a)	$\text{CO}$	$\text{N}_2$
(b)	$\text{O}_2$	$\text{O}_3$
(c)	$^{235}\text{UF}_6$	$^{238}\text{UF}_6$

Relative rates of effusion of gases A to B under similar condition in the order:

- (A)  $a < b < c$  (B)  $a < c < b$   
 (C)  $a > b > c$  (D)  $a > c > b$

**Q.3** The pressure of mixture of equal weights of two gases of molecular weight 4 and 40 is 1.1 atm. The partial pressure of the lighter gas in the gas mixture is:

- (A) 0.55 atm (B) 0.11 atm  
 (C) 1 atm (D) 0.1 atm

**Q.4** The density of gas A is twice that of B at the same temperature the molecular weight of gas B is thrice that of A. The ratio of pressure of gas A and gas B will be:

- (A) 1: 6 (B) 7: 8 (C) 6: 1 (D) 1: 4

**Q.5** For the reaction  $2\text{NH}_3(\text{g}) \rightarrow \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$ , what is the % of  $\text{NH}_3$  converted if the mixture diffuses twice as fast as that of  $\text{SO}_2$  under similar conditions:

- (A) 3.125% (B) 31.25%  
 (C) 6.25% (D) 62.5%

**Q.6** A gaseous reaction,  $3\text{A} \rightarrow 2\text{B}$  is carried out in a 0.0821 litre closed container initially containing 1 mole of gas A. After sufficient time a curve of  $P(\text{atm})$  vs  $T(\text{K})$  is plotted and the angle with x-axis was found to be  $42.95^\circ$ . The degree of association of gas A is [Given:  $\tan 42.95 = 0.8$ ]

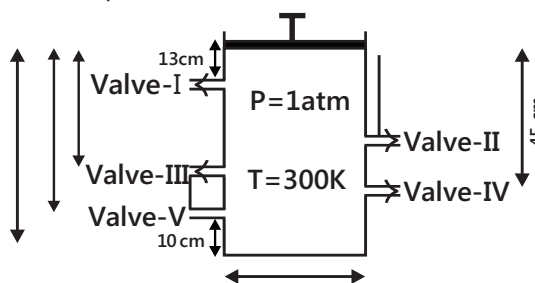
- (A) 0.4 (B) 0.6 (C) 0.5 (D) 0.8

**Q.7** A spherical balloon of 21 cm diameter is to be filled up with hydrogen at N.T.P. from a cylinder containing the gas at 20 atm at  $27^\circ\text{C}$ . If the cylinder can hold 2.82 litre of water, the number of balloon/s that can be filled up are:

- (A) 5 (B) 10 (C) 20 (D) None of these

**Q.8** A container fitted with frictionless massless piston consist of five valves-I, II, III, IV and V. These valves open automatically if pressure exceed over 1.5, 2.2, 2.5, 4.4 and 4.8 atm respectively. Under the given initial conditions (mentioned in given diagram) system is in state of equilibrium Piston is now pressed in downward direction very slowly.

[Note: Consider the diameter of value tube negligible and temperature remain constant.]

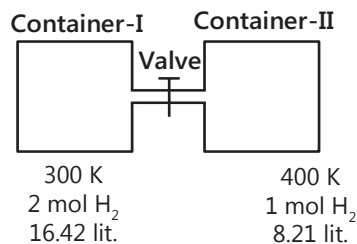


Select the correct option(s).

- (A) Valve-II will be opened first  
 (B) As the piston crosses the valve which will be opened first, the remaining number of moles in container are  $\frac{5}{3}$ .  
 (C) Valve-V will be the second valve which is open  
 (D) Number of moles will zero as piston crosses Valve-V

**Multiple Correct Choice Type**

**Q.9** Select the correct option(s):



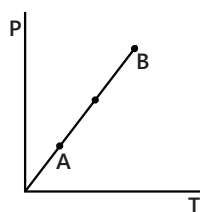
- (A) Pressure in container-I is 3 atm before opening the valve  
 (B) Pressure after opening the valve is 3.57 atm.  
 (C) Moles in each compartment are same after opening the valve  
 (D) Pressure in each compartment are same after opening the valve

**Q.10** Select the correct observation for a 8.21 lit container, filled with 2 moles of He at 300 K,

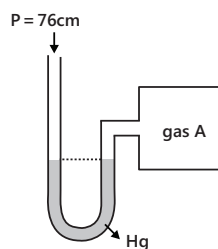
- (A) It has pressure 6 atm  
 (B) If it is an open rigid container, its pressure increases to 8 atm on heating to 400 K  
 (C) If it is closed non-rigid (like thin skin balloon), its volume increases to 16.42 lit. on heating to 600 K  
 (D) When connected with another similar empty container maintained at 150 K while maintaining original container at 300 K, pressure reduces to  $\frac{2}{3}$  atm.

**Q.11** Select the correct option for an ideal gas undergoing a process as shown in diagram.:

- (A) If 'n' is changing, 'V' must also be changing  
 (B) If 'n' is constant, 'V' must be constant  
 (C) If 'n' is constant, 'V' must be changing  
 (D) If 'h' is changing, 'V' must be constant



**Q.12** An open ended mercury manometer is used to measure the pressure exerted by a trapped gas as shown in the figure. Initially manometer shows no difference in mercury level in both columns as shown in diagram.

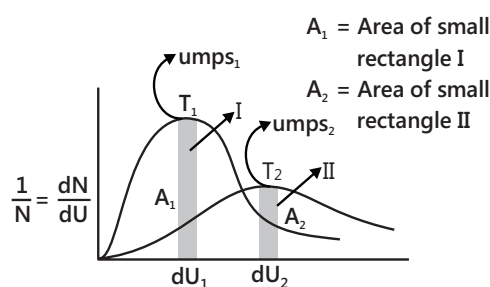


After sparking 'A' dissociates according to following reaction  $2A(g) \longrightarrow 3B(g) + 2C(g)$

If pressure of Gas "A" decreases to 0.8 atm, then (Assume temperature to be constant and is 300 K)

- (A) Total pressure increased by 1.3 atm  
 (B) Total pressure increased by 0.3 atm  
 (C) Total pressure increased by 22.3 cm of Hg  
 (D) Difference in mercury level is 228 mm

**Q.13** Following represents the Maxwell distribution curve for an ideal gas at two temperatures  $T_1$  &  $T_2$ . Which of the following option(s) are true?



- (A) Total area under the two curves is independent of moles of gas  
 (B) If  $du_1 = f \text{ umps}_1$  &  $du_2 = f \text{ umps}_2$  then  $A_1 = A_2$   
 (C)  $T_1 > T_2$  and hence higher the temperature, sharper the curve  
 (D) The fraction of molecules having speed = umps decreases as temperature increase

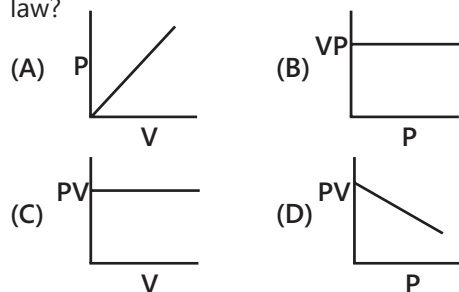
**Q.14** Select the correct option(s).

- (A) Fraction of molecule in the range  $u_{\text{avg}} = f u_{\text{avg}}$  is same for SO<sub>2</sub> and O<sub>2</sub> at same temperature ( $0 < f < 1$ ).  
 (B) Fraction n or f molecule in the range  $u_{\text{mps}} = 100(\text{m/sec})$  is same for SO<sub>2</sub> and O<sub>2</sub> at same temperature.  
 (C) Fraction of molecule in the range  $u_{\text{avg}} = f u_{\text{avg}}$  is same for O<sub>2</sub> at 300 K and at 200 K ( $0 < f < 1$ )  
 (D) None of these

**Q.15** Which of the following statements are correct?

- (A) Helium diffuses at a rate 8.65 times as much as CO does  
 (B) Helium escapes at a rate 2.65 times as fast as CO does  
 (C) Helium escapes at a rate 4 times as fast as CO<sub>2</sub> does  
 (D) Helium escapes at a rate 4 times as fast as SO<sub>2</sub> does

**Q.16** Which of the following graphs represent Boyle's law?



**Q.17** The value of the molar gas constant is:

- (A)  $8.3145 \times 10^3 \text{ (kg mol)}^{-1} \text{ K}^{-1}$   
 (B)  $1.987 \text{ cal mol K}^{-1}$   
 (C)  $0.083145 \times 10^3 \text{ dm}^3 \text{ bar mol}^{-1} \text{ K}^{-1}$   
 (D)  $0.083145 \text{ dm}^3 \text{ bar mol}^{-1} \text{ K}^{-1}$

**Q.18** When a gas is expanded at constant temperature:

- (A) The pressure decreases  
 (B) The kinetic energy of the molecules remains the same  
 (C) The kinetic energy of the molecules decreases  
 (D) The number of molecules of the gas decrease

**Q.19** Which of the following are correct statements?

- (A) Vander Waal's constant 'a' is a measure of attractive force  
 (B) Vander Waal's constant 'b' is also called co-volume or excluded volume  
 (C) 'b' is expressed in  $\text{L mol}^{-1}$   
 (D) 'a' is expressed in  $\text{atm L}^2 \text{ mol}^{-2}$

### Assertion Reasoning Type

In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as

- (A) If both assertion and reason are true and reason is the correct explanation of assertion  
 (B) If both assertion and reason are true but reason is not the correct explanation of assertion.  
 (C) If assertion is true but reason is false.  
 (D) If both assertion and reason are false.  
 (E) If assertion is false but reason is true.

**Q.20 Assertion:** Excluded volume or co-volume equal to  $(v-nb)$  for  $n$  moles.

**Reason:** Co- Volume depends on the effective size of gas molecules.

**Q.21 Assertion:** Plot of P Vs.  $1/V$ (volume) is a straight line.

**Reason:** Pressure is directly proportional to volume

**Q.22 Assertion:**  $\text{CO}_2$  above  $31.1^\circ\text{C}$  and 600 bar pressure is used to remove caffeine from coffee beans.

**Reason:**  $\text{CO}_2$  is gaseous in nature.

**Q.23 Assertion:** Gas with lower mass will effuse or diffuse faster.

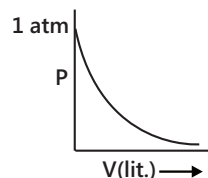
**Reason:** Kinetic energy of any gas depends upon its mass.

**Q.24 Assertion:**  $\text{CH}_4$ ,  $\text{CO}_2$  has value of Z (compressibility factor) less than one.

**Reason:**  $Z < 1$  is due to repulsive forces among the molecules.

### Comprehension Type

**Paragraph 1:** On the recently discovered 10th planet it has been found that the gases follow the relationship  $Pe^{V/2} = nCT$  where C is constant other notation are as usual (V in L, P in atm and T in Kelvin). A curve is plotted between P and V at 500 K and 2 moles of gas as shown in figure



**Q.25** The value of constant C is

- (A) 0.01      (B) 0.001      (C) 0.005      (D) 0.002

**Q.26** Find the slope of the curve plotted between P Vs T for closed container of volume 2 lit. having same moles of gas.

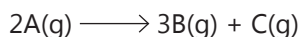
- (A)  $\frac{e}{2000}$       (B)  $2000e$   
 (C)  $500e$       (D)  $\frac{2}{1000e}$



**Q.27** If a closed container of volume 200 lit. of  $O_2$  gas (ideal gas) at 1 atm & 200 K is taken to planet. Find the pressure of oxygen gas at the planet at 821 K in same container

- (A)  $\frac{10}{e^{100}}$  (B)  $\frac{20}{e^{50}}$  (C) 1 atm (D) 2 atm

**Paragraph 2:** For a gaseous reaction,



Whose extent of dissociation depends on temperature is performed in a closed container, it is known that extent of dissociation of A is different in different temperature range. Within a temperature range it is constant. (Temperature range  $T_0 - T_1$ ,  $T_1 - T_2$ ,  $T_2 - T_\infty$ ). A plot of  $P$  v/s  $T$  is drawn under the given condition. Given:  $\tan 55 = 1.42$ ,  $\tan 50 = 1.19$ ,  $\tan 60 = 1.73$ .

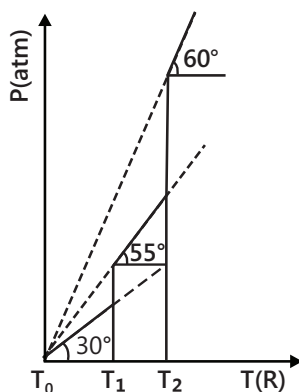
**Q.28** If  $\alpha_{T_i-T_{i+1}}$  is the degree of dissociation of A then in the temperature:

range  $T_i \rightarrow T_{i+1}$

- (A)  $\alpha_{T_0-T_1}$  is lowest (B)  $\alpha_{T_0-T_1}$  is highest  
(C)  $\alpha_{T_2-T_\infty} = 1$  (D)  $\alpha_{T_2-T_\infty} = 0$

**Q.29** If initially 1 mole of A is taken in a 0.0821 l container then [ $R = 0.0821$  atm lit/k]

- (A)  $\alpha_{T_0-T_1} = 0.19$   
(B)  $\alpha_{T_0-T_1} = 0.095$   
(C)  $\alpha_{T_1-T_2} = 0.42$   
(D)  $\alpha_{T_1-T_2} = 0.73$



### Match the Columns

**Q.30** Match the description in Column I with graph provided in Column II. For  $n$  moles of ideal gas at temperature  $T$ .

Column I	Column II
(A) $\frac{P}{V}$ vs $P$	(p)

(B) $\frac{P}{V}$ vs $V$	(q)
(C) $\frac{V}{P}$ vs $P^{-2}$	(r)
(D) $\frac{P}{V}$ vs $\log P$	(s)

**Q.31** Match the entries in column I with entries in Column II and then pick out correct options:

Column I	Column II
(A) $\frac{1}{V^2}$ vs $P$ for	(p) Ideal gas at constant $T$ and $n$
(B) $V$ vs $\frac{1}{T}$ for	(q) Ideal gas at constant $P$ and $n$
(C) $\log P$ vs $\log V$	(r) For ideal gas at constant $T$ and $n$ .
(D) $V$ vs $\frac{1}{P^2}$ for	(s) Ideal gas at constant $T$ and $n$ .

## Previous Years' Questions

**Q.1** The ratio of root mean square velocity to average velocity of a gas molecule at a particular temperature is **(1981)**

- (A) 1.086: 1                      (B) 1: 1.086  
(C) 2: 1.086                      (D) 1.086: 2

**Q.2** Equal weights of methane and oxygen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by oxygen is **(1981)**

- (A)  $\frac{1}{3}$             (B)  $\frac{1}{2}$             (C)  $\frac{2}{3}$             (D)  $\frac{1}{3} \times \frac{273}{298}$

**Q.3** Helium atom is two times heavier than a hydrogen molecule. At 298 K, the average kinetic energy of a helium atom is **(1982)**

- (A) Two times that of a hydrogen molecule  
(B) Same as that of a hydrogen molecule  
(C) Four times that of a hydrogen molecule  
(D) Half that of a hydrogen molecule

**Q.4** The value of van der Waals' constant 'a' for the gases O<sub>2</sub>, N<sub>2</sub>, NH<sub>3</sub> and CH<sub>4</sub> are 1.360, 4.170 and 2.253 L<sub>2</sub> atm mol<sup>-2</sup> respectively. The gas which can most easily be liquefied is **(1989)**

- (A) O<sub>2</sub>            (B) N<sub>2</sub>            (C) NH<sub>3</sub>            (D) CH<sub>4</sub>

**Q.5** A gas will approach ideal behaviour at **(1999)**

- (A) Low temperature and low pressure  
(B) Low temperature and high pressure  
(C) High temperature and low pressure  
(D) High temperature and high pressure

**Q.6** The rms velocity of hydrogen is  $\sqrt{7}$  times the rms velocity of nitrogen. If T is the temperature of the gas **(2000)**

- (A)  $T(\text{H}_2) = T(\text{N}_2)$             (B)  $T(\text{H}_2) > T(\text{N}_2)$   
(C)  $T(\text{H}_2) < T(\text{N}_2)$             (D)  $T(\text{H}_2) = \sqrt{7} T(\text{N}_2)$

**Q.7** At 100°C and 1 atm if the density of the liquid water is 1.0 g cm<sup>-3</sup> and that of water vapour is 0.0006 g cm<sup>-3</sup> then the volume occupied by water molecules in 1 L of steam at this temperature is **(2000)**

- (A) 0.040 cm<sup>3</sup>                      (B) 0.065 cm<sup>3</sup>  
(C) 0.060 cm<sup>3</sup>                      (D) 0.045 cm<sup>3</sup>

**Q.8** The term that corrects for the attractive forces present in a real gas in the van der Waals' equation is **(2009)**

- (A) nb                                      (B) n<sup>2</sup>a/V<sup>2</sup>  
(C) - (n<sup>2</sup>a/V<sup>2</sup>)                      (D) - nb

**Q.9** If a gas is expanded at constant temperature **(1986)**

- (A) The pressure decreases  
(B) The kinetic energy of the molecules remains the same  
(C) The kinetic energy of the molecules decreases  
(D) The number of molecules of the gas increases

**Q.10** As gas described by van der Waals' equation **(2008)**

- (A) Behaves similar to an ideal gas in the limit of large molar volumes  
(B) Behaves similar to an ideal gas in the limit of large pressures  
(C) Is characterized by van der Waals' coefficients that are dependent on the identity of the gas but are independent of the temperature.  
(D) Has the pressure that is lower than the pressure exerted by the same gas behaving ideally

**Q.11** According to kinetic theory of gases **(2011)**

- (A) Collisions are always elastic  
(B) Heavier molecules transfer more momentum to the wall of the container  
(C) Only a small number of molecules have very high velocity  
(D) Between collisions, the molecules move in straight lines with constant velocities

Read the following question and answer as per the direction given below:

- (a) Statement-I is true; statement-II is true; statement-II is the correct explanation of statement I.  
(b) Statement-I is true; statement-II is true; statement-II is not the correct explanation of statement I.  
(c) Statement-I is true; statement-II is false.  
(d) Statement-I is false; statement-II is true.

**Q.12 Statement-I:** The value of van Waals' constant 'a' is larger for ammonia than for nitrogen.

**Statement-II:** Hydrogen bonding is present in ammonia. **(1998)**

**Q.13 Statement-I:** The pressure of a fixed amount of an ideal gas is proportional to its temperature.

**Statement-II:** Frequency of collisions and their impact both increase in proportion to the square root of temperature. **(2000)**

**Q.14** Match the gases under specified conditions listed in Column I with their properties/laws in Column II. **(2007)**

Column I	Column II
(A) Hydrogen gas (p = 200 atm, T = 273 k)	(p) Compressibility factor $\neq 1$
(B) Hydrogen gas (p ~ 0, T = 273 K)	(q) Attractive forces are dominant
(C) CO <sub>2</sub> (p = 1 atm, T = 273 K)	(r) pV = nRT
(D) Real gas with very large molar volume	(s) P(V - nb) = nRT

**Q.15** To an evacuated vessel with movable piston under external pressure of 1 atm, 0.1 mole of He and 1.0 mole of an unknown compound (vapour pressure 0.68 atm 0°C) are introduced. Considering the ideal gas behaviour, the total volume (in litre) of the gases at 0°C is close to **(2011)**

**Q.16** A mixture of ethane (C<sub>2</sub>H<sub>6</sub>) and ethene (C<sub>2</sub>H<sub>4</sub>) occupies 40 L at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of O<sub>2</sub> to produce CO<sub>2</sub> and H<sub>2</sub>O. Assuming ideal gas behaviour, calculate the mole fractions of C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> in the mixture.

**Q.17** The compression factor (compressibility factor) for one mole of a van der Waals' gas at 0°C and 100 atm pressure is found to be 0.5. Assuming that the volume of a gas molecule is negligible, calculate the van der Waals' constant 'a'. **(2001)**

**Q.18** At 400 K, the root mean square (rms) speed of a gas X (molecular weight = 40) is equal to the most probable speed of gas Y at 60 K. The molecular weight of the gas Y is **(2009)**

**Q.19** Match gases under specified conditions listed in Column I with their properties/laws in Column II. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. **(2007)**

Column I	Column II
(A) Hydrogen gas (P = 200 atm, T = 273K)	(p) Compressibility factor $\neq 1$
(B) Hydrogen gas (P ~ 0, T = 273K)	(q) Attractive forces are dominant
(C) CO <sub>2</sub> (P = 1 atm, T = 273K)	(r) PV = nRT
(D) Real gas with very large molar volume	(s) P(V - nb) = nRT

**Q.20** A gas described by van der Waal's equation **(2008)**

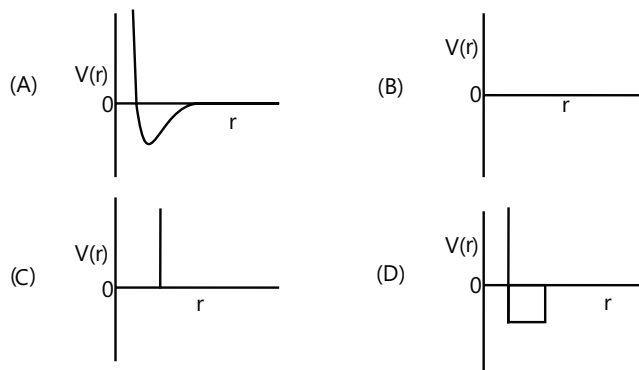
(A) behaves similar to an ideal gas in the limit of large molar volumes

(B) behaves similar to an ideal gas in the limit of large pressures

(C) is characterized by van der Waal's coefficients that are dependent on the identity of the gas but are independent of the temperature

(D) has the pressure that is lower than the pressure exerted by the same gas behaving ideally

**Q.21** One mole of a monoatomic real gas satisfies the equation  $p(V - b) = RT$  where b is a constant. The relationship of interatomic potential V(r) and interatomic distance r for the gas is given by **(2015)**



**Q.20** The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases x times. The value of x is **(2015)**

# MASTERJEE Essential Questions

## JEE Main/Boards

### Exercise 1

Q.4            Q.6            Q.11  
Q.16         Q.20         Q.21  
Q.26

### Exercise 2

Q.3            Q.5            Q.10  
Q.12         Q.28

### Previous Years' Questions

Q.1            Q.6            Q.10

## JEE Advanced/Boards

### Exercise 1

Q.5            Q.7            Q.11  
Q.16         Q.20         Q.26  
Q.30

### Exercise 2

Q.6            Q.8            Q.11  
Q.21

### Previous Years' Questions

Q.5            Q.6            Q.14  
Q.16

## Answer Key

## JEE Main/Boards

### Exercise 1

**Q.1** 1870.65J  
**Q.2** 41.33 g  
**Q.3** 3.42 g per litre  
**Q.4** Volume of the gas will remain constant  
**Q.5** 89.65 L  
**Q.6**  $S_8$   
**Q.7**  $1 : \sqrt{24}$   
**Q.8** 5.24 Litres  
**Q.9**  $\sqrt{8} : 1$   
**Q.10** 0.137

**Q.11**  $14.14 \text{ dm}^3$   
**Q.12**  $390 \text{ m sec}^{-1}$   
**Q.13**  $2.7 \times 10^{10}$   
**Q.14** 0.856 litres  
**Q.15** 1.0043  
**Q.16**  $-173^\circ\text{C}$ , 0.82 litre  
**Q.17** 0.787 atoms  
**Q.18** 750 K  
**Q.19** 1: 3  
**Q.20** 2.197 atmosphere  
**Q.21**  $7.09 \times 10^6 \text{ g}$   
**Q.22**  $P_A : P_B$  is 8: 1  
**Q.23** 83.75 cm of Hg

Q.24 3 cm

Q.26 123. 15

Q.25  $a = 6.52 \text{ atm L}^2 \text{ mole}^{-1}$ 

Q.27 0.492 atm 0.246 atm

**Exercise 2****Single Correct Choice Type**

Q.1 B

Q.2 A

Q.3 C

Q.4 B

Q.5 B

Q.6 B

Q.7 C

Q.8 D

Q.9 C

Q.10 D

Q.11 B

Q.12 B

Q.13 B

Q.14 A

Q.15 A

Q.16 A

Q.17 C

Q.18 B

Q.19 B

**Previous Years' Questions**

Q.1 A

Q.2 C

Q.3 A

Q.4 B

Q.5 C

Q.6 A

Q.7 A

Q.8 C

Q.9 B

Q.10 C

Q.11 B

Q.12 A

Q.13 D

Q.14 A

Q.15 A

Q.16 C

Q.17 C

Q.18 B

Q.19 B

**JEE Advanced/Boards****Exercise 1**

Q.1 71.4 L

Q.3 16.07 gm; 12 dm<sup>3</sup>

Q.5 25%

$$P_{\text{final}} = 19.66 \times 10^5 \text{ N/m}^2$$

Q.7 (i)  $\frac{2}{1}$ ; (ii)  $\frac{3}{16}$ ; (iii) 2: 1

Q.9 2

Q.11 183,800 cm/sec

Q.13  $u_{\text{rms}} = 493 \text{ m/s}$ ,  $u_{\text{ms}} = 403 \text{ m/s}$ ,  $u_{\text{av}} = 454.4 \text{ m/s}$ 

Q.15 0.199

Q.16 (i) 0.012 atm; (ii)  $2.5 \times 10^{22}$ ; (iii) 3.05 J; (iv) 258; (v)  $\frac{1}{\sqrt{2}}$ ; (vi)  $0.4 \times 10^{-3}$ : 1

Q.17 He

Q.19 (i)  $P_1 = 5 \text{ atm}$ ; (ii)  $T_3 = 360 \text{ K}$ ; (iii)  $V_1 = 16 \text{ lit}$ ; (iv)  $P_2 = 1.5 \text{ atm}$ ; (v)  $T_4 = 90 \text{ K}$ Q.2  $P = 0.062 \text{ atm}$ ,  $T = 75 \text{ K}$ Q.4  $\frac{1}{4}$ Q.6  $P_{\text{total}} = 27.54 \times 10^5 \text{ N/m}^2$ ,

Q.8 4.46

Q.10 Yes

Q.12  $8.68 \times 10^5 \text{ (cm/s)}$ ; 71.27 KQ.14  $8.303 \times 10^{-3}$ Q.18 (a)  $5.306 \times 10^2 \text{ Pa}$ , (b)  $1.281 \times 10^{21} \text{ mol/vol}$

**Q.20**  $P \propto d$ ;  $p = kd$  &  $k = \frac{1 \text{ atm}}{1 \text{ meter}}$ ; (a) 80; (b) 1295 moles

**Q.21** 6 atm, No

**Q.22** 314 pm, 7.051 cm,  $6742 \text{ s}^{-1}$ ,  $1.08 \times 10^{17} \text{ cm}^{-3} \text{ s}^{-1}$

**Q.23**  $n = \frac{-T}{100} + 5$ ,  $V = \frac{-RT^2}{100} + 5RT$ ,  $V_{\text{max}} = 51.3125$

**Q.24** 2 atm

**Q.25** 421.9 K

**Q.26** 2.2 g

**Q.27** (a) 0.625, (b) 4

**Q.28** 10 Step, 27.78 mol  $\text{CH}_4$ , 5333.3 mol  $\text{O}_2$

**Q.29** 4: 7: 5

**Q.30** (a) Bulb A:  $\text{N}_2(\text{g})$ ,  $\text{CO}_2(\text{g})$ ; Bulb B:  $\text{N}_2(\text{g})$ ,  $\text{H}_2\text{O}(\text{s})$

(b) No. of mole of  $\text{H}_2(\text{g}) = 0.0025$ ; (c) Bulb A:  $\text{N}_2(\text{g})$ ; Bulb B:  $\text{N}_2(\text{g})$ ,  $\text{H}_2\text{O}(\text{s})$ ; Bulb C:  $\text{N}_2(\text{g})$ ,  $\text{CO}_2(\text{s})$

## Exercise 2

### Single Correct Choice Type

**Q.1** C

**Q.2** B

**Q.3** C

**Q.4** C

**Q.5** C

**Q.6** B

**Q.7** B

**Q.8** C

### Multiple Correct Choice Type

**Q.9** B, D

**Q.10** A, D

**Q.11** A, B

**Q.12** B, D

**Q.13** A, B, D

**Q.14** A, C

**Q.15** B, C

**Q.16** B, C

**Q.17** B, D

**Q.18** A, B

**Q.19** A, B, C, D

### Assertion Reasoning Type

**Q.20** E

**Q.21** D

**Q.22** A

**Q.23** C

**Q.24** A

### Comprehension Type

**Paragraph 1:** **Q.25** B

**Q.26** D

**Q.27** A

**Paragraph 2:** **Q.28** A

**Q.29** C

### Match the Columns

**Q.30** A  $\rightarrow$  s; B  $\rightarrow$  r; C  $\rightarrow$  q; D  $\rightarrow$  p

**Q.31** A  $\rightarrow$  r; B  $\rightarrow$  s; C  $\rightarrow$  p; D  $\rightarrow$  q

### Previous Years' Questions

**Q.1** A

**Q.2** A

**Q.3** B

**Q.4** C

**Q.5** C

**Q.6** C

**Q.7** C

**Q.8** B

**Q.9** A, B

**Q.10** A, C

**Q.11** A, C, D

**Q.12** A

**Q.13** D

**Q.14** A  $\rightarrow$  p, s; B  $\rightarrow$  r; C  $\rightarrow$  p, q; D  $\rightarrow$  r

**Q.15** 7

**Q.16** 0.34

**Q.17** a = 1.25 atm L<sup>2</sup> mol<sup>-2</sup>

**Q.18** D

**Q.19** A  $\rightarrow$  p, s; B  $\rightarrow$  r; C  $\rightarrow$  p, q; D  $\rightarrow$  p, s

**Q.20** A, C, D

**Q.21** C

**Q.22** D

## Solutions

### JEE Main/Boards

#### Exercise 1

**Sol 1:**  $T = 27^\circ\text{C} = 300\text{ K}$

Mass of  $\text{CH}_4$  (per mole) = 16 g

Mass of  $\text{CH}_4$  (given) = 8 g

$$\Rightarrow n = \text{number of moles} = \frac{8}{16} = 0.5$$

$$\text{K.E. (per mole)} = \frac{3}{2} RT$$

$$\begin{aligned} \text{K.E. (Total)} &= \frac{3}{2} RT \times n \\ &= \frac{3}{2} \times 8.314 \times 300 \times 0.5 = 1870.65 \text{ J} \end{aligned}$$

**Sol 2:** Let molecular weight of gas be 'M' grams

$$\Rightarrow \text{moles of gas (at } 25^\circ\text{C)} = \frac{3.7}{M}$$

$$PV = nRT$$

$$\Rightarrow P_1 V_1 = \frac{3.7}{M} R \times 298$$

For hydrogen,

$$n \text{ (given)} = \frac{0.184}{2} = \frac{0.184}{2}$$

$$T = (17 + 273) = 290 \text{ K}$$

$$P_2 V_2 = \frac{0.184}{2} R \times 290$$

As pressure and volumes are same,

$$P_1 V_1 = P_2 V_2$$

$$\Rightarrow \frac{3.7}{M} R \times 298 = \frac{0.184}{2} R \times 290$$

$$\Rightarrow M = \frac{3.7 \times 298 \times 2}{0.184 \times 290} = 41.33 \text{ g}$$

**Sol 3:**  $T = 30^\circ\text{C} = 303 \text{ K}$

$P = 5 \text{ atm}$

$R = 0.0821 \text{ lit atm / (mol k)}$

$M_{(\text{NH}_3)} = 17 \text{ g} = 17 \times 10^{-3} \text{ kg}$

Using  $PM = \rho RT$

$$5 \times 17 \times 10^{-3} = \rho \times 0.0821 \times 303$$

$$\Rightarrow \rho = 3.42 \times 10^{-3} \text{ kg/litre} = 3.42 \text{ g/l}$$

**Sol 4:** Volume will remain constant because volume of container cannot be increased or decreased. Hence mole of  $\text{N}_2$  will decrease with decrease in pressure.

$$\text{Sol 5: Moles of } \text{H}_2 = \frac{6}{2} = 3 \text{ moles}$$

$P = 1.5 \text{ atm}$

$$T = 273 + 273 = 546 \text{ K}$$

Using  $PV = nRT$

$$1.5V = 0.0821 \times 3 \times 546$$

$$V = 89.65 \text{ litres}$$

$$\text{Sol 6: Moles of sulphur} = \frac{3.2}{32} = 0.1$$

$$nS \rightarrow S_n$$

$$1 \text{ atm} = 760 \text{ mm of Hg}$$

$$\text{Pressure} = \frac{723}{760} \text{ atm} = 0.95 \text{ atm}$$

$$\text{Volume} = 780 \text{ mL} = 0.78 \text{ l}$$

$$T = 450^\circ\text{C} = 723 \text{ K}$$

$$PV = nRT$$

$$\Rightarrow n = \frac{0.95 \times 0.78}{0.0821 \times 723}$$

$$N = 0.012$$

$$\Rightarrow 0.1 = 0.012 \times n \quad [\text{Sulphur mass balance}]$$

$$\Rightarrow n = \frac{0.1}{0.012} = 8$$

**Sol 7:** Given

$$\frac{r_A}{r_B} = \frac{1}{4} \text{ and } \frac{M_A}{M_B} = \frac{W_A}{W_B} = \frac{2}{3}$$

According to Graham's law of diffusion

$$r_A \propto \frac{P}{\sqrt{M}} ; \quad P = \frac{nRT}{V}$$

$$\frac{r_A}{r_B} = \frac{n_A \sqrt{M_B}}{n_B \sqrt{M_A}}$$

$$\frac{1}{4} = \sqrt{\frac{M_B n_A^2}{M_A n_B^2}}$$

$$\Rightarrow \frac{n_B^2 M_A}{n_A^2 M_B} = \frac{16}{1}$$

$$\frac{n_A M_A}{n_B M_B} = \frac{2}{3} \Rightarrow \frac{M_A}{M_B} = \frac{2}{3} \frac{n_B}{n_A}$$

$$\frac{n_B^3}{n_A^3} \frac{2}{3} = 16$$

$$\Rightarrow \left( \frac{n_B}{n_A} \right)^3 = 24$$

$$n_A : n_B = 1 : \sqrt[3]{24}$$

Ratio of mole fractions = ratio of moles

**Sol 8:** Acetylene =  $C_2H_2$   $H-C \equiv C-H$

$$(n) \text{ moles of acetylene} = \frac{5}{26}$$

$$T = 50^\circ C = 313 \text{ K}$$

$$P = 740 \text{ mm of Hg} = \frac{740}{760} \text{ atm}$$

$$PV = nRT$$

$$\frac{740}{760} \times V = \frac{5}{26} \times 0.0821 \times 323$$

$$\Rightarrow v = 5.24 \text{ litres}$$

**Sol 9:**  $P = 20 \text{ bar}$

$$\frac{r_{He}}{r_{CH_4}} = \frac{n_{He}}{n_{CH_4}} \sqrt{\frac{M_{CH_4}}{M_{He}}} = \sqrt{\frac{16}{2}} = \sqrt{8}$$

$$= \sqrt{8} : 1$$

**Sol 10:**  $Cl_2 \longrightarrow 2Cl$

$$1 - x \quad 2x$$

$$T = 1200^\circ C = 1473 \text{ K}$$

$$\text{Given } \frac{r_{Kr}}{r_{mix}} = \frac{1}{1.16}$$

$$\frac{r_{Kr}}{r_{mix}} = \sqrt{\frac{M_{mix}}{M_{Kr}}} \Rightarrow \frac{M_{mix}}{84} = \frac{1}{(1.16)^2}$$

$$\Rightarrow M_{mix} = \frac{84}{(1.16)^2}$$

$$M_{mix} = 62.425$$

We know

$$62.425 = \frac{(1-x) \times 71 + 2x \times 35.5}{1+x}$$

$$62.425 = \frac{71}{1+x}$$

$$\Rightarrow 1+x = \frac{71}{62.425}$$

$$\therefore x = \frac{71 - 62.425}{62.425} = 0.137$$

**Sol 11:**  $V = 20 \text{ dm}^3 = 20 \times 10^{-3} \text{ m}^3 = 20 \text{ litre}$

$$T = 60 \text{ sec}$$

We know

$$\text{Rate of diffusion} \propto \frac{1}{\sqrt{\text{Molecular weight}}}$$

$$\Rightarrow \frac{r_{SO_2}}{r_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{SO_2}}}$$

$$\frac{V_{SO_2} / 60}{V_{O_2} / 30} = \sqrt{\frac{32}{64}}$$

$$\Rightarrow \frac{20 \times 30}{60 \times V_{O_2}} = \sqrt{\frac{1}{2}}$$

$$\Rightarrow V_{O_2} = 10\sqrt{2}$$

$$V_{O_2} = \sqrt{200}$$

$$V_{O_2} = 14.14 \text{ dm}^3$$

**Sol 12:**  $T = 20^\circ C = 293 \text{ K}$ ;  $P = 82 \text{ cm of Hg}$

$$\Rightarrow P = \frac{82}{76} = 1.08 \text{ atm} = 1.09 \times 10^5 \text{ Pa}$$

$$O_3 \Rightarrow \text{Molecular weight} = 48 \times 10^{-3} \text{ g}$$

Root mean square velocity

$$v = \sqrt{\frac{3RT}{M}}$$



$$V = \sqrt{\frac{3 \times 8.314 \times 293}{48 \times 10^{-3}}}$$

$$V = 390 \text{ m/s}$$

**Sol 13:**  $P = 7.6 \times 10^{-10} \text{ mm pf Hg}$

$$V = 1 \text{ litre}$$

$$T = 0 \text{ }^\circ\text{C} = 273 \text{ K}$$

$$\text{Number of molecules} = \text{Moles} \times N_A$$

$$PV = nRT; \frac{7.6 \times 10^{-10}}{760} \times 1 = n \times 0.0821 \times 273$$

$$\Rightarrow n = \frac{10^{-12}}{0.0821 \times 273}$$

$$\begin{aligned} \text{Number of molecules} &= \frac{6.023 \times 10^{23} \times 10^{-12}}{0.0821 \times 273} \\ &= 2.7 \times 10^{10} \text{ molecules} \end{aligned}$$

**Sol 14:**  $T = 27 \text{ }^\circ\text{C} = 300 \text{ K}$

$$P = 2 \text{ atm}$$

$$P(\text{solid CO}_2) = 1.53 \text{ g/ml}$$

$$V_{\text{occupied}} = 2 \text{ ml}$$

$$\Rightarrow M(\text{Solid CO}_2) = p \times v$$

$$= 1.53 \times 2 \text{ g} = 3.06 \text{ g}$$

$$\Rightarrow \text{Moles of solid CO}_2$$

$$= \frac{3.06}{44} = 0.07$$

Using  $PV = nRT$  (for gaseous  $\text{CO}_2$ );

$$2 \times V = 300 \times 0.07 \times 0.0821$$

$$V = 0.86 \text{ litre}$$

**Sol 15:**  $M(^{336}\text{UF}_6) = 235 + 18 \times 6 = 343$

$$M(^{238}\text{UF}_6) = 238 + 18 \times 6 = 346$$

$$r^2 \propto \frac{1}{M}$$

$$\frac{r^{235}\text{UF}_6}{r^{238}\text{UF}_6} = \sqrt{\frac{346}{343}}$$

**Sol 16:** Let molecular weight =  $M = 120 \text{ g}$

$$\Rightarrow \text{Moles of gas} = \frac{12}{M} = \frac{12}{120} = 0.1 \text{ moles}$$

$$P_1 = P$$

$$P_2 = 1.1 P$$

$$T_1 = T^\circ\text{C} = T + 273 \text{ K}$$

$$T_2 = (T + 10) \text{ }^\circ\text{C} = T + 283 \text{ K}$$

$$P_1 = 1 \text{ atm}$$

Using  $P \propto T$

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

$$\frac{P}{1.1P} = \frac{T + 273}{T + 283}$$

$$T + 283 = 1.1 T + 273 \times 1.1$$

$$\Rightarrow T = \frac{283 - 1.1 \times 273}{0.1}$$

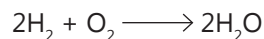
$$T = -173 \text{ }^\circ\text{C}$$

$$1 \times V = 0.0821 \times 0.1 \times (-173 + 273)$$

$$\Rightarrow V = 0.0821 \times 0.1 \times 100$$

$$V = 0.821 \text{ litre}$$

**Sol 17:**  $\frac{n_{\text{H}_2}}{n_{\text{O}_2}} = 2 : 1$



Total pressure (before reaction) = 0.8 atm

$$T = 20 \text{ }^\circ\text{C} = 293 \text{ K}$$

Let total moles in container be

$$\therefore 3 \text{ (2 moles of H}_2 \text{ and 1 mole O}_2\text{)}$$

After the reaction (180% complete)

$$\text{Moles of H}_2 = 2 - 2 \times 0.8 = 0.4$$

$$\text{Moles of O}_2 = 1 - 1 \times 0.8 = 0.2$$

$$\text{Moles of H}_2\text{O} = 0.8 \times 2 = 1.6$$

$$\Rightarrow \text{Total moles after reaction}$$

$$= 1.6 \times 0.2 + 0.4 = 2.2 \text{ mole}$$

Using  $PV = nRT$

and same volume, we get

$$\frac{P_1}{n_1 t_1} = \frac{P_2}{n_2 t_2}$$

$$\frac{0.8}{3 \times 293} = \frac{P_2}{2.2 \times 393}$$

$$\Rightarrow P_2 = 0.787 \text{ atm}$$

**Sol 18:** Vessel is open  $\Rightarrow P_1 = P_2 = \text{atm}$  and volume is constant

$$\therefore n_1 T_1 = n_2 T_2$$

$$n \times 300 = \left(1 - \frac{3}{5}\right) n \times T$$

$$T_2 = \frac{300 \times 5}{2}$$

$$T_2 = 750 \text{ K}$$

**Sol 19:** Let molecular weight of a and B be  $M_A$  and  $M_B$  respectively

$$\Rightarrow n_A = \frac{2}{M_A}$$

$$n_B = \frac{3}{M_B}$$

$$\text{Given } 1 \times V = n_A \times R \times T$$

$$1.5 \times V = n_A + n_B \times R \times T$$

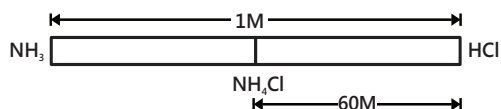
$$\Rightarrow \frac{1}{1.5} = \frac{n_A}{n_A + n_B}$$

$$\Rightarrow \frac{n_A}{n_B} = 2$$

$$\Rightarrow \frac{2N_B}{M_A \times 3} = 2$$

$$\Rightarrow M_B / M_A = 3 : 1$$

**Sol 20:**



We know

$$r \propto \frac{P}{\sqrt{M}}$$

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = \frac{1}{P} \times \sqrt{\frac{N_{\text{HCl}}}{M_{\text{NH}_3}}}$$

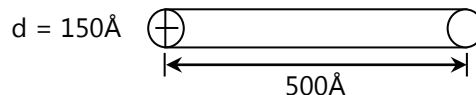
$$\frac{d_{\text{NH}_3} / t}{d_{\text{HCl}} / t} = \frac{1}{P} \times \sqrt{\frac{36.5}{17}}$$

$$\frac{d_{\text{NH}_3}}{d_{\text{HCl}}} = \frac{1}{P} \times 1.465$$

$$\frac{40}{60} = \frac{1.465}{P}$$

$$\Rightarrow P = 2.197 \text{ atm}$$

**Sol 21:**



Volume of particle

$$= \pi r^2 l = \frac{\pi d^2 L}{4} = \frac{3.14 \times (150)^2 \times 500 \times 10^{-30}}{4}$$

$$= 8.836 \times 10^{-24} \text{ m}^3$$

$$\text{Specific volume} = 0.75 \text{ cm}^3 / \text{g}$$

$$\text{Mass of virus} = \frac{\text{Volume}}{\text{Specific value}}$$

$$= \frac{8.836 \times 10^{-24} \text{ m}^3}{0.75 \times 10^{-6} \text{ m}^3 / \text{g}} = 1.178 \times 10^{-17} \text{ g}$$

$$\text{Molecular weight} = \text{mass} \times N_A = 7.09 \times 10^6 \text{ g}$$

**Sol 22:** Gives  $m_A = 2m_B$

$$\text{r.m.s. (A)} = 2 \text{ r.m.s. (B)}$$

Both contain same no. of molecules  $\Rightarrow V$  is same

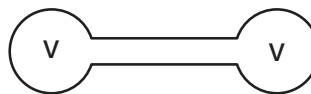
$$\text{r.m.s.} \propto \sqrt{\frac{P}{M}}$$

$$\frac{\text{r.m.s. A}}{\text{r.m.s. B}} = \sqrt{\frac{P_A \times M_B}{M_A \times P_B}}$$

$$2 = \sqrt{\frac{P_A}{2P_B}}$$

$$\Rightarrow \frac{P_A}{P_B} = 8 : 1$$

**Sol 23:**



$$T_1 = 0^\circ \text{C}$$

Let initially there be  $n$ -moles in both the bulbs.

When bulb-2 is placed in water both the pressure in both bulbs must be same

$$\Rightarrow n_1 \times R \times (62 + 273) = n_2 \times R \times 273$$

$$\Rightarrow \frac{n_I}{n_{II}} = \frac{273}{335}$$

$$\text{and } n_I + n_{II} = n$$

$$\Rightarrow n_{II} + \frac{273}{335} n_{II} = n$$

$$\Rightarrow n_{II} = \frac{335n}{608}$$

$$\Rightarrow n_I = \frac{273n}{608}$$

Pressure in bulbs

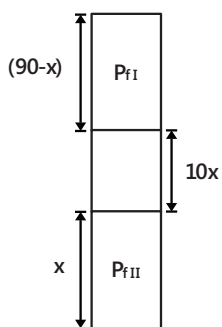
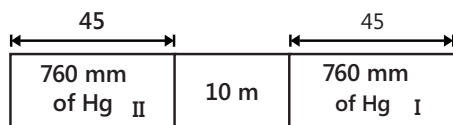
$$P_1 \times V_1 = \frac{n}{2} \times R \quad (273)$$

$$P_2 \times V_2 = \frac{273n}{608} \times R \times (273 + 62)$$

$$\Rightarrow \frac{P_2}{P_1} = \frac{335 \times 273 \times 2}{608 \times 273}$$

$$P_2 = \frac{335 \times 2}{608} \times P_1 = 1.10 P_1 = 83.75 \text{ cm of Hg}$$

**Sol 24:**



Applying P and P-V balance

# for compartment-I

$$760 \times 45 = P_{fI} \times (90 - x)$$

For compartment-II

$$760 \times 45 = (P_{fI} + 10) \times x$$

$$\Rightarrow P_{fI} = \frac{760 \times 45}{90 - x}$$

$$P_{fI} = \frac{760 \times 45}{x} - 100$$

$$\Rightarrow \frac{760 \times 45}{90 - x} = \frac{760 \times 45}{x} - 100$$

$$\Rightarrow 3420 x = (3420 - 10x)(90 - x)$$

$$3420 x = 3420 \times 90 - 900x +$$

$$10x^2 - 3420x$$

$$10x^2 - 7740 x + 3420 \times 90 = 0$$

$$\Rightarrow x^2 - 774 x + 30780 = 0$$

$$x = \frac{774 \pm \sqrt{774^2 - 4 \times 30780}}{2}$$

$$\Rightarrow x = 42 \text{ cm}$$

\(\therefore\) In the vertical column the mercury column has shifted by 3 cm

**Sol 25:**  $P = 11 \text{ V}$ ;  $V = 4 \text{ litre}$

$$T = 300 \text{ K}; n = 2$$

$$b = 0.05 \text{ litre} / n$$

$$\left( P + \frac{an^2}{V^2} \right) \cdot (V - nb) = nRT$$

$$\left( 11 + \frac{a \times 4}{16} \right) \cdot (4 - 2 \times 0.05) = 2 \times 0.0821 \times 300$$

$$\left( 11 + \frac{a}{4} \right) (4 - 0.1) = 49.26$$

$$\left( 11 + \frac{a}{4} \right) = 12.62$$

$$a = 6.492$$

**Sol 26:** Mass of liquid =  $148 - 50 = 48 \text{ g}$

$$\text{Density} = 0.98 \text{ g/mL}$$

$$\text{Volume} = \frac{48}{0.98} \text{ mL} = 48.98 \text{ mL} = 0.049 \text{ l}$$

$$\text{Mass of gas} = 50.5 - 50 = 0.5 \text{ g}$$

$$P = 760 \text{ mm of Hg} = 1 \text{ atm}$$

$$T = 300 \text{ K}; PV = nRT$$

$$1 \times 0.049 = \frac{0.5}{M} \times 0.0821 \times 300$$

$$\Rightarrow M = 5 \times 300 \times 0.0821$$

$$M = 123.15 \text{ g}$$

**Sol 27:**  $V = 10$  litre $T = 27^\circ\text{C}$ 

$$n(\text{He}) = \frac{0.4}{4} \text{ g} = 0.1 \text{ mole}$$

$$\Rightarrow P_{\text{He}} \times 10 = 300 \times 0.0821 \times 0.2$$

$$P_{\text{He}} = 0.2464$$

$$n_{\text{O}_2} = \frac{1.6}{32} = 0.05$$

$$P_{\text{O}_2} \times 10 = 0.05 \times 0.0821 \times 300$$

$$P_{\text{O}_2} = 0.123$$

$$n_{\text{N}_2} = \frac{1.4}{28} = 0.05$$

$$\Rightarrow P_{\text{N}_2} \times 10 = 0.05 \times 0.082 \times 300 = 0.123$$

$$P_{\text{total}} = P_{\text{O}_2} + P_{\text{N}_2} + P_{\text{He}}$$

$$= 0.123 + 0.123 + 0.246 = 0.492$$

## Exercise 2

### Single Correct Choice Type

**Sol 1: (B)**  $V = 0.16 \ell$ AIM  $\longrightarrow$  to find slope of P-T curve

$$PV = nRT$$

$$\frac{P}{T} = \frac{nR}{V}$$



$$1-0.4 \quad \quad \frac{3}{2}(0.4) \quad \quad \frac{2}{2} \times 0.4$$

$$0.6 \quad \quad 0.6 \quad \quad 0.4$$

$$\text{Total moles} \longrightarrow 0.6 + 0.6 + 0.4$$

$$\longrightarrow 1.6$$

$$\text{Slope } \tan\theta = \frac{P}{T} = \frac{nR}{V} = \frac{1.6 \times 0.08}{0.16}$$

$$\tan\theta = 0.8$$

$$\theta = \tan^{-1} 0.8$$

$$\text{Sol 2: (A)} \quad r_{\text{O}_2} \propto \frac{P_{\text{O}_2}}{\sqrt{M_{\text{O}_2}}} \propto \frac{n_{\text{O}_2}}{\sqrt{M_{\text{O}_2}}}$$

$$r_{\text{H}_2} \propto \frac{P_{\text{H}_2}}{\sqrt{M_{\text{H}_2}}} \propto \frac{n_{\text{H}_2}}{\sqrt{M_{\text{H}_2}}}$$

$$\frac{r_{\text{O}_2}}{r_{\text{H}_2}} = \frac{\sqrt{M_{\text{H}_2}}}{\sqrt{M_{\text{O}_2}}} \frac{n_{\text{O}_2}}{n_{\text{H}_2}} = \sqrt{\frac{2}{32}} \left( \frac{16/32}{2/3} \right) = \frac{1}{8}$$

**Sol 3: (C)** Kinetic energy of  $\text{CO}_2$  at T K

$$\text{Total K.E. of energy} \longrightarrow \frac{3}{2} RT$$

$$\text{Sol 4: (B)} \quad \text{K.E.} = \frac{3}{2} RT$$

So at  $T = 300$ 

$$\text{K.E.} = E = \frac{3}{2} R(300)$$

At  $T = 1500$ 

$$\text{K.E.} = \frac{3}{2} R(1500) = \left( \frac{3}{2} R(300) \right) (5) = 5E = 5E$$

Answer = B

$$\text{Sol 5: (B)} \quad \text{RMS velocity} = \sqrt{\frac{3RT}{M}}$$

Let temperature be to

$$\text{RMS}_{\text{O}_2} = \text{RMS}_{\text{SO}_2}$$

$$\Rightarrow \sqrt{\frac{3RT_0}{M_{\text{O}_2}}} = \sqrt{\frac{3RT(300)}{M_{\text{SO}_2}}}$$

$$\Rightarrow T_0 = \frac{300 \times 32}{64} = 150 \text{ K} = -123^\circ\text{C}$$

$$\text{Sol 6: (B)} \quad \sqrt{\frac{2RT_0}{M_{\text{O}_2}}} = \sqrt{\frac{3RT}{M_{\text{N}_2}}} = \frac{2 \times T_0}{32} = \frac{3 \times 700\text{K}}{28}$$

$$\Rightarrow T_0 = 1200 \text{ K}$$

**Sol 7: (C)** Final pressure, temperature =  $P_f, T_f$ Initial pressure, temperature =  $P_0, T_0$ 

Mole ratio = Mass ratio

$$\begin{aligned} & \frac{1}{2} P_0 (V_0) \\ & = \frac{n_i}{n_0} = \frac{\frac{P_i V_i}{T_i}}{\frac{P_0 V_0}{T_0}} = \frac{m_i}{m_0} = \frac{\frac{2}{3} T_0}{\frac{P_0 V_0}{T_0}} = \frac{m_i}{m_0} = \frac{3}{4} \end{aligned}$$

$$\therefore \text{Escaped gas} = 10 - 10 \times \frac{3}{4} = 2.5 \text{ gms}$$

**Sol 8: (D)**  $P_0 V_0 = nRT_0$

When pressure and temperature doubled

$$P_i V_i = nRT_i$$

$$2P_0 V_i = nR(2T_0)$$

$$V_i = \frac{nRT_0}{P_0} = V_0 \text{ from (i)}$$

∴ Volume remains same

**Sol 9: (C)**  $P_0 V_0 = nRT_0$

$$P_i V_i = n_i RT_i$$

$$\text{Now } T_i = T_0, n_i = 2n_0, V_i = 2V_0$$

$$\therefore P_i = \frac{n_0 RT_0}{V_0} = P_0$$

$$P_i = P_0 = 1 \text{ atm}$$

**Sol 10: (D)** At very low pressure, attractive forces are low, volume occupied is higher compared to volume occupied by molecule

$$\Rightarrow V \gg b$$

⇒ Real gas equation

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

**Sol 11: (B)**  $y_i$  mole fraction of  $N_2 = \frac{0.3}{0.3+0.2+0.5} = 0.3$

$$\Rightarrow \text{Partial pressure} = y_i P$$

$$= 0.3 P \text{ atm}$$

$$= 0.3 P \times 760 \text{ mm of Hg}$$

**Sol 12: (B)** 10 g each of  $SO_2$ ,  $PH_3$  and  $H_2$  are kept in 3 flasks

We know,

Number of atom  $\propto$  Number of molecule

And, for a given mass of gas

$$\text{Number of mole} = \frac{\text{Mass}}{\text{Molecular weight}}$$

Which implies

$$\Rightarrow \text{Number of molecules} \propto \text{Number of moles} \propto$$

$$\frac{1}{\text{Molecular weight}}$$

As molecular weight of  $H_2 <$  Molecular weight  $PH_3 <$  molecular weight of  $SO_2$

.....(i) Hence, Number of molecules is in the order

$$H_2 > PH_3 > SO_2$$

**Sol 13: (B)**  $P_{\text{real}} < P_{\text{ideal}}$

Due to intermolecular forces of attraction, which reduce the velocity. Hence, momentum impact on collision with wall.

**Sol 14: (A)** Order of Vander waal constant

$$A = 5.6, B = 3.6, C = 2.4$$

$$\Rightarrow A > B > C$$

Higher the Vander waal constant, higher are the attractive forces between molecules of gases and due to high attraction, liquefaction becomes easier.

Hence, ease of liquefaction has order

$$A > B > C$$

**Sol 15: (A)** Moles of  $H_2 = \frac{6}{2} = 3$

$$P = 1.5 \text{ atm}; T = 273^\circ\text{C} = 546 \text{ K}$$

$$V = \frac{nRT}{P} = \frac{3 \times 0.0821 \times 546}{1.5}$$

$$V = 89.65 \text{ mL}$$

**Sol 16: (A)**  $P_{\text{max}} = 14.9 \text{ atm}$

$$P_1 = 12 \text{ atm}, T_1 = 27^\circ\text{C} = 300 \text{ K}$$

At exploding temp  $P = P_{\text{max}}$

Using  $P \propto T$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow T_2 = \frac{300 \times 14.9}{12}$$

$$\Rightarrow T_2 = 372 \text{ K}$$

**Sol 17: (C)** Moles of A =  $\frac{2}{M_A}$

$$\text{Moles of B} = \frac{3}{M_B}$$

As we know volume and R are same

$$\Rightarrow \frac{P_1}{n_1 T_1} = \frac{P_2}{n_2 T_2}$$

$$\frac{1}{\frac{2}{M_A} \times 298} = \frac{1.5}{\left( \frac{2}{M_A} + \frac{3}{M_B} \right) \times 298}$$

$$\frac{2}{M_A} + \frac{3}{M_A} = \frac{1.5 \times 2}{M_A}$$

$$\Rightarrow \frac{3}{M_A} = \frac{1}{M_A}$$

$$\frac{M_A}{M_B} = 1 : 3$$

**Sol 18: (B)** We know volume and temperature are same

$$\Rightarrow P \propto n$$

$$\frac{P_1}{P_2} = \frac{n_1}{n_2}; \quad \frac{P_1}{1} = \frac{44 \times M_{\text{CO}_2}}{M_{\text{H}_2} \times 44}$$

$$P_1 = \frac{44}{2} = 22$$

**Sol 19: (B)** For ideal gas

$$\text{Most probable speed} = \sqrt{\frac{3RT}{M}}$$

$\therefore$  Statement A is correct and statement D is incorrect

The equation for fraction of molecule, moving with a speed at any time (equation) required

$$\frac{dN}{N} = \left( \frac{M}{2\pi RT} \right)^{1/2} e^{-\frac{mv^2}{2RT}} dv$$

Under similar condition of P, V and T,  $\mu$  is same, hence fraction of molecules moving with  $\mu_{\text{m.p.s.}}$  is

$$\text{frac} \propto M$$

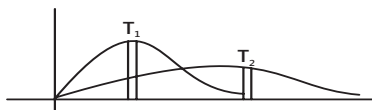
Hence, Fraction  $\text{Cl}_2 > \text{frac H}_2$

Fraction of molecules moving with mps increases with increases in temperature

$$\mu_{\text{most probal}} \propto \frac{1}{\sqrt{M}}$$

$$\therefore \mu_{\text{H}_2} > \mu_{\text{Cl}}$$

$$T_1 > T_2$$



## Previous Years' Questions

**Sol 1: (A)**  $P_1 V_1 = RT$

$$P_2 (V_1 + dV) = R(T + 1)$$

$$\therefore P_2 = RT + R$$

$$\text{Since } \left( \frac{P_2}{V_1 + dV} = 1 \right)$$

$$= 2 \left( \frac{dP_2}{dT} \right) v = R$$

$$= \left( \frac{dP_2}{dT} \right) = \frac{R}{2}$$

$$\text{Since } C = C_v + \left( \frac{dP}{dT} \right)$$

$$= \frac{3R}{2} + \frac{R}{2}$$

$$= 2R$$

**Sol 2: (C)**  $PV = nRT \therefore \frac{n}{V} = \frac{P}{RT}$

**Sol 3: (A)** In isolated system, the expansion of gas is carried out adiabatically. Since heat exchange between system and surrounding is not possible i.e.,  $q = 0$  and secondary work is always greater than work. Therefore, for reversible process, there must be comparatively higher decrease in internal energy i.e.,  $\Delta U$  for reversible process will be more negative. Hence final temperature in reversible process will be smaller than irreversible process.

$$\therefore (T_f)_{\text{irr}} > (T_f)_{\text{rev}}$$

**Sol 4: (B)**  $r \propto \frac{1}{\sqrt{M}}$

$$\therefore r = \frac{\text{Volume effused}}{\text{time taken}} = \frac{V}{t}$$

$$\frac{V}{t} \propto \frac{1}{\sqrt{M}}$$

$\therefore$  For same volumes (V constant)

$$t \propto \sqrt{M}$$

$$\therefore \frac{t_1}{t_2} = \sqrt{\frac{M_1}{M_2}}$$

$$t_{\text{He}} = t_{\text{H}_2} \sqrt{\frac{M_{\text{He}}}{M_{\text{H}_2}}}$$

$$5\sqrt{\frac{4}{2}} = 5\sqrt{2}s$$

$$t_{O_2} = t = 5\sqrt{\frac{32}{2}} = 20s$$

$$t_{CO} = 5\sqrt{\frac{28}{2}} = 5\sqrt{14}s; t_{CO_2}$$

$$= 5\sqrt{\frac{44}{2}} = 5\sqrt{22}s$$

**Sol 5: (C)** Let the mass of methane and oxygen is w

$$\text{Mole fraction of oxygen} = \frac{\frac{w}{32}}{\frac{w}{32} + \frac{w}{16}} = \frac{\frac{1}{32}}{\frac{1}{32} + \frac{1}{16}}$$

$$= \frac{\frac{1}{32}}{\frac{1}{32} + \frac{2}{32}} = \frac{1}{3}$$

Let the total pressure be P

The pressure exerted by oxygen (partial pressure)

$$= X_{O_2} \times P_{\text{total}}$$

$$\Rightarrow P \times \frac{1}{3}, \text{ Hence, (C) is correct.}$$

**Sol 6: (A)**  $PV = nRT$

$$3170 \times 10^{-3} = n \times 8.314 \times 300$$

$$n = \frac{3170 \times 10^{-3}}{8.314 \times 300}$$

$$V = 1 \text{ Lt} = 1 \text{ dm}^3 = 10^{-3} \text{ m}^3$$

$$n = 1.27 \times 10^{-3} \text{ mol}$$

**Sol 7: (A)** When average speed of molecule is increased due to increase in temperature then the change in momentum during collision between wall of container and molecules of gas also increases.

**Sol 8: (C)**

$$\frac{u_{H_2}}{u_{O_2}} = \sqrt{\frac{T_{H_2} \cdot M_{O_2}}{M_{H_2} \cdot T_{O_2}}}$$

$$= \sqrt{\frac{50}{2} \cdot \frac{32}{800}} = 1$$

**Sol 9: (B)** Most probable velocity increase and fraction of molecule possessing most probable velocity decrease.

**Sol 10: (C)** Vander Waals equation for non-ideal gas

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

**Sol 11: (B)** Ideal gas has no attractive force between the particles.

**Sol 12: (A)** Vander Waal's constant for volume correction b is the measure of the effective volume occupied by the gas molecule.

**Sol 13: (D)** We know that

$$Z = \frac{PV}{RT}$$

$$\Rightarrow 0.5 = \frac{100 \times V}{0.0821 \times 273}$$

$$\Rightarrow V = 0.112 \text{ litre}$$

According to vander waal's equation

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

$$\left( 100 + \frac{a}{(0.112)^2} \right) (0.112 - 0) = 0.0821 \times 273$$

$$a = 1.253 \text{ L}^2 \text{ mol}^{-2} \text{ atm}$$

**Sol 14: (A)** Average kinetic energy  $\propto$  (T Kelvin)

(Factor)

$$\frac{K.E_2}{K.E_1} = \frac{T_2}{T_1}$$

$$= \frac{40 + 273}{20 + 273} = \frac{313}{293}$$

**Sol 15: (A)** Root mean square speed

$$= \left[ \frac{n_1 C_1^2 + n_2 C_2^2 + n_3 C_3^2 + \dots}{n_1 + n_2 + n_3 + \dots} \right]^{1/2}$$

**Sol 16: (C)**

$$n = \frac{PV}{RT} = 128 \times 10^{-5} \text{ moles}$$

$$= \frac{3170 \times 10^{-5} \text{ atm} \times 1\text{L}}{0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 300\text{K}} = 1.27 \times 10^{-3} \text{ mol}$$

**Sol 17: (C)** Ease of liquefaction  $\propto \frac{a}{b}$

For ethane  $a = 5.49$ ,  $b = 0.0638$

For  $\text{Cl}_2$   $a = 6.49$ ,  $b = 0.0562$

**Sol 18: (B)**  $C^* =$  Most probable speed  $= \sqrt{\frac{2RT}{M}}$

$\bar{C} =$  Average speed  $= \sqrt{\frac{8RT}{\pi M}}$

$C =$  Mean square speed corrected as rms  $= \sqrt{\frac{3RT}{M}}$

$C^* < \bar{C} < C$

$C^* : \bar{C} : C = 1 : \sqrt{\frac{4}{\pi}} : \sqrt{\frac{3}{2}} = 1 : 1.128 : 1.225$

**Note:** As no option correspond to mean square speed, it is understood as misprint. It should be root Means square speed.

**Sol 19: (B)** Compressibility factor  $(Z) = \frac{PV}{RT}$

(For one mole of real gas)

van der Waal equation

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

At low pressure

$V - b \approx V$

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

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

$$PV = RT - \frac{a}{V}$$

$$\frac{PV}{RT} = 1 - \frac{a}{VRT}$$

$$\text{So, } Z = 1 - \frac{1}{VRT}$$

**Sol 20:** Initial moles = final moles

$$\frac{P_i \times V}{RT_1} + \frac{P_i \times V}{RT_1} = \frac{P_f \times V}{RT_2} + \frac{P_f \times V}{RT_1}$$

$$\frac{P_i}{T_1} + \frac{P_i}{T_1} = \frac{P_f}{T_2} + \frac{P_f}{T_1}$$

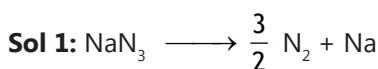
$$\frac{2P_i}{T_1} = P_i \left[ \frac{1}{T_2} + \frac{1}{T_1} \right]$$

$$\frac{2P_i}{T_1} = P_i \left[ \frac{T_1 + T_2}{T_1 T_2} \right]$$

$$P_f = 2P_i \left[ \frac{T_2}{T_1 + T_2} \right]$$

## JEE Advanced/Boards

### Exercise 1



125 g  $\text{NaN}_3$  mass of  $\text{NaN}_3 = 23 + 14 \times 3 = 42 + 23 = 65$

$$\therefore \text{Moles of } \text{NaN}_3 = \frac{125}{65}$$

$$\text{Moles of } \text{N}_2 \text{ formed} = \frac{125}{65} \times \frac{3}{2} = \frac{375}{130}$$

$$756 \text{ torr} = \frac{756}{760} \text{ atm}$$

$\therefore$  Volume occupied by  $\text{N}_2$   $PV = nRT$

$$\frac{756}{760} \times V = \frac{375}{130} \times 0.0821 \times 300$$

$$V = 71.42 \text{ L}$$

**Sol 2:** We know,  $V$  remains constant

and if  $P$  is same

Then,  $n_1 T_1 = n_2 T_2$

$$\Rightarrow \frac{3.6}{44} \times T = \frac{(3.6 - 0.6)}{44} \times (T + 15)$$

$$3.6 T = 3T + 45$$

$$0.6T = 45$$

$$T = \frac{45}{0.6}$$

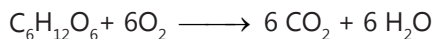
$$T = 75 \text{ K}$$

$$P \times 8 = \frac{3.6}{44} \times 0.0821 \times 75$$

$$P = 0.062 \text{ atm}$$



**Sol 3:** Mole use  $0.2 \text{ dm}^3 \text{ O}_2$  per hour at atm and 273 K per Kg of body



For a 1 kg body moles of air ( $\text{O}_2$ ) used,

$$PV = nRT$$

$$1 \times 0.2 = n \times 0.0821 \times 273$$

$$\Rightarrow n = 8.923 \times 10^{-3}$$

For a 60 kg body moles of  $\text{O}_2$  used

$$\Rightarrow 60 \times 8.923 \times 10^{-3}$$

$$\therefore \text{Moles of glucose used} = \frac{60 \times 8.923 \times 10^{-3}}{6}$$

$$n' = 8.923 \times 10^{-2}$$

Mass of glucose used

$$= 180 \times n' = 16.06 \text{ g}$$

1 mole of  $\text{O}_2$  produces, mole of  $\text{CO}_2$  and rest condition of temperature and pressure are same

$\therefore$  Volume of  $\text{CO}_2$  produced

= Volume of  $\text{O}_2$  used

$$= 0.2 \times 60 = 12 \text{ dm}^3$$

**Sol 4:**  $T = 200 \text{ K}$ ,  $P = 8.21 \text{ atm}$

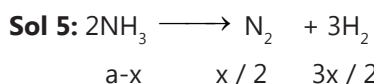
$$8.21 \times V = 0.821 \times n \times 200$$

$$V = 2n$$

$$\Rightarrow V^2 = 4n^2$$

$\therefore$  Slope is constant slope =  $1/4$

$$x = 4y \Rightarrow y = \frac{x}{4}$$



$$P_1 = 760 \text{ mm} = 1 \text{ atm}$$

After sparking  $\longrightarrow$  due to reaction, number of moles increases.

$\therefore$  pressure gas ( $V$  and  $T$  are constant)

$$\therefore P_2 = 760 + 190 = \frac{950}{760} \text{ atm}$$

$$P \propto n$$

$$\frac{P_1}{P_2} = \frac{n_1}{n_2}$$

$$\frac{760}{950} = \frac{a}{a + \frac{3\alpha}{2} + \frac{\alpha}{2} - \alpha}$$

$$\frac{760}{950} = \frac{a}{a + \alpha}$$

$$\therefore \alpha = \frac{190}{760}$$

$\therefore$  % dissociation  $\alpha$

$$= \frac{190 \times 100}{760} = 25\%$$

**Sol 6:**  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{g})$

$$n_{\text{H}_2} = \frac{10^{-2} \times 10^3}{2} = \frac{10}{2} = 5 \text{ moles}$$

$$n_{\text{O}_2} = \frac{6.4 \times 10^{-2} \times 10^3}{32} = \frac{64}{32} = 2 \text{ moles}$$

$\therefore$  Total moles of ideal gas = 7

$$V = 10 \times 10^{-3} \text{ m}^3$$

$$T = 473 \text{ K}$$

$$R = 8.314 \text{ J / mol / K}$$

$$\therefore P = \frac{nRT}{V} = \frac{7 \times 8.314 \times 473}{10^{-2}} \text{ Pa}$$

$$P = 27.54 \text{ bar}$$

If the mixture ignites and the reaction complexes,

$$\text{For } \text{H}_2 = \frac{N}{v} = \frac{5}{2} = 2.5$$

$$\text{For } \text{O}_2 = \frac{2}{1} = 2$$

$\therefore$   $\text{O}_2$  is limiting reagent

Number of moles of  $\text{H}_2$  left after reaction =  $5 - 2 \times 2 = 1$

Number of moles of  $\text{H}_2\text{O}$  formed =  $2 \times 2 = 4$

$\therefore$  Total moles of ideal gas =  $1 + 4 = 5$

$$\therefore \frac{P_i}{P_t} = \frac{7}{5}$$

$$P_t = \frac{5}{7} P_i = \frac{5}{7} \times 27.54 \text{ bar} = 19.67 \text{ bar}$$

**Sol 7:** (i) Under similar condition of  $P$  and  $T$

$$r \propto \frac{1}{\sqrt{\text{Molecular weight}}}$$

$$\frac{r_{\text{SO}_2}}{r_{\text{CH}_4}} = \sqrt{\frac{64}{16}}$$

$$\left(\frac{r_{\text{SO}_2}}{r_{\text{CH}_4}}\right) = 2 : 1$$

(ii) A container contains  $\text{SO}_2$  and  $\text{CH}_4$  in ratio 3 : 2

$$\frac{w_{\text{SO}_2}}{w_{\text{CH}_4}} = \frac{3}{2}$$

$$\therefore \frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} \times \frac{64}{16} = \frac{3}{2}$$

$$\therefore \frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} = \frac{3}{8}$$

We know partial pressure of a gas  $\propto$  molar fraction of gas

$$\therefore \frac{P_{\text{SO}_2}}{P_{\text{CH}_4}} = \frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} = \frac{3}{8}$$

We know,  $r \propto \frac{P}{\sqrt{M.w.}}$

$$\frac{r_{\text{SO}_2}}{r_{\text{CH}_4}} = \frac{P_{\text{SO}_2}}{P_{\text{CH}_4}} \times \sqrt{\frac{M.w._{\text{CH}_4}}{M.w._{\text{SO}_2}}}$$

$$\frac{r_{\text{SO}_2}}{r_{\text{CH}_4}} = \frac{3}{8} \times \sqrt{\frac{16}{64}} = \frac{3}{16}$$

(iii) After n-steps of effusion,

$$\frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} = \left(\frac{r_{\text{SO}_2}}{r_{\text{CH}_4}}\right)^n$$

$$\therefore \frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} = \left(\frac{8}{1}\right)^{1/n} \quad n = 3$$

$$\therefore \frac{n_{\text{SO}_2}}{n_{\text{CH}_4}} = 2 : 1$$

**Sol 8:** We know  $r \propto \frac{1}{\sqrt{M.w.}}$

$$\frac{\text{rate}_{\text{mix}}}{\text{rate of O}_2} = \sqrt{\frac{M.w._{\text{O}_2}}{M.w._{\text{mix}}}}$$

$$\frac{\frac{V_{\text{mix}}}{\text{time}}}{\frac{V_{\text{O}_2}}{\text{time}}} = \sqrt{\frac{32}{M_{\text{mix}}}}$$

Equal volume are diffused in unequal the

$$\frac{V}{234} = \sqrt{\frac{32}{M_{\text{mix}}}}$$

$$\frac{224}{234} = \sqrt{\frac{32}{M_{\text{mix}}}}$$

$$\therefore M_{\text{mix}} = 34.92$$

Mass of mixture containing 50%  $\text{O}_2$  and 20% other gas with molecular weight m.

$$\therefore M_{\text{mix}} = \frac{80 \times 32 + 20 \times m}{100}$$

$$34.92 \times 100 = 2560 + 20m$$

$$\frac{932}{20} = m$$

$$M = 46.6$$

**Sol 9:** We know,  $V = 3$ ;  $P = 24.6$

$$T = 300 \text{ K}$$

$$24.6 \times 3 = 0.082 \times 300 \times x$$

$$\therefore n = 3 \text{ mole}$$

1 mole of  $\text{O}_2$  and 2 moles of  $\text{H}_2$

$\therefore$  Partial pressure of both gases are in the ratio 2 : 1

We want finally

$$\frac{w_{\text{D}_2}}{w_{\text{H}_2}} = \frac{1}{4}$$

$$\frac{n_{\text{D}_2} \times 2}{n_{\text{H}_2} \times 1} = \frac{1}{4}$$

$$\therefore \frac{n_{\text{D}_2}}{n_{\text{H}_2}} = \frac{1}{8}$$

We know

$$\frac{n_{\text{D}_2}}{n_{\text{H}_2}} = \left(\frac{r_{\text{D}_2}}{r_{\text{H}_2}}\right)^n \quad \text{and} \quad \frac{r_{\text{D}_2}}{r_{\text{H}_2}} = \frac{P_{\text{D}_2}}{P_{\text{H}_2}} \sqrt{\frac{M.w._{\text{H}_2}}{M.w._{\text{D}_2}}} = \frac{1}{2} \sqrt{\frac{2}{4}} = \frac{1}{2} \sqrt{\frac{2}{2}}$$

$$\frac{1}{8} = \left(\frac{1}{2\sqrt{2}}\right)^{(n-1)}$$

$$\therefore n = 3$$

$$(2)^{-3} = 2^{-\frac{3}{2}}$$

$$n = 2$$

**Sol 10:**  $P = 250 \text{ kPa}$  $T = 300 \text{ K}$ Using,  $PV = nRT$  $V$  moles remain constant $\therefore$  Point when cylinders blows up, $P = 10^6 \text{ Pa}$ Using  $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ 

$$\frac{250 \times 10^3}{300} = \frac{10^6}{T_2}$$

$$\Rightarrow T_2 = \frac{10^6 \times 300}{250 \times 10^3} = 1200 < 1800$$

 $\therefore$  The cylinder will blow up before it melts.**Sol 11:** Density =  $0.00009 \text{ g/cc}$  $= 0.00009 \times 10^3 \text{ kg/nm}$ 

$$u_{\text{r.m.s.}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 1 \times 1.0323 \times 10^3}{0.09}}$$

 $PM = \rho RT$ 

$$\frac{RT}{M} = \frac{P}{\rho}$$

$$u_{\text{r.m.s.}} = 1838 \text{ m/s} = 183800 \text{ cm/s}$$

**Sol 12:**  $V = 1 \text{ dm}^3 = 10^{-3} \text{ m}^3$  $M.w. = 2 \times 10^{-3} \text{ g}$  $P = 101.325 \text{ kPa}$  $1.03 \times 10^{23} \text{ H}_2$  molecules $\Rightarrow$  Number of moles

$$= \frac{\text{Number of molecules}}{N_A} = \frac{1.03}{6.023}$$

$$101.325 \times 10^3 \times 10^{-3} = 8.314 \times \frac{1.03}{6.023} \times T$$

 $\therefore T = 71.27 \text{ K}$ 

$$u_{\text{avg}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.314 \times 71.27}{3.142 \times 2 \times 10^{-3}}}$$

$$u_{\text{avg}} = 868.53 \text{ m/s}$$

**Sol 13:**  $T = 273 \text{ K}$ ,  $P = \text{atm}$ Density =  $1.2505 \text{ kg/m}^3$ 

$$M = 12 + 16 = 28$$

$$\text{R.M.S.} = \sqrt{3 \frac{P}{D}} = \sqrt{\frac{3 \times 1.01325 \times 10^5}{1.2504}}$$

$$u_{\text{r.m.s.}} = 493.05 \approx 493 \text{ m/s}$$

We know

$$u_{\text{avg}} = \sqrt{\frac{8}{\pi} \times \frac{1.01323 \times 10^5}{1.2504}}$$

$$u_{\text{avg}} = 454.37$$

$$u_{\text{mp}} = \sqrt{\frac{2P}{D}} = \sqrt{\frac{2}{3}} \mu_{\text{r.m.s.}}$$

$$u_{\text{mp}} = 402.63 \approx 403$$

**Sol 14:** Fraction of molecules in the range $\mu_p$   $0.005 \text{ m/s}$  to  $\mu_p$  to  $0.005 \text{ m/s}$ 

$$\frac{dNu}{N} = 4\pi \left[ \frac{M}{2\pi RT} \right]^{-3/2} e^{-\frac{Mu^2}{2RT}} u^2 du$$

We know  $u^2 = \frac{2RT}{M}$  and

$$du = 0.005 \times 2 = 0.01$$

 $\therefore$  Fraction of moles

$$\text{Frac} = 2\pi \times \frac{M}{2\pi RT} \times \left( \frac{M}{2\pi RT} \right)^{1/2} \times e^{-1} \times \frac{2RT}{M} du$$

$$\text{Frac} = \frac{4x}{e} \left( \frac{M}{2\pi RT} \right)^{1/2} \times 0.01 \times \text{ups}$$

$$= \frac{4}{e} \times \left( \frac{M}{2\pi RT} \right)^{1/2} \times 0.01 \times \left( \frac{2RT}{M} \right)^{1/2}$$

$$= \frac{4}{\sqrt{\pi e}} \times du = \frac{4 \times 0.01}{e \times \sqrt{\pi}} = 8.304 \times 10^{-3}$$

$$\text{Sol 15: Ratio} = \frac{4\pi \left( \frac{M}{2\pi RT} \right)^{3/2} e^{-\frac{M(2u)^2}{2RT(2u)^2} du}}{4\pi \left( \frac{M}{2\pi RT} \right)^{3/2} e^{-\frac{Mu^2}{2RTu^2} du}}$$

$$U^2 = \frac{2RT}{M}$$

$$\therefore \text{Ratio} = \frac{e^{-\frac{4M}{2RT} \times \frac{2RT}{M} \times u^2}}{e^{-\frac{M}{2RT} \times \frac{2RT}{M} \times u^2} du}$$

$$\text{Ratio} = \frac{e^{-4}}{e^{-1}} \times 4$$

$$\text{Ratio} = 4 \times e^{-3}$$

$$\therefore \text{Ratio} = 0.199$$

**Sol 16:**  $R = 8J$ ,  $N_A = 6 \times 10^{23}$

$$V_A = V_B = 2 \text{ litre} = 2 \times 10^{-3} \text{ m}^3$$

(i) For container A

$$T = 300 \text{ K}$$

$$N = 6 \times 10^{20}$$

$$\therefore \text{No. of moles} = \frac{6 \times 10^{20}}{6 \times 10^{23}} = 10^{-3}$$

$$P_A = \frac{nRT}{V} = \frac{10^{-3} \times 8 \times 300}{2 \times 10^{-3}} = 1200 \text{ Pa} = 0.012 \text{ atm}$$

(ii)  $P_B = 1 \text{ atm}$ ,  $T = 600 \text{ K}$

$$\begin{aligned} \therefore n &= \frac{PV}{RT} = \frac{1.01325 \times 10^5 \times 2 \times 10^{-3}}{48 \times 600} \\ &= \frac{1.01325}{24} \end{aligned}$$

$$W = n \times N_A = \frac{1.01325}{24.4} \times 6 \times 10^{23}$$

$$N = 25.33 \times 10^{21} = 2.5 \times 10^{22}$$

$$\begin{aligned} \text{K.E.}_{\text{avg}} &= \frac{1}{2} MV u_{\text{avg}}^2 = \frac{1}{2} \times n \times \text{M.w.} \times u_{\text{avg}}^2 \\ &= \frac{n}{2} \times \frac{\text{M.w.} \times 8RT}{\pi \text{M.w.}} \end{aligned}$$

$$\text{K.E.}_{\text{avg}} = \frac{4RTn}{\pi} = \frac{4PV}{\pi}$$

$$\text{(iii) K.E.}_A = \frac{uP_A V_A}{\pi} = \frac{4 \times 1200 \times 2 \times 10^{-3}}{3.14} = 3.05 \text{ J}$$

$$\text{(iv) K.E.}_B = \frac{4P_B V_B}{\pi} = \frac{105 \times 2 \times 10^{-3} \times 4}{3.14}$$

$$\text{K.E.}_B = 258.15 \text{ J}$$

$$\text{(v) Ratio of } u_{\text{mps}} = \frac{\sqrt{\frac{2RT_A}{M}}}{\sqrt{\frac{2RT_B}{M}}} = \sqrt{\frac{T_A}{T_B}} = \sqrt{\frac{1}{2}}$$

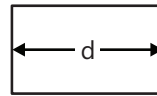
$$Z_{11} = \frac{1}{\sqrt{2}} \pi \sigma^2 \text{cav}\rho^2$$

(vi) Ratio of  $Z_{11}$

$$\begin{aligned} \frac{(\text{Cav}\rho^2)_A}{(\text{Cav}\rho^2)_B} &= \frac{\sqrt{\frac{8RT_A}{\pi M}} \times \left(\frac{6 \times 10^{20}}{V}\right)^2}{\sqrt{\frac{8RT_B}{\pi M}} \times \left(\frac{2.5 \times 10^{22}}{V}\right)^2} \\ &= \sqrt{\frac{T_A}{T_B}} \times \left(\frac{6}{2.5 \times 100}\right)^2 = \frac{1}{\sqrt{2}} \times \left(\frac{6}{250}\right)^2 \end{aligned}$$

$$\text{Ratio} = 0.4 \times 10^{-3} : 1$$

**Sol 17:** No. of wall collision / per unit line of molecules



Let length of container be  $d$  and  $v_{\text{r.m.s.}}$  be  $V$

then time taken for 1 colles  $Q = \frac{d}{V} \text{ s}$

It collision in 1 sec =  $\frac{V}{d}$

If  $N$  molecules are present

Then total collision =  $\frac{VN}{d}$

We have been given

$$\begin{aligned} \frac{V_{\text{He}} N_{\text{He}}}{d} &= \frac{V_{\text{H}_2} N_{\text{H}_2}}{d} \\ \sqrt{\frac{3RT}{M_{\text{He}}}} N_{\text{He}} &= \sqrt{\frac{3RT}{M_{\text{H}_2}}} \times N_{\text{H}_2} \end{aligned}$$

$$\therefore \frac{N_{\text{He}/V}}{N_{\text{H}_2}/V} \sqrt{\frac{M_{\text{He}}}{M_{\text{H}_2}}} = \sqrt{2} > 1$$

$$\frac{N_{\text{He}}}{V} > \frac{N}{V} \text{ H}_2$$

Conc. of He > Conc. of  $\text{H}_2$

**Sol 18:** Mean free path ( $\lambda$ ) =  $2.6 \times 10^{-5} \text{ m}$

(at 300 K)

$$\sigma = 0.26 \text{ nm}$$

$$\lambda = \frac{KT}{\sqrt{2} \pi \sigma^2 P}$$

$$\therefore P = \frac{KT}{\sqrt{Z\pi\sigma^2\lambda}}$$

$$K = \frac{R}{N_A}$$

$$\therefore P = \frac{R \times T}{N_A \sqrt{2\pi\sigma^2\lambda}}$$

$$\frac{8.314 \times 300}{6.023 \times 10^{23} \times \sqrt{2\pi \times (0.26 \times 10^{-10})^2 \times 2.6 \times 10^{-5}}} = \frac{2494.2}{4700.86}$$

$$\therefore P = 5.30 \times 10^2 \text{ Pa}$$

$$PV = nRT$$

$$P = cRT$$

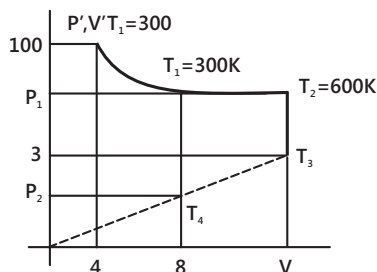
$$5.30 \times 10^2 = C \times 8.314 \times 300$$

$$\therefore c = 2.12 \times 10^{-3}$$

No. of molecules / volume

$$= c \times N_A = 1.28 \times 10^{21} \text{ molecule/vol}$$

### Sol 19:



In the constant temperature curve,

$$T_1 = 300 \text{ K}$$

$$P = 10, V = 4$$

$$10 \times 4 = 300 \times 0.081 \times n$$

$$\therefore n = 1.624$$

(i) At  $T_1 = 300 \text{ K}$

$$\text{Using } P_1 V_1 = P' V'$$

$$P_1 \times 8 = 10 \times 4$$

$$P_1 = 5$$

(ii)  $T_2 - T_3$  constant

$$\therefore \frac{P_1}{T_2} = \frac{3}{T_3}$$

$$\frac{5}{600} = \frac{3}{T_3}$$

$$\therefore T_3 = 360 \text{ K}$$

(iii) At  $T_2 = 600 \text{ K}, P = 5 \text{ atm}$

$T_1$  &  $T_2$  constant present

$$\frac{600}{V_1} = \frac{300}{8}$$

$$\therefore V_1 = 16$$

(iv)  $T_3 \rightarrow T_4$

$$P \propto V$$

$$(v) \frac{3}{V_1} = \frac{P_2}{8} \Rightarrow P_2 = 1.5$$

$$\frac{3}{16} = \frac{P_2}{8}$$

$$\frac{1.5 \times 8}{T_4} = \frac{3 \times 16}{T_3}$$

$$T_4 = \frac{T_3}{4}$$

$$T_4 = \frac{360}{4} = 90$$

$$T_4 = 90$$

**Sol 20:** Balloon initially contain 1 mole air at 1 atm balloon filled till  $P_f = 3 \text{ atm}$

(a)  $P \propto r$

$$P_{\text{final}} = 3 \text{ atm}$$

$$d_f = \frac{P_f \times d_i}{P_i}$$

$$d_f = \frac{3 \times 1}{1} = 3 \text{ m}$$

$$\therefore \frac{P_i V_i}{n_i} = \frac{P_f V_f}{n_f}$$

Temperature is same

$$\frac{1 \times \frac{4}{3} \pi \times (r_1)^3}{1} = \frac{3 \times \frac{4}{3} \pi \times (r_f)^3}{n_f}$$

$$N_f = 3 \left( \frac{r_f}{r_i} \right)^3 = 3 \times 3^3$$

$$N_f = 81$$

$$\text{Number of moles of air added} = 81 - 1 = 80$$

(b) If  $p_{\text{final}} = 7 \text{ atm}$ ,

$$\text{Then } r_{\text{final}} = \frac{7}{2} \text{ m}$$

$$\therefore V = \frac{4}{3} \pi \times \left(\frac{7}{2}\right)^3 = 57.166 \pi > 36 \pi$$

$\therefore$  If volume increases greater than  $36 \pi \text{ m}^3$  balloon burst

At  $V = 36 \pi$

$$\frac{4}{3} \pi r^3 = 36 \pi$$

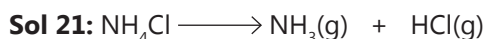
$$\therefore r = 3$$

$\therefore P = 6 \text{ atm}$

$$\frac{6 \times 36 \pi}{n_f} = \frac{1 \times \frac{4}{3} \pi \left(\frac{1}{2}\right)^3}{1}$$

$$n_f = \frac{6 \times 36}{\frac{1}{6}}$$

$\therefore$  Number of extra moles added =  $1296 - 1 = 1295$



1 mole      1 mole      1 mole

$T = 600 \text{ K}$

$V = 24.63$

$N = 2 \text{ moles}$

$$\therefore P_{\text{developed}} = \frac{nRT}{V} = \frac{2 \times 0.0821 \times 600}{24.63}$$

$$P_{\text{developed}} = 4$$

$$P_{\text{difference}} = 4 - 1$$

$$= 3 \text{ atm} < 5.5$$

$\therefore$  The lid does not bounce off

**Sol 22:**  $b = 39.1$

$$P = 10^{-3} \text{ mm Hg} = 1.316 \times 10^{-6} \text{ atm}$$

$$= 0.133 \text{ Pa}$$

$T = 298 \text{ K}$

$$M = 28 \times 10^{-3}$$

$$4 \times N_A \times V_{\text{molecule}} = b$$

$$4 \times 6.023 \times 10^{23} \times \frac{4}{3} \pi r^3 = 39.1 \text{ cm}^3$$

$$\therefore r = 1.57 \text{ \AA}$$

$$\sigma = 2r = 314 \text{ pm}$$

$$\lambda = \frac{KT}{\sqrt{Zn\sigma^2P}} = \frac{RT}{N_A \sqrt{Zn\sigma^2P}}$$

$$= \frac{8.314 \times 298}{6.023 \times 10^{23} \times \sqrt{2} \times \pi \times (314 \times 10^{-12})^2 \times 0.133}$$

$$= \frac{2477.57}{35072.639}$$

$$\lambda = 0.0701 \text{ m}$$

$$\lambda = 7.051 \text{ m}$$

$$C_{\text{avg}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.314 \times 298}{3.14 \times 28 \times 10^{-3}}}$$

$$= 474.8 \text{ m/s} = 47480.39 \text{ m/s}$$

$$Z_1 = \sqrt{2} \sigma \pi^2 C_{\text{avg}} p$$

We know,  $PV = nRT$

$$0.133 \times V = 8.314 \times n \times 298$$

$$\therefore \frac{n}{V} = 5.36 \times 10^{-5}$$

$$p = \frac{\text{Number of molecule}}{\text{Volume}} = \frac{nN_A}{V}$$

$$= 3.233 \times 10^{19} \text{ molecules/m}^3$$

$$Z_1 = \sqrt{2} \pi \sigma^2 C_{\text{qv}} \times P$$

$$= \sqrt{2} \times \pi \times (3.14 \times 10^{-12})^2 \times 474.80 \times 3.023 \times 10^{19}$$

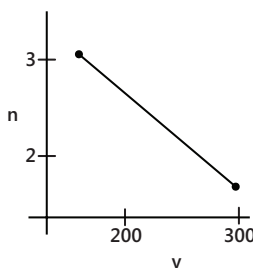
$$\Rightarrow Z_1 = 6742 \text{ s}^{-1}$$

$$Z_{11} = \frac{Z_1 \times p}{Z}$$

$$= \frac{6742 \times 3.023 \times 10^{19}}{2} = 1.017 \times 10^{23} \text{ m}^3/\text{s}$$

$$= 1.017 \times 10^{25} \text{ cm}^3/\text{s}$$

**Sol 23:**



$$N = mT + c$$

$$(3 = m \times 200 + c)$$

$$(2 = m \times 300 + c) \times 2$$

$$9 - 4 = c$$

$$\therefore c = 5$$

$$3 = 200m + 5$$

$$\therefore m = \frac{-1}{100}$$

$$\therefore n = 5 - \frac{T}{100}$$

$$PV = nRT$$

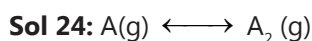
$$1 \times V = R \left( 5 - \frac{T}{100} \right) \times T$$

$$V = 5RT - \frac{RT^2}{100}$$

$$\frac{2V}{2T} = 5R - \frac{2RT}{100} = 0$$

$$\text{at } T = \frac{500}{2} = 250 \text{ K}$$

$$\therefore V_{\text{max/mix}} = R \left( 5 - \frac{250}{100} \right) \times 250 = 51.312 \text{ litre}$$



M.Weight 48                      96

$V = 33.6$  litre

$T = 273^\circ\text{C} = 546 \text{ K}$

Given 50% of weight is dimer

$\therefore$  Mass of dimer =  $0.5 \times 96$

$\therefore$  Moles of dimer =  $\frac{0.5 \times 96}{96} = 0.5$

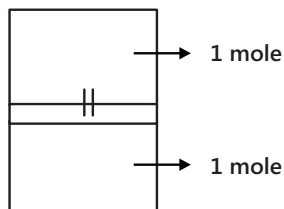
Moles of monomer =  $\frac{96 \times 0.5}{48} = 1$

Total moles =  $1 + 0.5 = 1.5$

$\therefore P = \frac{nRT}{V} = \frac{1.5 \times 0.0821 \times 546}{33.6}$

$P = 1.998 \approx 2$

**Sol 25:**



Moles are same

$$P_{\text{lower}} = P_{\text{upper}} + P_{\text{friction}}$$

Using,  $P_v V_v = P_L V_L$

$$\frac{P_{\text{upper}}}{P_{\text{lower}}} = \frac{1}{4}$$

$$\frac{P_{\text{upper}}}{P_{\text{upper}} + P_{\text{piston}}} = \frac{1}{4}$$

$$\therefore P_{\text{piston}} = 3P_{\text{upper}}$$

$$P_{\text{lower final}} = P_{\text{upper final}} + P_{\text{piston}}$$

$$\frac{P_{\text{Lower}}}{P_{\text{upper}}} = \frac{V_{\text{upper}}}{V_{\text{lower}}}$$

$$\frac{P_{\text{upper}} + P_{\text{piston}}}{P_{\text{upper}}} = 3$$

$$\therefore 2P_{\text{upper final}} = 2P_{\text{piston}}$$

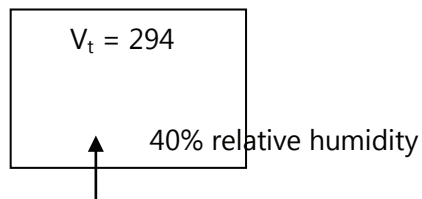
$$\therefore P_{\text{upper final}} = \frac{3}{2} P_{\text{upper initial}}$$

Using  $\frac{PV}{T}$  balance for upper chamber

$$\frac{P_{\text{upper}} \times 0.8V}{300} = \frac{3}{2} \frac{P_{\text{upper}} \times 0.75V}{T_f}$$

$$T_f = \frac{3}{2} \times \frac{3}{4} \times \frac{300}{0.8} = 421.875 \text{ K}$$

**Sol 26:**



At  $21^\circ\text{C}$   $P \approx 19$  torr

40% humidity,

$$\therefore P \text{ due to } H_2O = 0.4 \times n = \frac{0.4 \times 19}{760} \text{ atm} = 0.01 \text{ atm}$$

$R = 0.082$ ;  $T = 294 \text{ K}$

$$0.01 \times 294 = 0.082 \times 294 \times n$$

$$\therefore n = 0.123$$

$\therefore$  0.122 moles of water added/minutes

Mass of  $H_2O = 2.215\text{g}$  of  $H_2O$  added/min

$\approx 2.2\text{g}$

**Sol 27:** If theoretical is correct

$$\text{Then } \frac{1.54}{3.2} = \frac{T + 273}{T + 10 + 273}$$

$$\therefore \frac{1.54}{3.2 - 1.54} = \frac{T + 273}{10}$$

Theoretical  $T' = -263.72$  °K

(a) Real case

$$\frac{1.25}{2.2875} = \frac{T' + 273}{T' + 10 + 273}$$

$$\frac{1.25}{2.2875 - 1.25} = \frac{T' + 273}{10}$$

$T' = 12.048$  K

Using  $\frac{P}{nT}$  balance between theoretical and real

$$\frac{1.54}{9.27 \times n_{\text{theoretical}}} = \frac{1.25}{12.048 \times n_{\text{Actual}}}$$

$$\therefore \frac{n_{\text{exp}}}{n_{\text{case}}} = \frac{1.25 \times 9.27}{12.048 \times 1.54} = 0.624$$

$n_A \longrightarrow$  A 50% yield

$$\frac{n_A}{2} = \frac{n_{\text{theor}}}{n} \times 2$$

$$\text{Total} = n_{\text{exp}} = \frac{n_A}{2} + \frac{n_A}{2n}$$

$$\frac{\frac{n_A}{2} + \frac{n_A}{2n}}{n_A} = 0.625$$

$$(b) \frac{1}{2n} = 0.625 - 0.5; \quad n = \frac{1}{2 \times (0.625 - 0.5)} = 4$$

**Sol 28:**  $\text{CH}_4 + 2\text{O}_2 \longrightarrow \text{CO}_2 + 2\text{H}_2\text{O}$

3 times  $\text{O}_2$  theoretical is required for optimal fuel

$$\therefore \text{For optimal fuel, } \frac{n_{\text{CH}_4}}{n_{\text{O}_2}} = \frac{1}{2 \times 3} = \frac{1}{6}$$

We know,

$$\frac{r_{\text{CH}_4}}{r_{\text{O}_2}} = \frac{n_{\text{CH}_4}}{n_{\text{O}_2}} \times \sqrt{\frac{M_{\text{O}_2}}{M_{\text{CH}_4}}}$$

$$\therefore \frac{1}{6} = \sqrt{\frac{32}{16}}$$

$$\frac{1}{6} = \frac{1}{192} \times (\sqrt{2})^n; \quad \frac{192}{6} = (\sqrt{2})^n$$

$$32 = (\sqrt{2})^n$$

$\therefore n = 10$  steps

Let initial moles be  $n_A, n_B$

$\therefore$  After 1 effusion

$$\frac{n_A}{n_B} = \frac{n_{A_i}}{n_{B_i}} \times (\sqrt{2})$$

And 90% of  $n_A$  is remove

$$\therefore \frac{n_A}{n_B} = \frac{n_{A_i}}{n_{B_i}} \times (\sqrt{2}) \times (0.9)$$

$\therefore$  After 10 steps,

We know

1 mole  $\text{CH}_4$  produces 100 – fours

$\therefore$  To produces

$$\frac{1}{3} = \frac{n_{A_i}}{n_{B_i}} \times (\sqrt{2})^x$$

$$\therefore \frac{1}{6} = \frac{n_{A_i}}{n_{B_i}} \times 32^x$$

$$\therefore \frac{n_{A_i}}{n_{B_i}} = \frac{1}{32}$$

Also to produce 1000 cal, 10 moles of  $\text{CH}_4$  is begin

$$\therefore 10 = n_{\text{CH}_4} \times (0.9)^{10}$$

$$\therefore n_{\text{CH}_4} = 27.78 \text{ mole}$$

$$\begin{aligned} \text{Moles of } \text{O}_2 &= 2778 \times 3 \times 0.36 \times 32 \\ &= 5333.33 \text{ moles} \end{aligned}$$

**Sol 29:**

V = 50		
V <sub>1</sub> =50/3	V <sub>2</sub> =50/3	V <sub>3</sub> =50/3
60 H <sub>2</sub> N = 30 mole	160g O <sub>2</sub> n <sub>O<sub>2</sub></sub> = 5 ml	100g N <sub>2</sub> n <sub>N<sub>2</sub></sub> = 5 moles

The SPN will permit the flow of  $\text{N}_2$  or  $\text{H}_2$  till the concentrations in chambers are equal (As volume is same for all chambers)



∴ At equilibrium

Moles of  $H_2$  in all 3 chambers is same  $n_{H_2}$  in each chamber

$$= \frac{30}{3} = 10 \text{ moles in each}$$

In left and middle chamber, number of moles of  $N_2$  must be same.

$$\therefore \text{Total number of moles of } N_2 \text{ in both chambers} = \frac{5}{2} = 2.5$$

∴ Total number of moles in each chamber

$$\text{Left} = \text{moles of } H_2 = 10$$

$$\text{Right} = \text{moles of } N_2 + \text{moles of } H_2 = 2.5 + 10 = 12.5$$

$$\text{Middle} = \text{moles of } O_2 + \text{moles of } N_2 + \text{moles of } H_2 = 5 + 2.5 + 10 = 17.5$$

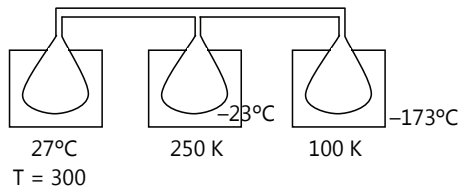
We know, volume and temperature are same

$$\therefore P \propto n$$

$$\therefore P_L : P_M : P_R = nL : nM : nR$$

$$= 10 : 17.5 : 12.5 = 4 : 7 : 5$$

**Sol 30:** Volume of all bulbs = 1 litre



$$P_i = \frac{547.2}{760}$$

$$n_i = \frac{P_i V_i}{R T_i} = \frac{0.72 \times 1}{0.821 \times 300} = 0.029$$

(a) **Case-1**

A and B are connected

$$P = 228 \text{ mn Hg} = 0.3 \text{ atm}$$

$$V = 1 \text{ l}$$

$$T_A = 300 \text{ k}$$

$$\therefore n_A = \frac{P V}{R T} = \frac{0.3 \times 1}{0.821 \times 300} = 0.0122$$

$$n_B = \frac{P_B V_B}{R T_B} = \frac{0.3 \times 1}{0.821 \times 250} = 0.0143$$

$$(b) n_{\text{total}} = 0.0265$$

$$\therefore n_{\text{frozen}} = 0.029 - 0.026 = 0.0025 \text{ moles of } H_2O \text{ frozen}$$

To be in equilibrium the partial pressure of gases in both bulbs must be same.

∴ All  $H_2O$  gets converted to solid as it keeps flowing to bulbs 2 to achieve equilibrium

$$\therefore \text{Moles of } H_2O = 2.5 \times 10^{-3}$$

(c) Both stopcocks are opened

Now since  $CO_2$  gets solidified in bulbs C, the entire  $CO_2$  solidifies in bulbs C.

$$P_{\text{at equilibrium}} = 45.6 \text{ mm of Hg}$$

$$= \frac{45.6}{760} = 0.06 \text{ atm}$$

$$0.06 \times 1 = 0.0821 \times 300 \times n$$

$$\therefore n_A = 2.536 \times 10^{-3}$$

$$n_B = \frac{P V}{R T} = \frac{0.06 \times 1}{0.0821 \times 250} = 2.923 \times 10^{-3}$$

$$n_C = \frac{P V}{R T} = \frac{0.06 \times 1}{0.082 \times 100} = 7.3038 \times 10^{-3}$$

## Exercise 2

### Single Correct Choice Type

**Sol 1: (C)** Suppose initial ratio is represented by  $n_0$

$$\frac{r_1}{r_2} \propto \frac{n_1^0}{n_2^0} \sqrt{\frac{M_2}{M_1}}$$

$$\frac{n_1^1}{n_2^1} \propto \frac{n_1^0}{n_2^0} \sqrt{\frac{M_2}{M_1}}$$

$n^{\text{th}}$  step ratio of moles

$$\frac{n_1^n}{n_2^n} = \frac{n_1^0}{n_2^0} \left( \sqrt{\frac{M_2}{M_1}} \right)^n$$

$$\therefore \frac{3072/2}{20/32} = \frac{240/2}{160/32} \left( \sqrt{\frac{32}{2}} \right)^n$$

$$1024 = 4^n$$

$$n = 5$$

**Sol 2: (B)**  $\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$

(a)  $\frac{r_A}{r_B} = \sqrt{\frac{28}{28}} = 1$

(b)  $\frac{r_{O_2}}{r_{O_3}} = \sqrt{\frac{48}{32}} = \sqrt{\frac{3}{2}}$

(c)  $\frac{r_{UF_{235}}}{r_{UF_{238}}} = \sqrt{\frac{238}{325}}$

$b > c > a$

**Sol 3: (C)**  $MA = 4 MB = 40$

Let weight be  $x_g$  each

Mole fraction of  $M_A$

$$= \frac{n_A}{n_A + n_B} = \frac{\frac{x}{M_A}}{\frac{x}{M_A} + \frac{x}{M_B}}$$

$\therefore$  Partial pressure of A (lighter)

= Mole fraction  $\times$  P

$$= \frac{1}{1.1} \times 1.1 = 1 \text{ atm}$$

**Sol 4: (C)**  $PV = nRT$

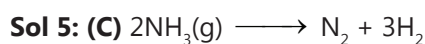
$$\Rightarrow PV = \frac{m}{M} RT \quad M = \text{Molar mass}$$

$$\Rightarrow PV = \frac{dV}{M} RT \quad d = \text{Density}$$

$$\Rightarrow PM = dRT$$

$$\frac{P_A}{P_B} = \frac{\frac{d_A T_A}{M_A}}{\frac{d_B T_B}{M_B}}$$

$$\Rightarrow \frac{\frac{2d_B T_B}{M_A}}{\frac{d_B T_B}{3M_A}} \Rightarrow 6 : 1$$



$$\frac{r_{SO_2}}{r_{mix}} = \frac{1}{2}$$

$$\sqrt{\frac{M_{mix}}{M_{SO_2}}} = \frac{1}{2}$$

Or rate of diffusion  $\propto \frac{1}{\sqrt{M}}$

$$\Rightarrow M_{mix} = \frac{M_{SO_2}}{4} = \frac{32 + 32}{4}$$

$$M_{mix} = 16$$

Let 'x' fraction  $NH_3$  converts to  $N_2$  and  $H_2$

$$\Rightarrow M_{mix} = 2(1-x) \times 17 + 3x \times 2 + 28 \times x$$

$$16 = \frac{34 - 34x + 34x}{2(1-x) + 3x + x}$$

$$16 = \frac{34}{2 + 2x}$$

$$32 + 32x = 34$$

$$32x = 2$$

$$X = \frac{2}{32} = \frac{1}{16}$$

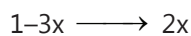
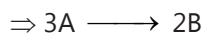
$$\% \text{ convert to} = \frac{100}{16} = 6.25\%$$



$$V = 0.0821 \ell$$

Initially  $n_A = 1$  Mole

Let degree of dissociation be x%



$$\therefore \text{Total moles} = 1 - 3x + 2x = 1 - x$$

We know  $PV = nRT$

$$P \times 0.0821 = 1 - x \times 0.0821 \times 7$$

We know slope =  $\tan(\text{angle between P-T curve})$

$$= \tan(42.95^\circ) = 0.8$$

$$\Rightarrow 1 - x = 0.8$$

$$\Rightarrow x = 0.2$$

% percentage conversion

$$= \frac{n_{A_{initial}} - n_{A_{final}}}{n_{A_{initial}}} = \frac{1 - (1 - 3 \times 0.2)}{1}$$

$$= 3 \times 0.2 = 0.6$$

**Sol 7: (B)** For a balloon,

$$P_1 V_2 = nRT_1$$

$$20 \times 2.82 = n_{\text{vessel}} \times 0.0821 \times 300$$

$$\Rightarrow n_{\text{H}_2} \text{ in vessel} = 2.29$$

$n_{\text{H}_2}$  is one balloon

$$1 \times \frac{4}{3} \pi \times \left(\frac{21}{2}\right)^3 \times 10^{-3}$$

$$= n_b \times 0.0821 \times 273$$

$$\Rightarrow \text{Total number of balloon } N$$

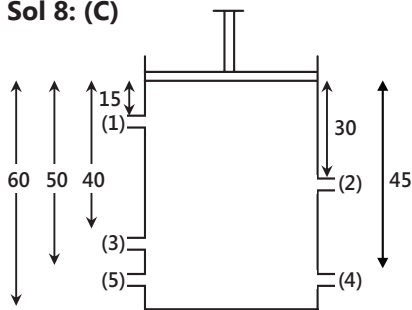
We know  $N \times n_b = n$  used

$$N = \frac{n_{\text{vessel}}}{n_b} = \frac{2.29}{0.216}$$

$$N = 10.56$$

$$N \approx 10 \text{ balloon}$$

**Sol 8: (C)**



$$\text{Volume initial} = 821 \times 60 \text{ cm}^6$$

$$P = 1 \text{ atm}$$

$$T = 300 \text{ K}$$

$$1 \times 821 \times 60 \times 10^{-3} = 0.821 \times 300 \times 4$$

$$n = \frac{821 \times 6 \times 10^{-2}}{3 \times 8.21} \quad \therefore n = 2 \text{ initially}$$

Using PV balance

$$P_1 V_1 = P_2 V_2$$

$$\therefore 1 \times 60 \times 821 = P_2 \times 821 \times (60 - x)$$

$$\therefore P_2 = \frac{60}{60 - x}$$

$$\therefore \text{At } x = 15$$

$$P_2 = 60/45 = 4/3 < 1.3$$

Valve - 1 does not open

$$\text{At } x = 30$$

$$P_2 = \frac{60}{30} = 2 < 2.2$$

Valve-II does not open

$$\text{At } x = 40$$

$$P_2 = \frac{60}{20} = 3 > 2.5$$

$\therefore$  Before reaching

Valve 3  $\rightarrow$  Opens as V-3 opens

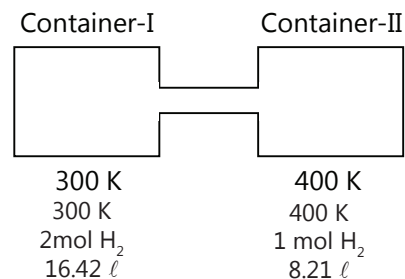
$$P = 1 \text{ atm}$$

$$V = \frac{V_{\text{initial}}}{3}$$

$$\text{So, } n = \frac{2}{3} \text{ mole}$$

**Multiple Correct Choice Type**

**Sol 9: (B, D)**



$$P_I \times 16.42 = 0.821 \times 300 \times 2$$

$$P_{I_{\text{initial}}} = 3 \text{ atm} \quad P_{II_{\text{initial}}} = 4 \text{ atm}$$

After opening the valve (to reach equilibrium), pressure & temperature in compartment must be same

$$3 < P_{\text{final}} < 4$$

$$PV = nRT$$

After opening valve,  $P_{\text{final}}, T_{\text{final}}$  will be same in both container

$$P_{I_{\text{final}}} = P_{II_{\text{final}}} = P_{\text{final}}$$

$$P_f(16.42 + 8.21) = (2 + 1)(0.821)T_f$$

$$T_f = x_I T_I + x_{II} T_{II} = 357 \text{ K}$$

$$P_f = 3.57 \text{ atm}$$

**Sol 10: (A, D)**  $V = 8.21 \text{ l}$ ,  $n = 2 \text{ moles}$   $T = 300 \text{ K}$

$$P = \frac{nRT}{V} = \frac{0.821 \times 2 \times 300}{8.21}$$

$$P = 6 \text{ atm}$$

If the container is open

Then  $P \propto nT$  and  $P \propto T$  (is wrong) hence statement B is incorrect

Similarly if container is closed-non-rigid.

$$PV \propto T \text{ and not } V \propto T$$

If another container is introduced,

P must be same

$$\therefore n_1 T_1 = n_2 T_2$$

$$n \times 300 = (2 - n) \times 150$$

$$2n = 2 - n$$

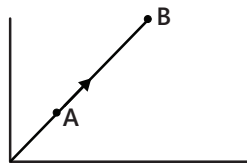
$$\Rightarrow n = 2/3$$

$$\frac{P_{\text{final}}}{P_1} = \frac{n_f}{n_i}$$

(all other parameter constant)

$$P_{\text{final}} = \frac{2}{3} \times P_{\text{initial}} = \frac{2}{3} \times 6 = 4 \text{ atm}$$

### Sol 11: (A, B)



As you can see,  $P - T$  curve is a straight line passing through origin

Hence  $P \propto T$

$$P = nT$$

and we know  $PV = nRT$

$$mV = n$$

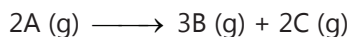
Hence if  $n$  changes,  $V$  also changes and vice-versa

If  $n = \text{Constant}$

then  $V = \text{Constant}$

### Sol 12: (B, D) $P_i = 76 \text{ cm of Hg} = 1 \text{ atm}$

$$P_A = 1 \text{ atm}$$



$$1 - 2x \qquad 3x \qquad 2x$$

$$P_{A_{\text{final}}} = 0.8$$

$$1 - 2x = 0.8$$

$$\Rightarrow x = 0.1$$

$$P_B = 3 \times 0.3 = 0.9$$

$$P_C = 2 \times 0.1 = 0.2$$

$$\Rightarrow P_{\text{total}} = 0.8 + 0.2 + 0.3 = 1.3 \text{ atm}$$

$$P_{\text{increase}} = 0.3 \text{ atm} = 0.3 \times 760 = 228 \text{ mm of Hg}$$

**Sol 13: (A, B, D)** Total area under the curve is integration of fraction of molecules with all possible speed

$\Rightarrow$  Total area = 1 (in dependent of  $T$  and molecule weight of gas)

As temperature increases  $u_{\text{mps}} \uparrow$ es,

$$\text{As } \mu_{\text{mps}} T_2 > \mu_{\text{mps}} T_1$$

$$\Rightarrow T_2 > T_1 (\therefore \text{statement-II false})$$

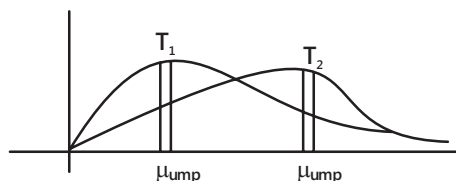
(Statement-II incorrect)

According to the equation, the fraction of molecules with

$u_{\text{mps}} + \frac{1}{2} u_{\text{mp}}, u_{\text{mp}} + \frac{1}{2} u_{\text{mps}}$  is constant

$$\text{And fraction} = \frac{4f}{\sqrt{\pi}e} \therefore A_1 = A_2$$

As temperature  $\uparrow$ es, mole



Fraction of molecules with  $u_{\text{mps}}$ . Decreases as temperature  $\uparrow$ es.

### Sol 14: (A, C) Fraction of molecules with $u_{\text{avg}} + f u_{\text{avg}}$

$$\int \frac{dN_u}{w} = 4\pi \left( \frac{M}{2\pi RT} \right)^{3/2} e^{-\frac{Mu}{2Rt}} u^2 du$$

$$du = f u_{\text{avg}}$$

$$= 4\pi \left( \frac{M}{2\pi RT} \right)^{3/2} e^{-\frac{Mu^2}{2RT}} u^3$$

$$U = 8 \frac{RT}{\pi M}$$

$\therefore$  fraction

$$= 4\pi \times \left( \frac{M}{2\pi RT} \right)^{3/2} e^{-\frac{M}{2RT} \times \frac{8}{\pi}} \left( \frac{8RT}{\pi M} \right)^{3/2} \times 1$$

$$\text{Frac} = 4\pi \times \frac{1}{(2\pi)^{3/2}} \left(\frac{8}{\pi}\right)^{3/2} \times e^{-4/\pi}$$

$$\text{Frac} = \frac{4\pi \times (4)^{3/2}}{\pi^{3/2}} \times e^{-4/\pi}$$

Fraction is independent of nature or state of gas is  
 $du = fu$  in range of  $\mu$

If  $p = 2.5$ ,

$$1 \times 60 = 2.5 \times (60 - x)$$

$$\therefore x = 36 \text{ cm}$$

As piston passes the cylinder will value 3

$$V = 821 \times 20$$

$$P = 2.5$$

$$\frac{2.5 \times 821 \times 20}{n_f} = \frac{1 \times 821 \times 60}{2}$$

$$n_f = \frac{2.5 \times 2 \times 20}{60}$$

$$\Rightarrow n_f = \frac{5}{3}$$

At  $x = 49$ ,

$$P = \frac{60 \times 1}{15} = 4 < 4.4$$

Valve 4 does not open

At  $x = 50$ ,

$$P = \frac{60}{10} = 6 > 4.8, \therefore \text{valve open}$$

But as it reaches  $x = 10$ ,  $P = 4.8$ ,

$$\frac{4.8 \times 10}{n_f} = \frac{1 \times 60}{2}$$

$$\therefore n_f = \frac{2 \times 48}{60} = \frac{8}{5}$$

$$\text{Sol 15: (B, C)} \quad \frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$$

$$\text{b) } \sqrt{\frac{M_{\text{CO}}}{M_{\text{He}}}} = \sqrt{\frac{28}{4}} = \sqrt{7} = 2.65$$

$$\text{(c) } \sqrt{\frac{M_{\text{CO}_2}}{M_{\text{He}}}} = \sqrt{\frac{44}{4}} = \sqrt{11}$$

$$\text{d) } \sqrt{\frac{M_{\text{SO}_2}}{M_{\text{He}}}} = \sqrt{\frac{64}{4}} = 4$$

$\therefore$  B, D

**Sol 16: (B, C)** Boyles' law

Temperature is constant

$$P \propto \frac{1}{V} \text{ or } PV = \text{constant}$$

Which is clear from graph B & C

Where PV is constant

**Sol 17: (B, D)** Molar gas constant

$$[R] = \left[ \frac{PV}{nRT} \right] = \text{pascal } n^3 \text{ mole}^{-1} \text{ K}^{-1} = \text{pascal } m^3 = J$$

$$[R] = J \text{ mol}^{-1} \text{ K}^{-1}$$

$$1J = \frac{1}{4.18} \text{ cal}$$

$$R = 8.314 J \text{ mol}^{-1} \text{ K}^{-1}$$

$$R = 8.314 \left( \frac{1}{4.18} \right) \text{ cal mol}^{-1} \text{ K}^{-1}$$

$$= 1.987 \text{ cal mol}^{-1} \text{ K}^{-1}$$

$$R = 8.314 \text{ pascal } m^3 \text{ mol}^{-1} \text{ K}^{-1}$$

$$= 8.314 \frac{\text{bar}}{10^5} 10^3 \text{ dm}^3 \text{ mol}^{-1} \text{ K}^{-1}$$

$$R = 0.08314 \text{ dm}^3 \text{ bar mol}^{-1} \text{ K}^{-1}$$

Answer B, D

**Sol 18: (A, B)** Gas expands at constant T

$V \uparrow$

$$PV = nRT$$

$$\text{or } PV = k$$

$V \uparrow$   $P \downarrow$

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

A, B

**Sol 19: (A, B, C, D)** (a) a corrects the pressure term which is affected by attraction between molecules.

(b)  $(V - nb)$   $\therefore$  b corrects the volume and excludes the volume occupied by molecules itself

$$(c) [P] = \left[ \frac{an^2}{V^2} \right] \Rightarrow [a] = \left[ \frac{PV^2}{n^2} \right]$$

$$\Rightarrow \text{atm L}^2 \text{ mol}^{-2}$$

$$(d) [V] = [nb] \Rightarrow [b] = \left[ \frac{V}{n} \right]$$

$$\Rightarrow \text{L mol}^{-1}$$

**Assertion Reasoning Type****Sol 20: (E)** Assertion is wrong as co-volume = bb = 4πR<sup>3</sup> → Dependent on size of particle reason is true**Sol 21: (D)** Both are falseP vs  $\frac{1}{V}$  is not always a straight line

$$P = \frac{nRT}{V} \text{ (temp may vary)}$$

$$P \propto V (X)$$

**Sol 22: (A)** Factual**Sol 23: (C)** Rate of diffusion  $\propto \frac{1}{\sqrt{\mu}}$ 

∴ Assertion is correct

The reason is false

As K.E. =  $\frac{3}{2} RT$ , independent of mass**Sol 24: (A)** CH<sub>4</sub>, CO<sub>2</sub> has value of Z < 1**Reason:** Z < 1 due to repulsive forces**Comprehension Type****Paragraph 1:****Sol 25: (B)**  $Pe^{V/2} = nCT$ 

At V = 0, P = 1 of 500 K

At 2 moles of gas

$$\Rightarrow 1 \times 1 = 2 \times 500 \times C$$

$$\Rightarrow \frac{1}{1000} = 10^{-3}$$

**Sol 26: (D)** V = 2 litre, n = 2 mole

$$\Rightarrow P \times e^{2/2} = n \times 0.001 \times T$$

$$\Rightarrow \frac{P}{T} = \text{slope}$$

$$= \frac{0.002}{e} = \frac{2}{1000e}$$

**Sol 27: (A)** V = 200 l of O<sub>2</sub> at 1 at 200 K

Ideal gas

$$PV = nRT$$

$$1 \times 200 = 0.0821 \times 200 \times n$$

$$n = \frac{1}{0.0821}$$

$$P \times e^{\frac{200}{2}} = \frac{1}{0.0821} \times 821 \times \frac{1}{1000}$$

$$P \times e^{100} = \frac{821}{82.1}$$

$$P = \frac{10}{e^{100}}$$

**Paragraph 2:****Sol 28: (A)** 2(A) g → 3B(g) + C(g)

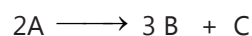
For a closed container,

Slope P – T curve

$$= \frac{nR}{V} \text{ as } V \text{ is constant}$$

Slope  $\propto n$ 

If a is the degree of dissociation of A



$$\text{Then } n_A - a \rightarrow \frac{3\alpha}{2} \quad \frac{\alpha}{2}$$

$$\text{Total moles} = n_A - a + \frac{3\alpha}{2} + \frac{\alpha}{2} = n_A + \alpha$$

$$\therefore \text{Slope} \propto n_A + \alpha$$

Hence as slope ↑ es,  $\propto$  ↑ es

$$\therefore \alpha \text{ is lowest in } T_0 - T_1 \text{ range}$$

**Sol 29: (C)** If n<sub>A</sub> = 1 mole, V = 0.0821,

$$R = 0.0821$$

$$\Rightarrow PV = nRT$$

$$\therefore \text{Slope} = n = 1 + \alpha$$

$$\therefore \alpha_{T_0-T_1} = \tan 50^\circ - 1 = 1.19 - 1 = 0.19$$

$$\alpha_{T_1-T_2} = 1.42 - 1 = 0.42$$

**Match the Columns****Sol 30:** A  $\rightarrow$  s; B  $\rightarrow$  r, C  $\rightarrow$  q; D  $\rightarrow$  p

(A)  $PV = nRT$

n and T are constant

$\Rightarrow PV = \text{constant}$

$PV = C$

$P^2 = C \frac{P}{V}$

$x^2 = cy$

A represent parabolic curve,  $x^2 = cy$  passing through origin

A  $\longrightarrow$  s

(B)  $PV = nRT$

Graph similar to  $\frac{1}{x^2}$ 

$\frac{P}{V} V^2 = C$

B  $\longrightarrow$  r

$yx^2 = C$

$y = \frac{C}{x^2} \quad P^{-2} = x$

(C)  $\frac{V}{P}$  Vs  $P^2 \quad \frac{PV}{PV^2} = \frac{\text{Constant}}{P^2}$

y = x constant same as x

C  $\longrightarrow$  q

(D)  $\frac{P}{V}$  v/s log P

$PV = \text{constant}$

$P^2 = \text{constant} \frac{P}{V}$

Log P = x D  $\longrightarrow$  p

$\Rightarrow P = e^x$

 $e^x = y$  constant  $\longrightarrow$  similar to exponential function.**Sol 31:** A  $\rightarrow$  r; B  $\rightarrow$  s, C  $\rightarrow$  p; D  $\rightarrow$  q

(A)  $\frac{1}{V^2}$  Vs P

$PV = k; \Rightarrow P = \frac{k}{V}$

$\Rightarrow P = k \sqrt{\frac{1}{V^2}}$

P  $\rightarrow$  x  $\frac{1}{V^2} \rightarrow$  y

$\Rightarrow x = k \sqrt{y}$

$y = \frac{x^2}{k}$



(B)  $V = kT \quad V$  Vs  $\frac{1}{T}$

$V = y$

$\frac{1}{T} = x \Rightarrow T = \frac{1}{x}$

$y = \frac{k}{x}$

$xy = k$



(C) log P Vs log V

$PV = k$

Log P + log V = log k

y = x = log k



(D) V Vs  $\frac{1}{P^2}$

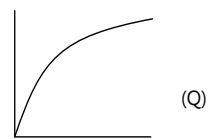
$PV = k$

$V = y, \frac{1}{P^2} = x$

$P = \frac{1}{\sqrt{x}}$

$\frac{1}{\sqrt{x}} y = k$

$y = \sqrt{x}$

**Previous Years' Questions****Sol 1: (A)** The two types of speeds are defined as; Roots

mean square speed ( $u_{rms}$ ) =  $\sqrt{\frac{3RT}{M}}$

Average speed ( $u_{avg}$ ) =  $\sqrt{\frac{8RT}{\pi M}}$

For the same gas, at a given temperature, M and T are same therefore

$$\begin{aligned}\frac{u_{\text{rms}}}{u_{\text{avg}}} &= \sqrt{\frac{3RT}{M}} : \sqrt{\frac{8RT}{\mu M}} \\ &= \sqrt{3} : \sqrt{\frac{8}{\pi}} \\ &= \sqrt{3} : \sqrt{2.54} \\ &= 1.085 : 1\end{aligned}$$

**Sol 2: (A)** If  $x$  g of both oxygen and methane are mixed then :

$$\text{Mole of oxygen} = \frac{x}{32}$$

$$\text{Mole of methane} = \frac{x}{16}$$

$$\Rightarrow \text{Mole fraction of oxygen} = \frac{\frac{x}{32}}{\frac{x}{32} + \frac{x}{16}} = \frac{1}{3}$$

According to law of partial pressure

Partial pressure of oxygen ( $p_{\text{O}_2}$ )

= Mole-fraction  $\times$  total pressure

$$\Rightarrow \frac{p_{\text{O}_2}}{P} = \frac{1}{3}$$

**Sol 3: (B)** According to kinetic theory, average kinetic energy ( $\epsilon$ ) =  $\frac{3}{2} K_b T$

Where,  $k_b$  is Boltzmann's constant. Since, it is independent of molar mass, it will be same for He and  $\text{H}_2$  at a given temperature.

**Sol 4: (C)** The ease of liquification of a gas depends on their intermolecular force of attraction which in turn is measured in terms of van der Waals' constant 'a'. Hence, higher the value of 'a', greater the intermolecular force of attraction, easier the liquification. In the present case,  $\text{NH}_3$  has highest 'a', can most easily be liquefied.

**Sol 5: (C)** At high temperature and low pressure, the gas volume is infinitely large and both intermolecular force as well as molecular volume can be ignored. Under this condition postulates of kinetic theory applies appropriately and gas approaches ideal behaviour.

**Sol 6: (C)** Root mean square speed  $U_{\text{rms}} = \sqrt{\frac{3RT}{M}}$

$$\Rightarrow \frac{u_{\text{rms}}(\text{H}_2)}{u_{\text{rms}}(\text{N}_2)} = \sqrt{7} = \sqrt{\frac{T(\text{H}_2)}{2} \times \frac{28}{T(\text{N}_2)}}$$

$$\Rightarrow 7 = \frac{14T(\text{H}_2)}{T(\text{N}_2)}$$

$$\Rightarrow T(\text{N}_2) = 2T(\text{H}_2), \text{ ie, } T(\text{H}_2) < T(\text{N}_2)$$

**Sol 7: (C)** Let us consider, 1.0 L of liquid water is converted into steam Volume of  $\text{H}_2\text{O}$  (l) = 1L, mass = 1000 g

$$\Rightarrow \text{Volume of 1000 g steam} = \frac{1000}{0.0006} \text{ cm}^3$$

$$\therefore \text{Volume of molecules in } \frac{1000}{0.0006} \text{ cm}^3$$

$$\text{steam} = 1000 \text{ cm}^3$$

$\therefore$  Volume of molecules in

$$1000 \text{ cm}^3 \text{ steam} = \frac{1000}{1000} \times 0.0006 \times 1000 = 0.60 \text{ cm}^3$$

**Sol 8: (B)** In the van der Waals' equation :

$$\left( p + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

The additional factor in pressure, ie,  $\frac{n^2 a}{V^2}$  corrects for intermolecular force while 'b' corrects for molecular volume.

**Sol 9: (A, B)** Pressure is inversely proportional to volume at constant temperature, hence (A) is correct.

Average kinetic energy of a gas is directly proportional to absolute temperature, hence (B) is correct.

Expansion at constant temperature cannot change the number of molecules, hence (D) is incorrect.

**Sol 10: (A, C)** (A) is correct because in the limit of large volume, both intermolecular force and molecular volume becomes negligible in comparison to volume of gas.

(B) is wrong statement because in the limit of large pressure  $Z > 1$

(C) is correct statement. For a van der Waals' gas, van der Waals constants 'a' and 'b' are characteristic of a gas, independent of temperature.

(D) is wrong statement because 'Z' can be either less or greater than unity, hence real pressure can be less or greater than ideal pressure.

**Sol 11: (A, C, D)** (A) According to a postulate of kinetic theory of gases, collision between the molecules as well as with the wall of container is perfectly elastic in nature.



(B) If a gas molecule of mass 'm' moving with speed 'u' collide to the wall of container, the change in momentum is  $\Delta p = -2mu$ . Therefore, heavier molecule will transfer more momentum to the wall as there will be greater change in momentum of the colliding gas molecule. However this is not postulated in kinetic theory.

(C) According to Maxwell-Boltzmann distribution of molecular speed, very few molecules have either very high or very low speeds. Most of the molecules moves in a specific, intermediate speed range.

(D) According to kinetic theory of gases, a gas molecule moves in straight line unless it collide with another molecule or to the wall of container and change in momentum is observed only after collision.

**Sol 12: (A)** 'a' is the measure of intermolecular force of attraction. Greater the intermolecular force of attraction (H-bond in the present case) higher the value of 'a'.

**Sol 13: (D)** Assertion is wrong because besides amount, pressure also depends on volume. However reason is correct because both frequency of collisions and impact are directly proportional to root mean square speed with is proportional to square-root of absolute temperature.

**Sol 14:** A  $\rightarrow$  p, s; B  $\rightarrow$  r, C  $\rightarrow$  p, q; D  $\rightarrow$  r

(A) At  $p = 200$  atm, very high pressure,  $Z > 1$  also, at such a high pressure, the pressure correction factor  $\left(\frac{n^2 a}{V^2}\right)$  can be ignored in comparison to p.

(B) At  $P \sim 0$ , gas will behave like an ideal gas,  $pV = nRT$ .

(C)  $\text{CO}_2$  ( $p = 1$  atm,  $T = 273$  K),  $Z < 1$ .

(D) At very large molar volume, real gas behaves like an ideal gas.

**Sol 15:** Since, the external pressure is 1.0 atm, the gas pressure is also 1.0 atm as piston is movable. Out of this 1.0 atm partial pressure due to unknown compound is 0.68 atm.

Therefore, partial pressure of He

$$= 1.00 - 0.68$$

$$= 0.32 \text{ atm.}$$

$$\Rightarrow \text{Volume} = \frac{n(\text{He})RT}{p(\text{He})} = \frac{0.1 \times 0.082 \times 273}{0.32} = 7 \text{ L.}$$

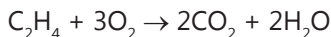
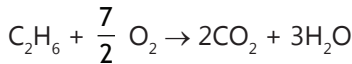
$$\Rightarrow \text{Volume of container} = \text{Volume of He.}$$

**Sol 16:** The total moles gaseous mixture

$$= \frac{pV}{RT} = \frac{1 \times 40}{0.082 \times 400}$$

Let the mixture contain x mole of ethane.

Therefore,



$$1.22 - x$$

Total moles of  $\text{O}_2$  required

$$= \frac{7}{2} x + 3(1.22 - x)$$

$$= \frac{x}{2} + 3.66$$

$$\Rightarrow \frac{130}{32} = \frac{x}{2} + 3.66$$

$$\Rightarrow x = 0.805 \text{ mole ethane and } 0.415 \text{ mole ethane.}$$

$$\Rightarrow \text{Mole fraction of ethane} = \frac{0.805}{1.22} = 0.66$$

$$\text{Mole fraction of ethane} = 1 - 0.66 = 0.34$$

**Sol 17:** In case of negligible molecular volume,  $b = 0$ , For 1 mole of gas

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

$$\Rightarrow pV + \frac{a}{V} = RT$$

$$\Rightarrow \frac{pV}{RT} + \frac{a}{VRT}$$

$$\left[\because \frac{pV}{RT} = Z\right] = 1$$

$$\Rightarrow Z + \frac{a}{\left(\frac{ZRT}{p}\right)RT} = 1$$

$$Z + \frac{ap}{ZR^2T^2} = 1$$

$$\begin{aligned} \Rightarrow a &= \frac{ZR^2T^2(1-Z)}{p} \\ &= \frac{0.5(0.082 \times 273)^2(1-0.5)}{100} \end{aligned}$$

$$a = 1.25 \text{ atm L}^2 \text{ mol}^{-2}$$

**Sol 18:(D)** Given,  $u_{\text{rms}} = u_{\text{rms}}$

$$\Rightarrow \sqrt{\frac{3RT}{M(X)}} = \sqrt{\frac{2RT}{M(Y)}}$$

$$\Rightarrow \frac{3R \times 400}{40} = \frac{2R \times 60}{M(Y)}$$

$$\Rightarrow M(Y) = 4.$$

**Sol 19:** A  $\rightarrow$  p, s; B  $\rightarrow$  r; C  $\rightarrow$  p, q; D  $\rightarrow$  p, s

(A)  $Z = \frac{PV_m}{RT}$  at high pressure and low temperature.

Equation  $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$  reduces to  $P(V - nb) = nRT$ .

(B) For hydrogen gas value of  $Z = 1$  at  $P = 0$  and it increase continuously on increasing pressure.

(C)  $\text{CO}_2$  molecules have larger attractive forces, under normal conditions.

(D)  $Z = \frac{PV_m}{RT}$ , at very large molar volume  $Z \neq 1$ .

**Sol 20: (A, C, D)**  $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$

At low pressure, when the sample occupies a large volume, the molecules are so far apart for most of the time that the intermolecular forces play no significant role, and the gas behaves virtually perfectly.

$a$  and  $b$  are characteristic of a gas and are independent

of temperature. The term  $\left(P + \frac{an^2}{V^2}\right)$  represents the

pressure exerted by an ideal gas while  $P$  represents the pressure exerted by a real gas.

**Sol 21: (C)** At large inter-ionic distances (because  $a \rightarrow 0$ ) the P.E. would remain constant. However, when  $r \rightarrow 0$ ; repulsion would suddenly increase.

**Sol 22: (D)** Diffusion coefficient  $\propto$  mean free path  $\times$  mean speed

$$D_1 \propto \lambda_1 C_1$$

$$C_2 = 2C_1$$

$$\lambda_2 = \frac{\lambda_1}{2} \times 4 = 2\lambda_1$$

$$D_2 \propto \lambda_2 C_2$$

$$\frac{D_2}{D_1} = \frac{\lambda_2 C_2}{\lambda_1 C_1} = 4$$