States of Matter

1. Sulphur dioxide and oxygen were allowed to diffuse through a porous partition. 20 dm^3 of SO_2 diffuses through the porous partition in 60 seconds. Calculate the volume of O_2 in dm^3 which diffuses under the similar condition in 30 seconds (atomic mass of sulphur = 32 u).
2. 4.5 g of PCl_5 on vapourisation occupied a volume of 1700 mL at 1 atmosphere pressure and 227°C temperature. Calculate its degree of dissociation.
3. 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 atmospheres at 27 °C. If the cylinder can hold 2.82 litres of water, calculate the number of balloons that can be filled up.
4. At 27°C, hydrogen is leaked through a tiny hole into a vessel for 20 minutes. Another unknown gas at the same temperature and pressure as that of H_2 is leaked through the same hole for 20 minutes. After the effusion of the gases the mixture exerts a pressure of 6 atmosphere. The hydrogen content of the mixture is 0.7 mole. If the volume of the container is 3 litres, what is the molecular weight of the unknown gas?
5. A bubble of gas released at the bottom of a lake increases to four times its original volume when it reaches the surface. Assuming that atmospheric pressure is equivalent to the pressure exerted by a column of water 10 m high, what is the depth of the lake (in m)?
6. A mixture of $NH_3(g)$ and $N_2H_4(g)$ is placed in a sealed container at 300 K. The total pressure is 0.5 atm. The container is heated to 1200 K at which both substances decompose completely according to the equations
   $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$
   and $N_2H_4(g) \rightarrow N_2(g) + 2H_2(g)$
   After decomposition is complete, the total pressure at 1200 K is found to be 4.5 atm. Find the mole % of N_2H_4 in the original mixture.
7. If 250 mL of N_2 over water at 30°C and a total pressure of 740 torr is mixed with 300 mL of Ne over water at 25°C and a total pressure of 780 torr, what will be the total pressure if the mixture is in a 500 mL vessel over water at 35°C?
   Given : vapour pressure (Aqueous tension) of H_2O at 25°C, 30°C and 35°C are 23.8, 31.8 and 42.2 torr respectively. Assume volume of $H_2O(l)$ is negligible in final vessel)
8. At 300 K, the density of a certain gaseous molecule at 2 bar is double to that of dinitrogen (N_2) at 4 bar. Find the molar mass of gaseous molecule.
9. Calculate the total pressure (in atm) in a 10.0 L cylinder which contains 0.4 g helium, 1.6 g oxygen and 1.4 g nitrogen at 27 °C.
10. At STP, a container has 1 mole of He, 2 mole Ne, 3 mole O_2 and 4 mole N_2 without changing total pressure if 2 mole of O_2 is removed. Calculate the percentage decrease in the partial pressure of O_2.
11. A gaseous mixture contains three gases A, B and C with a total number of moles of 10 and total pressure of 10 atm. The partial pressure of A and B are 3 atm and 1 atm respectively. If C has molecular weight of 2 g/mol then,
12. Two flasks A and B of equal volumes maintained at temperatures 300K and 600K contain equal mass of H_2 and CH_4 respectively. Calculate the ratio of total translational kinetic energy of gas in flask A to that in flask B.
13. If one mole of mono-atomic gas ($\gamma = 5/3$) is mixed with one mole of a diatomic gas ($\gamma = 7/5$). What is the value of γ for the mixture.
14. A mixture of Ne and Ar kept in a closed vessel at 250 K has a total K.E. of 3 kJ. The total mass of Ne and Ar is 30 g. Find mass % of Ne in gaseous mixture at 250 K.
15. What is the compressibility factor (Z) for 0.02 mole of a van der Waals' gas at pressure of 0.1 atm. Assume the size of gas molecules is negligible.
    Given : $RT = 20$ L atm mol^{-1} and $a = 1000$ atm L^2 mol^{-2}

SOLUTIONS

1. **(14.1)** According to Graham's Law of Diffusion:

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

Since rate of diffusion

$$= \frac{\text{Vol. of gas diffused (V)}}{\text{Time taken for diffusion(t)}}$$

$$\therefore \frac{r_1}{r_2} = \frac{V_1/t_1}{V_2/t_2}$$

$$\text{or } \frac{r_1}{r_2} = \frac{V_1/t_1}{V_2/t_2} = \sqrt{\frac{d_2}{d_1}}$$

$$= \frac{20/60}{V_2/30} = \sqrt{\frac{16/2}{32/2}} = \sqrt{\frac{1}{2}}$$

$\because$ Mol. wt = 2 × V.D

$$\therefore \text{V.D} = \frac{\text{Mol.wt}}{2}$$

On calculating, $V_2 = 14.1$

2. **(0.92)** Let the degree of dissociation be α, then

$$PCl_5 \longrightarrow PCl_3 + Cl_2$$
$$(1-\alpha) \qquad \alpha \qquad \alpha$$

(M) Molecular weight of $PCl_5 = 31 + 5 \times 35.5 = 208.5$
Total number of molecules before dissociation = 1
Total number of molecules after dissociation
$= 1 - \alpha + \alpha + \alpha = 1 + \alpha$
Thus each gram mole changes to $(1 + \alpha)$ gram-mole.

$$\text{Thus } PV = \frac{W}{M}(1+\alpha)RT$$

(V = volume after dissociation)

$$\text{or } 1 \times \frac{1700}{1000} = \frac{4.5}{208.5}(1+\alpha)RT$$

$$\left[1700\text{ml} = \frac{1700}{1000}\text{L}\right]$$

or $\alpha = 0.921$

3. **(10)** No. of balloons that can be filled

$$= \frac{\text{V of } H_2 \text{ available}}{\text{V of one balloon}}$$

Calculation of total volume of hydrogen in the cylinder at N.T.P.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 1$ atm $P_2 = 20$ atm
$V_1 = ?$ $V_2 = 2.82\ l$
$T_1 = 273$ K $T_2 = 273 + 27 = 300$ K

$$\therefore V_1 = \frac{20 \times 2.82 \times 273}{300 \times 1} = 51.324\text{l} = 51324\text{ mL}$$

Actual volume to be transferred into balloons
$= 51324 - 2820$ mL $= 48504$ mL
[$\because$ 2820 mL of H_2 will remain in cylinder]

$$\text{Volume of one balloon} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times \frac{22}{7} \times \left(\frac{21}{2}\right)^3$$

$$\left[\because r = \frac{\text{diameter}}{2}\right]$$

$= 4851$ mL $= 4.851$L
No. of balloons that can be filled up

$$= \frac{48504}{4851} = 9.999 \approx 10$$

4. **(1033)** Using gas equation; $PV = nRT$
Total no. of moles of gases in the mixture (n)

$$= \frac{PV}{RT} = \frac{6 \times 3}{0.0821 \times 300} = 0.7308 \text{ moles.}$$

Thus no. of moles of unknown gas $= 0.7308 - 0.7$
$= 0.0308$ moles

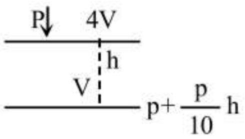
Now we know that

$$\frac{r_1}{r_2} = \frac{\text{moles of hydrogen gas}}{\text{moles of unknown gas}} = \frac{0.7}{0.0308}$$

$$\text{Also we know that } \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\therefore M_2 = \left(\frac{r_1}{r_2}\right)^2 M_1 \text{ or } M_2 = \left(\frac{0.7}{0.0308}\right)^2 \times 2 = 1033$$

5. **(30)**



$$P_1V_1 = P_2V_2$$

$$P \times 4V = P\left(1 + \frac{h}{10}\right)V$$

$$4 = 1 + \frac{h}{10}$$

$h = 30$ m

6. **(25)** Let initial mixture contains n_1 and n_2 moles of NH_3 and N_2H_4 respectively.
Total moles of gases originally present $= n_1 + n_2$
Total moles of gases after decomposition of gases
$= 2n_1 + 3n_2$
$0.5 \times V = (n_1 + n_2)R \times 300$
$4.5 \times V = (2n_1 + 3n_2) R \times 1200$

$$\frac{2n_1 + 3n_2}{n_1 + n_2} = \frac{9}{4}$$

$$\frac{n_2}{n_1} = \frac{1}{3}$$

$$\frac{n_2}{n_1 + n_2} \times 100 = 25\%$$

7. **(870.6)** $n_{N_2} = \dfrac{\left(\dfrac{708.2}{760} \times 0.25\right)}{0.0821 \times 303} = 9.36 \times 10^{-3}$

$n_{N_2} = \dfrac{\left(\dfrac{756.2}{760}\right) \times 0.3}{(0.0821) \times 298}$

$= 0.0122$

n_{total} moles $= 0.02156$

pressure in final vessel = p

$\dfrac{(n_{total})RT}{V} = \dfrac{0.02156 \times 0.0821 \times 308}{0.5}$

p = 1.09 atm or 828.4 torr

$P_{total} = p_{(N_2+Ne)} + \text{V.p. of } H_2O$

$= 828.4 + 42.2 = 870.6$ torr

8. **(112)** Density $(\rho) = \dfrac{PM}{RT}$ (1 bar = 0.987 atm)

$\rho_{N_2} = \dfrac{4 \times 0.987 \times 28}{R \times 300}$

Let the molar mass of gas be x

$\rho_{gas} = \dfrac{2 \times 0.987 \times x}{R \times 300}$

Given $\rho_{gas} = \rho_{N_2} \times 2$

$\dfrac{2 \times 0.987 \times x}{R \times 300} = \dfrac{4 \times 0.987 \times 28}{R \times 300} \times 2$

$\therefore x = 112$ g/mol

9. **(0.49)** Given T = 27 °C = 27 + 273 = 300 K

V = 10.0 L

Mass of He = 0.4 g

Mass of oxygen = 1.6 g

Mass of nitrogen = 1.4 g

$n_{He} = 0.4/4 = 0.1$

$n_{O_2} = 1.6/32 = 0.05$

$n_{N_2} = 1.4/28 = 0.05$

n total $= n_{He} + n_{O_2} + n_{N_2} = 0.1 + 0.05 + 0.05 = 0.2$

$P = \dfrac{nRT}{V} = \dfrac{0.2 \times 0.082 \times 300}{10} = 0.49$ atm

10. **(58.33)** $P_{O_2} = \dfrac{3}{10} \times P_T;$

After removing 2 mole of O_2,

$P'_{O_2} = \dfrac{1}{10} \times P_T;$

Decrease in partial pressure of O_2

$= \dfrac{\dfrac{3P_T}{10} - \dfrac{P_T}{8}}{\dfrac{3P_T}{10}} \times 100$

$= 58.33\ \%$

11. **(12)** Given P = 10 atm,

total numbers of moles; $n_A + n_B + n_C = 10$

$P_A = 3$ atm, $P_B = 1$ atm

$\therefore P_A = x_A \times P_{(total)} = \dfrac{n_A}{n_A + n_B + n_C} \times 10$

$= \dfrac{n_A}{10} \times 10 = 3$

Similarly, $P_B = x_B \times P_{(total)}$

So, $n_B = 1$

$\therefore n_C = 10 - (n_A + n_B) = 10 - 4 = 6$

Mass of C = 6 × 2 = 12 g

12. **(4)** $K.E. = \dfrac{3}{2}nRT$; $K.E(H_2) = \dfrac{3}{2} \times \dfrac{w}{2} \times R \times 300;$

$K.E.(CH_4) = \dfrac{3}{2} \times \dfrac{w}{16} \times R \times 600;$

Hence, $\dfrac{K.E.(H_2)}{K.E.(CH_4)} = 4$

13. **(1.5)** $\left.\begin{aligned} C_v &= \tfrac{3}{2}RT \\ C_p &= \tfrac{5}{2}RT \end{aligned}\right\}$ for monoatomic gas;

$\left.\begin{aligned} C_v &= \tfrac{5}{2}2RT \\ C_p &= \tfrac{7}{2}RT \end{aligned}\right\}$ for diatomic gas

Thus, for mixture of 1 mole each,

$C_v = \dfrac{\dfrac{3}{2}RT + \dfrac{5}{2}RT}{2}$ and $C_p = \dfrac{\dfrac{5}{2}RT + \dfrac{7}{2}RT}{2}$

Thus, $\dfrac{C_p}{C_v} = \dfrac{3RT}{2RT} = 1.5$

14. **(28.3)** $K = \dfrac{3}{2}n_T RT \Rightarrow n_T = \dfrac{3000 \times 2}{3 \times 250 \times 8.314}$

$3 \times 10^3 = \dfrac{3}{2} n_T \times 8.314 \times 250$

$\dfrac{x}{20} + \dfrac{30 - x}{40} = \dfrac{2}{8.314}$

% Ne = 28.3

15. **(0.5)** $\left(0.1 + \dfrac{1000 \times (0.02)^2}{V^2}\right)V = 20 \times 0.02$

$0.1\,V^2 - 0.4\,V + 0.4 = 0$

$V^2 - 4V + 4 = 0$

V = 2 L

$Z = \dfrac{PV}{nRT} = \dfrac{0.1 \times 2}{20 \times 0.02} = 0.5$