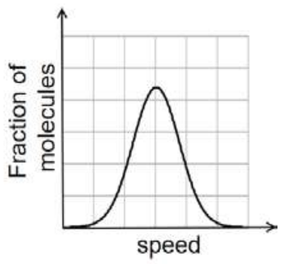
PHYSICAL CHEMISTRY

IDEAL GAS

1. If the distribution of molecular speeds of a gas is as per the figure shown below, then the ratio of the most probable, the average and the roots mean square speeds, respectively, is **[JEE(Advanced) 2020]**



(A) 1 : 1 : 1 (B) 1 : 1 : 1.224

(C) 1 : 1.128 : 1.224 (D) 1 : 1.128 : 1

2. Which of the following statement(s) is (are) correct regarding the root mean square speed (U_{rms}) and average translational kinetic energy (ε_{av}) of a molecule in a gas at equilibrium ? **[JEE(Advanced) 2019]**

(A) U_{rms} is doubled when its temperature is increased four times

(B) ε_{av} at a given temperature does not depend on its molecular mass

(C) U_{rms} is inversely proportional to the square root of its molecular mass

(D) ε_{av} is doubled when its temperature is increased four times

3. A closed tank has two compartments A and B, both filled with oxygen (assumed to be ideal gas). The partition separating the two compartments is fixed and is a perfect heat insulator (Figure 1). If the old partition is replaced by a new partition which can slide and conduct heat but does NOT allow the gas to leak across (Figure 2), the volume (in m^3) of the compartment A after the system attains equilibrium is_______. **[JEE(Advanced) 2018]**

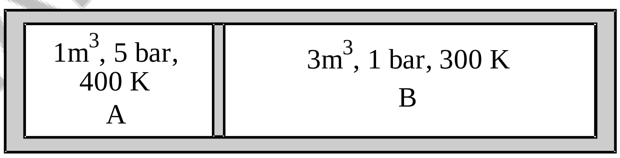


Figure 1

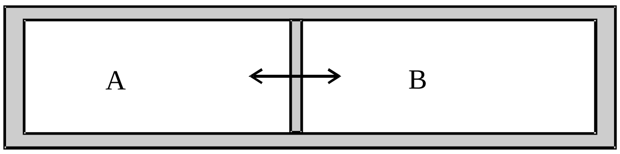


Figure 2

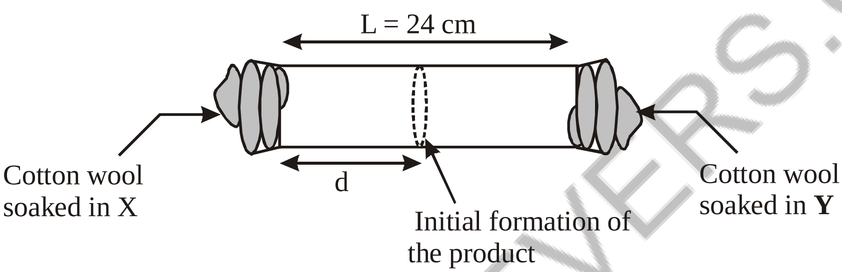
4. The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases x times. The value of x is **[JEE(Advanced) 2016]**

5. A closed vessel with rigid walls contains 1 mol of ${}^{238}_{92}U$ and 1 mol of air at 298 K. Considering complete decay of ${}^{238}_{92}U$ to ${}^{206}_{82}Pb$, the ratio of the final pressure to the initial pressure of the system at 298 K is -

[JEE(Advanced) 2015]

Paragraph for Question No. 6 and 7

X and Y are two volatile liquids with molar weights of 10g mol^{-1} and 40g mol^{-1} respectively. Two cotton plugs, one soaked in X and the other soaked in Y, are simultaneously placed at the ends of a tube of length L = 24 cm, as shown in the figure. The tube is filled with an inert gas at 1 atmosphere pressure and a temperature of 300K. Vapours of X and Y react to form a product which is first observed at a distance d cm from the plug soaked in X. Take X and Y to have equal molecular diameters and assume ideal behaviour for the inert gas and the two vapours.



6. The value of d in cm (shown in the figure), as estimated from Graham's law, is - **[JEE(Advanced) 2014]**

(A) 8 (B) 12 (C) 16 (D) 20

7. The experimetnal value of d is found to be smaller than the estimate obtained using Graham's law. This is due to - **[JEE(Advanced) 2014]**

(A) Larger mean free path for X as compared to that of Y

(B) Larger mean free path for Y as compared to that of X

(C) Increased collision frequency of Y with the inert gas as compared to that of X with the inert gas

(D) Increased collision frequency of X with the inert gas as compared to that of Y with the inert gas

SOLUTIONS

1. **Ans. (B)**

Sol. Graph represents symmetrical distribution of speed and hence, the most probable and the average speed should be same. But the root mean square speed must be greater than the average speed.

2. **Ans. (A,B,C)**

Sol. $U_{rms} = \sqrt{\frac{3RT}{M}}$

$E_{avg} = \frac{3}{2}kT$

3. **Ans. (2.22)**

Sol. $P_1 = 5$ $\quad$ $P_2 = 1$

$v_1 = 1$ $\quad$ $v_2 = 3$

$T_1 = 400$ $\quad$ $T_2 = 300$

$n_1 = \frac{5}{400R}$ $\quad$ $n_2 = \frac{3}{300R}$

Let volume be (v + x) $\quad$ v = (3–x)

15 – 5x = 4 + 4x

$\frac{P_A}{T_A} = \frac{P_B}{T_B}$

$\Rightarrow \frac{n_{b_1} \times R}{v_{b_1}} = \frac{n_{b_2} \times R}{v_{b_2}}$

$\Rightarrow \frac{5}{400(4+x)} = \frac{3}{300R(3-x)}$

$\Rightarrow 5(3 - x) = 4 + 4x$

$\Rightarrow x = \frac{11}{9}$

$v = 1 + x = 1 + \frac{11}{9} = \left(\frac{20}{9}\right) = 2.22$

4. **Ans. (4)**

Sol. Rate of diffusion $\propto \lambda \times U_{Avg}$

$\propto \frac{1}{\sqrt{2}\pi\sigma^2 N^*} \times U_{Avg}$

$\propto \frac{U_{Avg}}{\sqrt{2}\pi\sigma^2 N^*}$

$\propto \frac{U_{Avg}(kT)}{\sqrt{2}\pi\sigma^2 P}$

Rate of diffusion $\propto \frac{T^{\frac{3}{2}}}{P}$

$$\frac{r_{final}}{r_{initial}} = \frac{(4)^{\frac{3}{2}}}{2} = \frac{r_{final}}{r_{inital}} = 4$$

5. Ans. (9)

Sol. $_{92}U^{238} \longrightarrow {}_{82}Pb^{206} + 8 \cdot {}_{2}He^{4}{}_{(g)} + 6 \cdot {}_{-1}\beta^{o}$

1mole –

– 1mole 8 mole

$n_{He} = 8$

$n_f = n_{He} + n_{air} = 9$

$n_i = n_{air} = 1$

$\frac{P_F}{P_i} = \frac{n_F}{n_i} = 9$ (As V & T are constant)

6. Ans. (C)

Sol. $\left[\frac{d_x / t}{d_y / t}\right] = \sqrt{\frac{M_y}{M_x}}$

$\frac{d}{24-d} = \sqrt{\frac{40}{10}} = 2$

$d = 48 - 2d$

$d = 16$ cm

7. Ans. (D)

Sol. $z_1 = (\pi\sigma^2)\left(U_{avg}\right)N^*_{inert}$

λ = mean free path = $\frac{U_{avg}}{z_1} = \frac{1}{(\pi\sigma^2)N^*_{inert}}$

N* = Number of particles per unit volume

Since inert gas is present for both X & Y gases therefore number of particles per unit volume is same for both. Since both have same diameter therefore mean free path is same in both case

z_{12} = Collision frequency = $(z_1)N^*$

$z_{12} = (\pi\sigma^2)(U_{avg})(N^*_{inert} \times N^*_y)$

$z_{12} = (\pi\sigma^2)\sqrt{\frac{8}{\pi}\frac{RT}{\mu}}(N^*_{inert} \times N^*_y)$

σ and N^*_{inert} is same for both

$\therefore \ z_{12} \ \alpha \frac{1}{\sqrt{\mu}}$

μ is higher for Y(heavier gas) ; z_{12} is higher for lighter gas.

Lighter gas experience more collision than heavier therefore it will travel less distance than predicted by Grahams law.