Num :- If at NTP, the molecular velocity of hydrogen gas is $1.83 \times 10^5\ cm\ s^{-1}$ & its mean free path is 1.8×10^{-5} cm. The calculate collision (frequency) number.

Sol :- since mean free path $\lambda = \dfrac{\text{average velocity } (\bar{c})}{\text{collision (frequency) number}}$

$$Z_1 = \frac{1.83\times10^5\ cm\ s^{-1}}{1.8\times10^{-5}\ cm} = 1.0167\times10^{10}\ s^{-1}$$

Num :- The mean free path of a gas at 300K is 2.6×10^{-3} cm. If collision diameter of molecule is 2.6 Å, then calculate the number of molecules in one cc of the gas & its pressure

Sol :- given $\lambda = 2.6\times10^{-3}$ cm, $T = 300K$, $d = 2.6$ Å $= 2.6\times10^{-8}$ cm

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 \rho}$$

$$\therefore \rho = \frac{1}{\sqrt{2}\pi d^2 \lambda} = \frac{1}{1.414\times3.14\times(2.6\times10^{-8}\ cm)^2\times2.6\times10^{-3}\ cm}$$

$$\rho = \frac{1\times10^{19}}{78.04}\ cm^{-3} = 1.281\times10^{17}\ \text{molecule}\ cm^{-3}$$
$$= 1.281\times10^{20}\ \text{molecule}\ dm^{-3}$$

But $\rho = \dfrac{P}{kT}$

$$\therefore P = \rho k T$$
$$= \rho\left(\frac{R}{N_A}\right)T = 1.281\times10^{20}\times\frac{0.0821\ L\ atm\ K^{-1} mol^{-1}}{6.023\times10^{23}\ mol^{-1}}\times300K$$

$$= 1.281\times10^{20}\ dm^{-3}\times\frac{0.0821\ L\ atm\ K^{-1} mol^{-1}}{6.023\times10^{23}\ mol^{-1}}\times300\ K$$

$$= \frac{31.551\times10^{20}}{6.023\times10^{23}}\ atm$$

$$\boxed{P = 5.238\times10^{-3}\ atm}$$

Pm :- Calculate the mean free path of CO at 300K temperature & one atmospheric pressure. The collision diameter of CO is $= 3.61 \times 10^{-8}$ cm

Sol :-

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 \rho} = \frac{kT}{\sqrt{2}\pi d^2 P}$$

$$= \cancel{\frac{1}{1.414 \times 3.14 \times (3.61 \times 10^{-8} cm)^2 \times 1 atm}}$$

$$\rho = \frac{P}{kT} = \frac{P N_0}{RT}$$

$$= \frac{1 atm \; 6.023 \times 10^{23} mol^{-1}}{0.0821 \, L \, atm \, K^{-1} mol^{-1} \times 300K} = \frac{6.023 \times 10^{23}}{24.63} \text{ per litre}$$

$$= 2.445 \times 10^{22} \text{ per litre}$$

$$\rho = 2.445 \times 10^{22} \, dm^{-3} = 2.445 \times 10^{19} \, cm^{-3}$$

$$\therefore \lambda = \frac{1}{1.414 \times 3.14 \times (3.61 \times 10^{-8} cm)^2 (2.445 \times 10^{19} cm^{-3})}$$

$$= \frac{1}{114.058 \times 10^{3}} \, cm$$

$$\lambda = 8.767 \times 10^{-6} \, cm$$

Num :— Calculate the value of σ, λ, Z_1 & Z_{11} for oxygen at 298.15 K at the pressure of 101.325 kPa, given van der Waals constant $b = 3.183 \times 10^{-2}\ dm^3\ mol^{-1}$

Sol :—

$$\rho = \frac{P}{kT} = \frac{101325\ Pa}{(1.38 \times 10^{-23}\ J K^{-1})(298.15\ K)}$$

$$= \frac{101325}{411.447} \times 10^{23}\ m^{-3} = 246.265 \times 10^{23}\ m^{-3}$$

van der Waals const $b = 4 N_0 \left(\frac{4}{3}\pi d^3\right)$

$$d = \left(\frac{3b}{16\pi N_0}\right)^{1/3}$$

$$d = \left(\frac{3 \times 3.183 \times 10^{-2}\ dm^3 mol^{-1}}{16 \times 3.14 \times 6.023 \times 10^{23} mol^{-1}}\right)^{1/3} = \left(\frac{9.549 \times 10^{-2}}{302.595 \times 10^{23}}\ dm^3\right)^{1/3}$$

$$= \left(\frac{954.9 \times 10^{-4} \times 10^{-23}}{302.595}\ dm^3\right)^{1/3} = \left(3.156 \times 10^{-27}\ dm^3\right)^{1/3}$$

$$= 1.5 \times 10^{-9}\ dm = 1.5 \times 10^{-10}\ m$$

$$\sigma = 2d = 3.0 \times 10^{-10}\ m$$

$$\therefore \bar{c} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.314 \times 298.15}{3.14 \times 0.032}}$$

$$= \sqrt{\frac{19830.55}{0.1004}} = \sqrt{197515.43}\ ms^{-1}$$

$$= 444.2\ ms^{-1}$$

$$\therefore \lambda = \frac{1}{\sqrt{2}\pi\sigma^2\rho}$$

$$= \frac{1}{(1.414)(3.14)(3.0 \times 10^{-10})^2 \times 246.265 \times 10^{23} m^{-3}}$$

$$= \frac{1}{9840.66 \times 10^{3}}\ m = \frac{1}{9.84} \times 10^{-6}\ m$$

$$\lambda = 1.016 \times 10^{-7}\ m$$

$$Z_1 = \frac{444.2\ ms^{-1}}{1.016 \times 10^{-7} m}$$

$$= 437.20 \times 10^{7} s^{-1}$$

$$= 4.3 \times 10^{9} s^{-1}$$

$$Z_1 = \sqrt{2}\pi\sigma^2\bar{c}\rho = 1.414 \times 3.14 \times (3.0 \times 10^{-10})^2 \times (444.2) \times 246.265 \times 10^{23}$$

$$= \cancel{4377638 1.53 \times 10^{3}}\ s^{-1} = 4371221.5 \times 10^{3}$$

$$= 4.3 \times 10^{9}\ s^{-1}$$

$$Z_{11} = \frac{1}{2} Z_1 \rho = \frac{1}{2} \times 4.3 \times 10^{9} \times 246.265 \times 10^{23}$$

$$= 529.46 \times 10^{32} = 5.29 \times 10^{34}\ s^{-1} m^{-3}$$

Num:— The mean free path of the molecule of a certain gas at 300K is 2.6×10^{-5} m. The collision diameter of molecule is 0.26 nm. Calculate a) pressure of gas, & b) number of molecules per unit volume of gas

Sol:— ~~given~~ since $\lambda = \frac{1}{\sqrt{2}\pi\sigma^2\rho}$

$$\therefore \rho = \frac{1}{\sqrt{2}\pi\sigma^2\lambda} = \frac{1}{1.414 \times 3.14 \times (2.6 \times 10^{-10})^2 \times 2.6 \times 10^{-5}} \, m^{-3}$$

$$\rho = \frac{1}{78.03 \times 10^{-25}} = 0.0128 \times 10^{+25} = 1.28 \times 10^{23} \, m^{-3}$$

$\therefore$ since $\rho = \frac{P}{kT}$ $\therefore P = \rho kT$

$$= 1.28 \times 10^{23} \times (1.38 \times 10^{-23} \, JK^{-1}) \times (300 \, K)$$

$$= 529.92 \, J m^{-3} = 529.92 \, Pa$$

Num:— The Vander Waals constant b for n-heptane is $0.2654 \, dm^3 mol^{-1}$. Estimate the coeff. of viscosity of this gas at 298 K. Calculate σ from b assuming the molecule to be spherical

Sol:— since $b = 4 N_A \left(\frac{4}{3}\pi d^3\right)$

$$\therefore d = \left(\frac{3b}{16 N_A \pi}\right)^{1/3} = \left(\frac{3 \times 0.2654 \, dm^3 mol^{-1}}{16 \times 6.023 \times 10^{23} \, mol^{-1} \times 3.14}\right)^{1/3}$$

$$d = \left(\frac{0.7962}{\cancel{96.368} \times 10^{23}}\right)^{1/3} dm = (0.0826 \times 10^{-24})^{1/3} dm$$

302.59

$$= 0.29 \times 10^{-8} \, dm$$

$$\therefore \sigma = 2d = 0.594 \times 10^{-8} \, dm = 0.594 \times 10^{-9} \, m$$

molar mass of n hepten $M = 100 g/mol$

$$\therefore \eta = \frac{(MRT)^{1/2}}{\pi^{3/2} N_A \sigma^2} = \frac{\left[(100 \times 10^{-3}) \times 8.314 \times 298\right]^{1/2}}{(3.14)^{3/2} \times 6.023 \times 10^{23} \times (0.594 \times 10^{-9} \, m)^2}$$

$$= 4.91 \times 10^{-4} \, Kg m^{-1} s^{-1}$$