Tutorial 11 Solutions

PHY 101

Q1. One mole of a gas is contained in a cube of side 0.2m If these molecules, each of mass 5 $\times 10^{-26}$kg, move with translational speed 483ms^{-1} , calculate the pressure exerted by the gas on the sides of the cube.

Sol:One mole of a gas is contained in a cube of side 0.2m If these molecules, each of mass kg, move

with translational speed 483m, calculate the pressure exerted by the gas on the sides of the cube.

Solution: The change in the momentum of the gaseous molecule between any two successive collisions with a wall of the container will be

$\triangle p_x = 2mv_x = 2 \times (5\times10^{-26}$ kg$) \times (483ms^{-1}) = 4.83\times10^{-23}$ Ns

The time between successive collision on the same face

$\triangle t = \frac{2L}{V_x} =- \frac{2\times0.2m}{483ms^{-1}} = 8.3\times10^{-4}s$

Hence the rate of change of momentum of one molecule

$\frac{\triangle p_x}{\triangle t} = \frac{4.83\times10^{-23}\text{ Ns}}{8.3\times10^{-4}s} = 0.582\times10^{-19}$ N

Therefore, the total force exerted by all the molecules of the gas on a wall is

$f_x = (0.582\times10^{-19}\text{ N}) \times (6\times10^{23}) = 3.49 \times 10^4$ N

Hence average pressure exerted by all the molecules of the gas on the walls of the container

$P = \frac{3.49\times10^4\text{ N}}{3\times4\times10^{-2}\ m^2} = 2.9 \times 10^5\ Nm^{-2}$

Q2. A gas is at temperature 80°C and pressure 5×10^{-10}N m-2. What is the number of molecules per m^3 if Boltzmann's constant is 1.38×10^{-23} J K-1.

Sol:

Temperature of gas T = 80°C = 80 + 273 = 353K

Pressure of gas P = 5×10^{-10} Nm^{-2}

Boltzmann's constant k = 1.38×10^{-23} Jk^{-1}

Volume of gas V = 1 m^3

No. of molecules n = ?

$$n = \frac{PV}{kT} = \frac{5\times10^{-10}\times1}{1.38\times10^{-23}\times353} = \frac{5\times10^{-10}}{487\times10^{-23}}$$

Ans: 1.02×10^{11}

Q3. If a mixture of n_1 moles of monatomic gas and n_2 moles of diatomic gas has γ =1.5, then what will be the ratio of n_1 and n_2?
Sol:

Sol. The average number of degrees of freedom per molecule

$$f = \frac{\text{total number of degrees of freedom}}{\text{total number of molecules}} = \frac{n_1 N_A f_1 + n_2 N_A f_2}{n_1 N_A + n_2 N_A} \quad \ldots\ldots\ldots\ldots(1)$$

where N_A is the Avogadro constant, and f_1 and f_2 are degrees of freedoms of monatomic and diatomic gases

Hence, $f_1 = 3, f_2 = 5$

From Eq. (1) we can write

$$f = \frac{n_1 f_1 + n_2 f_2}{n_1 + n_2} = \frac{3n_1 + 5n_2}{n_1 + n_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Also, $\gamma = 1 + 2/f = 1.5$

$\Rightarrow f = 4$

Using Eq. (2), we find

$$f = \frac{3n_1 + 5n_2}{n_1 + n_2} = 4$$

$\rightarrow 3n_1 + 5n_2 = 4n_1 + 4n_2$

$\rightarrow n_1/n_2 = 1$