

(A) Mean Free Path: -

Gas molecules are always in state of rapid motion colliding with each other. The distance travelled by a gas molecule before colliding with another molecule is called Free Path, and the average length of a large number of such paths is called Mean free path and it is denoted by symbol 'l'.
The expression of Mean free Path is given as follows

$$l = \frac{1}{\sqrt{2} \pi \sigma^2 N}$$

where N = Number of Molecules per Cubic Metre of the gas

σ = Molecular Diameter in Metres

(B) Collision Diameter: -

When two gaseous molecules approach each other by continue moving till a point at which the mutual repulsion is so great that they have to retrace their paths.

The distance between centres of two such molecules at the point of the closest approach is called Collision diameter. The Collision diameter is denoted by Sigma ' σ '.

(C) Collision Frequency: - It is denoted by N_c . The number of collisions suffered by gas molecules per sec. per Cubic metre of a gas is called Collision frequency of the gas. It is given by following expression: -

$$N_c = \frac{1}{\sqrt{2}} \pi v \sigma^2 N^2 = 2 \sigma^2 N^2 \sqrt{\frac{\pi RT}{M}}$$

where v is the average molecular velocity in metre sec^{-1} . N is the number of molecules per Cubic metre of the gas.

σ is the molecular diameter in Metres.

At a particular temperature, distance travelled by a molecule between two successive collision depends upon the pressure of the gas.

When the temperature is very high, the molecules are comparatively near to each other and mutual collisions are larger as compared to those at low pressure, then the mean free path is expressed as

$$l = \frac{c}{N_c} \quad \text{where } c = \text{Velocity of molecule.}$$

Define (i) Root mean Square (r.m.s) velocity (ii) Average velocity
(iii) Most Probable Velocity.

(1) Root mean square velocity: - R.M.S or root mean square velocity is the square root or root of the mean of squares of velocities of all gas molecules present in the gas.

$$C_{r.m.s} = \sqrt{\frac{n_1 u_1^2 + n_2 u_2^2 + \dots}{n_1 + n_2 + \dots}}$$

$$C_{r.m.s} = \sqrt{\frac{c_1^2 + c_2^2 + \dots + c_n^2}{n}}$$

From kinetic gas equation, we know $PV = \frac{1}{3} M c^2$ [$\because n m = M$]

$$\text{or } PV = \frac{1}{3} M c^2$$

$$M c^2 = 3PV$$

$$c^2 = \frac{3PV}{M} = \frac{3P}{D} = \frac{3RT}{M}$$

$$\text{or, } C_{r.m.s.} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{D}} = \sqrt{\frac{3RT}{M}}$$

(2) Average Velocity: - Let us suppose there are n_1, n_2, \dots molecules possessing velocities u_1, u_2, u_3, \dots respectively.

The average velocity is given by

$$\text{Average Velocity} = \frac{n_1 u_1 + n_2 u_2 + \dots}{n_1 + n_2 + \dots}$$

or, Average velocity ' C_a ' is the arithmetic mean of velocities of all gas molecules present in a gas.

If the individual velocities of n gas molecules present in gas is c_1, c_2, \dots, c_n , then the average velocity of the gas is given by

$$C_a = \frac{c_1 + c_2 + c_3 + \dots + c_n}{n}$$

From Maxwell distribution of molecular velocities,
we know

$$C_a = \sqrt{\frac{8RT}{\pi M}} \quad \text{or, } C_a = \sqrt{\frac{8}{3\pi}} \times \sqrt{\frac{3RT}{M}} = \sqrt{\frac{8}{3\pi}} \cdot C_{r.m.s.} = 0.9213 \cdot C_{r.m.s.} \text{ velocity}$$

(3) Most Probable Velocities: - Most probable velocity C_{mp} is defined as the velocity possessed by the maximum number of gas molecules present in the gas at a particular temperature

According to Maxwell the expression for most probable velocity

$$\text{is given as } C_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2 \times 3RT}{3M}} = \sqrt{\frac{2}{3}} \cdot C_{r.m.s.} \text{ velocity} = 0.816 \cdot C_{r.m.s.} \text{ velocity}$$

Average, R.M.S. and most Probable Velocities.

We know By the Maxwell's distribution law of molecular velocities

$$\text{Average velocity, } C_{av} = \sqrt{\frac{8RT}{\pi M}} = \left(\frac{8RT}{\pi M}\right)^{1/2}$$

$$\text{R.M.S. velocity, } C_{r.m.s} = \sqrt{\frac{3RT}{M}} = \left(\frac{3RT}{M}\right)^{1/2}$$

$$\text{Most Probable velocity } C_{mp} = \sqrt{\frac{2RT}{M}} = \left(\frac{2RT}{M}\right)^{1/2}$$

The relation among the above molecular velocities are as follows.

$$C_p : C_{av} : C_{r.m.s} = \left(\frac{2RT}{M}\right)^{1/2} : \left(\frac{8RT}{\pi M}\right)^{1/2} : \left(\frac{3RT}{M}\right)^{1/2} \quad (1)$$

On dividing R.H.S by $\left(\frac{2RT}{M}\right)^{1/2}$

we get

$$C_p : C_{av} : C_{r.m.s} = 1 : \frac{2}{\sqrt{\pi}} : \sqrt{\frac{3}{2}}$$

$$C_{mp} : C_{av} : C_{r.m.s} = 1 : 1.218 : 1.224$$