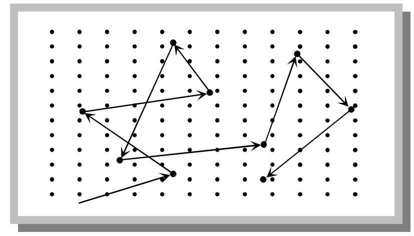
Mean Free Path.

The molecules of a gas move with high speeds at a given temperature but even then a molecule of the gas takes a very long time to go from one point to another point in the container of the gas. This is due to the fact that a gas molecule suffers a number of collisions with other gas molecules surrounding it. As a result of these collisions, the path followed by a gas molecule in the container of the gas is zig-zag as shown in the figure. During two successive collisions, a molecule of a gas moves in a straight line with constant velocity and the distance travelled by a gas molecule between two successive collisions is known as free path.



The distance travelled by a gas molecule between two successive collisions is not constant and hence the average distance travelled by a molecule during all collisions is to be calculated. This average distance travelled by a gas molecule is known as mean free path.

Let $\lambda_1, \lambda_2, \lambda_3, \ldots \lambda_n$ be the distance travelled by a gas molecule during n collisions respectively, then the mean free path of a gas molecule is given by $\lambda = \dfrac{\lambda_1 + \lambda_2 + \lambda_3 + \ldots. + \lambda_n}{n}$

(1) $\lambda = \dfrac{1}{\sqrt{2}\pi n d^2}$; where d = Diameter of the molecule, n = Number of molecules per unit volume

(2) As PV = μ RT = μNkT ⇒ $\dfrac{N}{V} = \dfrac{P}{kT} = n =$ Number of molecule per unit volume

So $\lambda = \dfrac{1}{\sqrt{2}} \dfrac{kT}{\pi d^2 P}$

(3) From $\lambda = \dfrac{1}{\sqrt{2}\pi n d^2} = \dfrac{m}{\sqrt{2}\pi(mn)d^2} = \dfrac{m}{\sqrt{2}\pi d^2 \rho}$ [As mn = Mass per unit volume = Density =ρ]

(4) If average speed of molecule is v then

$\lambda = v \times \dfrac{t}{N} = v \times T$ [As N = Number of collision in time t, T = time interval between two collisions]

Important points

(i) As $\lambda = \frac{m}{\sqrt{2}\pi d^2 \rho}$ $\therefore$ $\lambda \propto \frac{1}{\rho}$ i.e. the mean free path is inversely proportional to the density of a gas.

(ii) As $\lambda = \frac{1}{\sqrt{2}} \frac{kT}{\pi d^2 P}$. For constant volume and hence constant number density n of gas molecules, $\frac{P}{T}$ is constant so that λ will not depend on P and T. But if volume of given mass of a gas is allowed to change with P or T then λ∝ T at constant pressure and $\lambda \propto \frac{1}{P}$ at constant temperature.