(a) Mean Free Path

The Mean free path is the average distance travelled by molecule between two successive collisions. If $\lambda_1 \ \lambda_2 \ \lambda_3 \ldots\ldots\lambda_N$ denotes successive free length path traversed in time t and N is total number of collision suffered in this period then mean free path λ given by $\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 \ldots \lambda_N}{N}$ which is equivalent to total distance travelled divided by total number of collision.

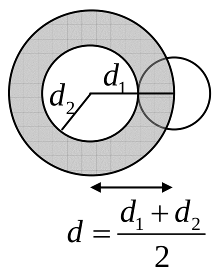

Figure 1

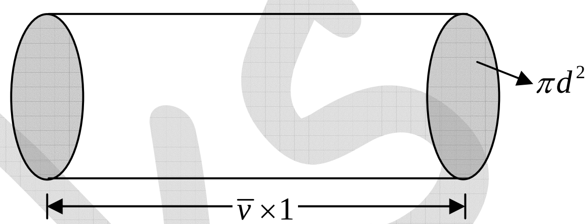

Figure 2

Consider two molecules of masses m_1 and m_2 and diameters d_1 & d_2 .

After collision they can be considered as one body system. Reduced mass, $\mu = \frac{m_1 m_2}{m_1 + m_2}$ and centre to centre distance, $d = \frac{d_1 + d_2}{2}$ (Figure 1). Let the number of densities of these gases $= n_1$ and n_2. We construct a cylinder of cross section area πd^2 (Figure 2), length $\bar{v} = \sqrt{\frac{8kT}{\mu\pi}}$, which defines Average speed characterizing maxwellian molecules when molecule of first type moves it collides will all the molecules of second type in the cylinder.

Total number of such collisions is given by $f_{12} = n_2 \pi d^2 \bar{v}$

$$= n_2 \pi d^2 \sqrt{\frac{8kT}{\frac{\pi m_1 m_2}{m_1 + m_2}}} = n_2 \pi d^2 \sqrt{\frac{8kT}{\pi}} \times \left(\frac{1}{m_1} + \frac{1}{m_2} \right)^{\frac{1}{2}}$$

If all molecule will identical $d_1 = d_2 = d$, $m_1 = m_2 = m$ and $n_1 = n_2 = n$

$$f = n\pi d^2 \sqrt{\frac{2 \times 8kT}{m\pi}} = \sqrt{2}\pi n d^2 \bar{v} \Rightarrow \lambda = \frac{\bar{v}}{f} = \frac{\bar{v}}{\sqrt{2}\pi d^2 \bar{v}}$$

$$\lambda = \frac{1}{\sqrt{2}\pi n d^2} \Rightarrow \frac{1}{\sqrt{2} n \sigma} \text{ where } \sigma = \pi d^2$$