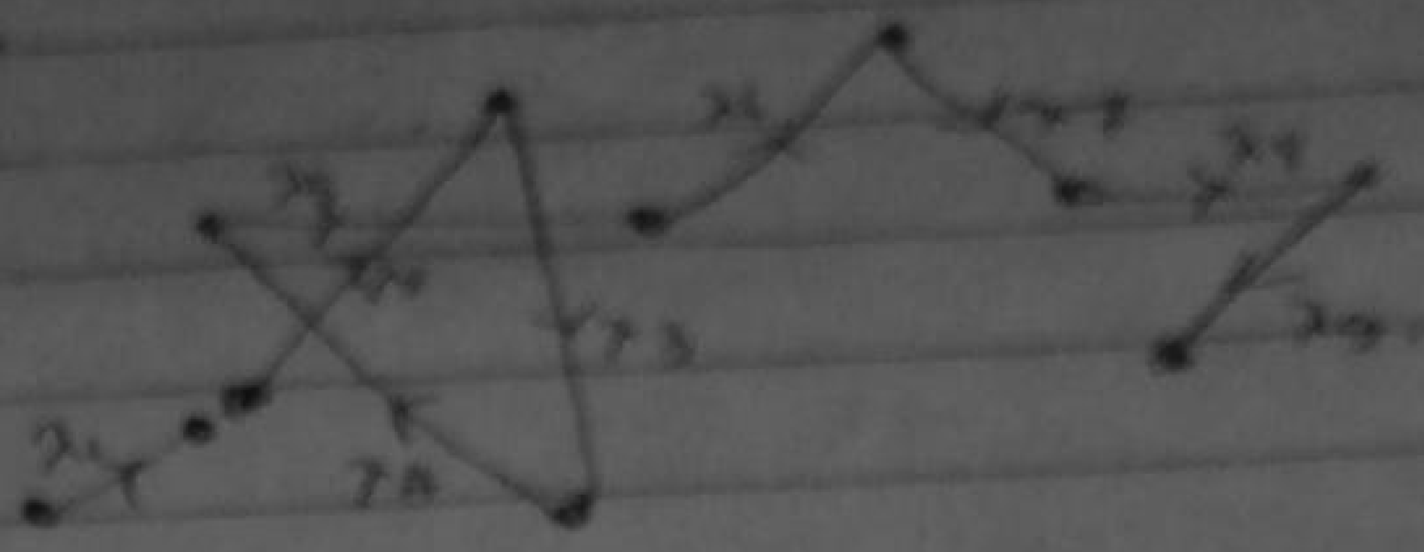
MEAN FREE PATH (λ) :-

The average distance travelled by a molecule between two successive collisons is known as the "mean free path". It is denoted by λ.



The average distance covered by a molecule between two successive collisions, viz mean free path is given by:

$$\lambda = \frac{\text{distance travelled by the molecule per unit time}}{\text{No. of collisions per unit time}}$$

or $$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_n}{n}$$

Where, n = total no. of collisions per unit time
and $\lambda_1 + \lambda_2 + \lambda_3 + \dots \lambda_n$ = total distance travelled by the molecule.

<u>Calculation of λ</u> $\rightarrow$

The value of λ is calculated from the following equation — $\lambda = \frac{C_{av}}{Z}$

or $\lambda = \frac{C_{av}}{\sqrt{2}\pi\sigma^2 C_{av} N}$ $\therefore$ $\lambda = \frac{1}{\sqrt{2}\pi\sigma^2 N}$. — (I)

$$\lambda = \frac{KT}{\sqrt{2} P \pi \sigma^2} \quad \text{— (II)}$$

Where, K = Boltzmann's const.
T = Absolute temp.
P = Pressure
σ = diameter of the molecule.
N = No. of molecules per unit volume
C_{av} = Average vel. of the molecule
and Z = collision frequency.

From the above equation it is evident that

(i) $\lambda \propto \frac{1}{P}$ i.e. mean free path decreases as pressure increases.

(ii) $\lambda \propto T$ i.e., mean free path increases as the temp. increases.

Mean free path has the dimension of length. It is clear that mean free path is independent of average vel. ($C_{av.}$) and time. So long as n remains constant. Thus, a knowledge of mean free path gives us an idea about the molecular diameter (σ).

Dependence of mean free path :-> The mean free path depends on the following factors —

size of the molecule -> Larger the molecular size, greater will be the no. of collisions. Hence shorter will be the mean free path.

Pressure of the gas -> Lower is the pressure of the gas, greater is the mean free path (λ).

Density of the gas :-> Higher the density of the gas, shorter is the λ.

Temperature of the gas -> Higher the temp. of the gas, greater is the λ.

Viscosity of the gas -> λ increases with increase in viscosity of the gas.

The λ in terms of viscosity coefficient (η) is given as

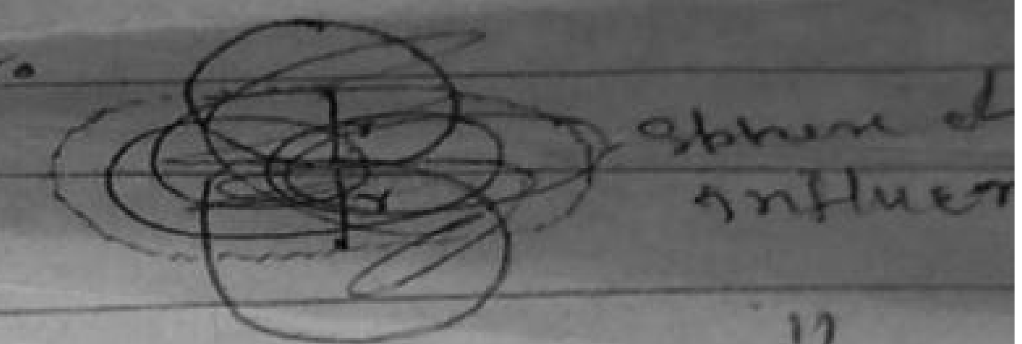
$$\lambda = \eta \sqrt{\frac{3}{P \times D}}$$

where, P = pressure of the gas,
D = density of the gas
and η = viscosity coefficient

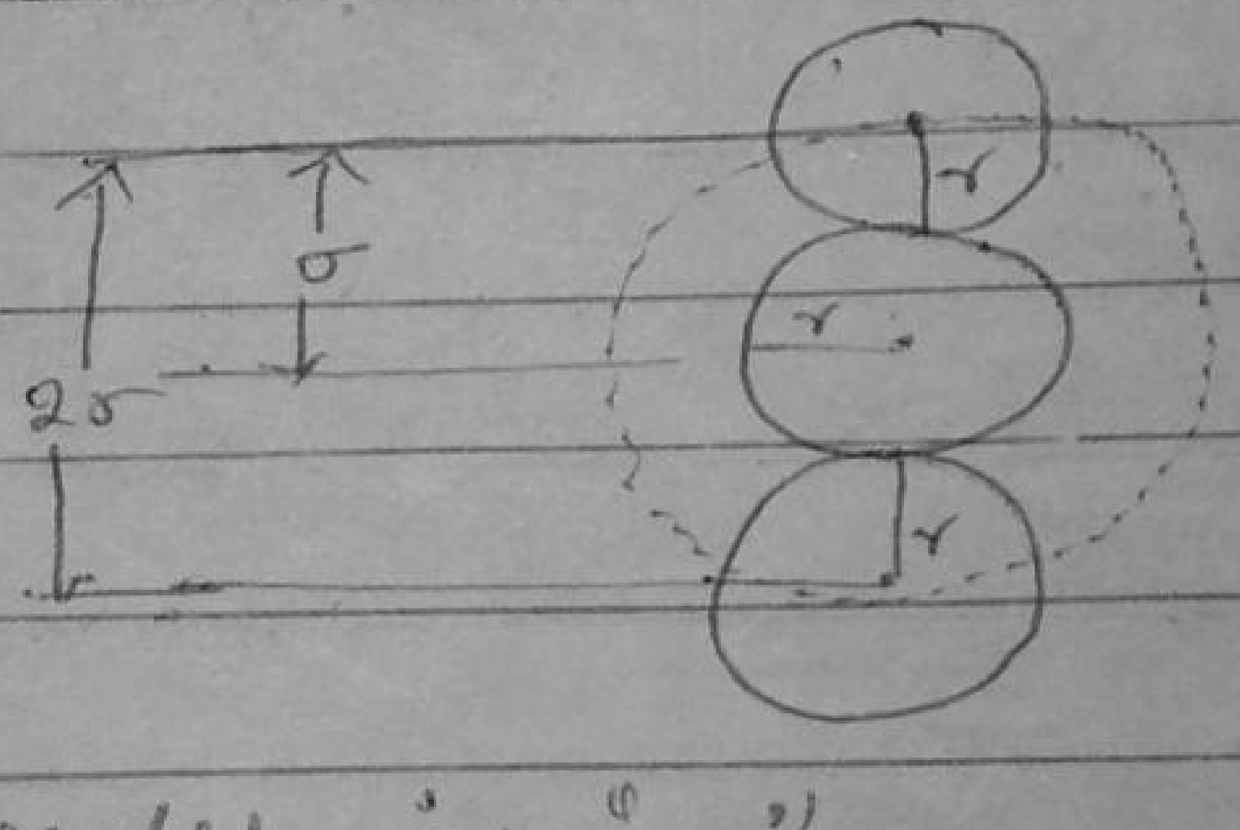
Molecular Diameter or collision diameter (σ) →.

When two molecules of a gas approach each other, there is a certain distance beyond which they can not come closer.

"The distance of closest approach between the centres of two molecule is known collision diameter (σ)".



A collision takes place whenever the distance between the centres of two molecules is "σ".



Note

from fig.:

Radius of sphere of influence (σ) = r + r = 2r.

The volume of sphere of influence (B)

$$= \frac{4}{3}\pi\sigma^3 = \frac{4}{3}\pi(2r)^3$$

$$= 8 \cdot \frac{4}{3}\pi r^3$$

$$\boxed{B = 8b_i}$$ where $b_i = \frac{4}{3}\pi r^3$

Collision Frequency or Collision Number

:→ The no. of collisions occuring per unit time per unit volume is called collision frequency.

The collision frequency (z) is given by

$$z = \frac{1}{2} \sqrt{2}\, \pi \sigma^2 C_{av}\, n^2$$ per unit time per unit volume.

since,

$$C_{av} = \sqrt{\frac{8KT}{\pi m}}$$

$$\therefore z = \frac{1}{\sqrt{2}} \pi \sigma^2 n^2 \cdot 2\sqrt{2} \sqrt{\frac{KT}{\pi m}}$$

$$\boxed{z = 2\sigma^2 n^2 \sqrt{\frac{\pi KT}{m}}}$$

where, σ = molecular diameter

C_{av} = Average velo. of the molecule

n = No. of molecules per unit volume

K = Boltzmann's const.

T = absolute temp.

and m = mass of the molecule