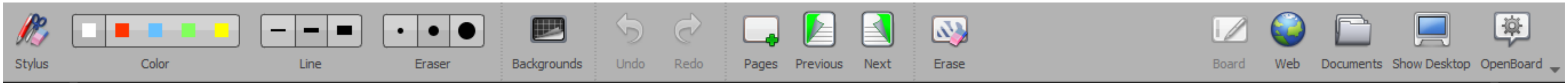
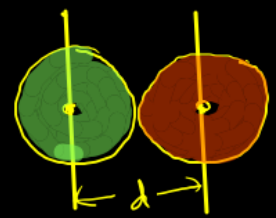
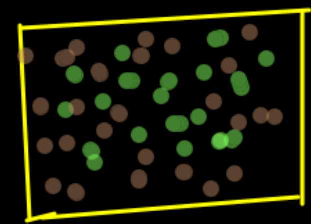
Semester-1 Chemistry Core -2

Unit-1 Gaseous State, Lecture-4 ,1. Collison Diameter, Collison frequency



① Collision Diameter ('d') collision Diameter is the distance (d) between the centres of two colliding molecules i.e the distance of closest approach.





② Collision Number (N_c) The no. of collision which the given molecule suffers with other molecules in 1 sec is called collision number.

$$N_c = \sqrt{2}\,\pi\, v\, \sigma^2\, n$$

where
σ = Molecular diameter
v = Average velocity of gas molecules
n = No. of molecules per cm^3

by Anil Kumar, Assistant Professor, Department of Chemistry, A.S. College, Deoghar using Open Board 1.4 Software

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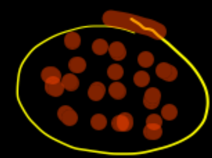
Q. What is collision frequency? Derive an expression for the collision frequency.

Z = collision frequency is no. of collisions which takes place in 1 second among all the molecules in 1 cm^3 of the gas.

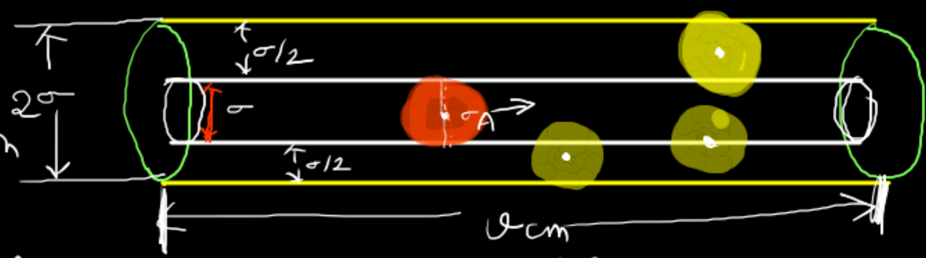


$$\boxed{Z = \frac{1}{\sqrt{2}} \pi \sigma^2 v n^2}$$

Let molecule A is moving with velocity v cm/sec in the direction shown.

In 1 sec molecule 'A' will collide with all the molecules whose centre lie within the cylinder of length v cm and the radius σ.

Volume of the cylinder = $\underline{\pi \sigma^2 v}$



time = 1 sec

2σ = diameter of cylinder

σ = molecular diameter

= radius of cylinder

=

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Let n = no. of molecules in 1 cm^3 of gas

Then the no. of molecules present in given volume of cylinder

$$= n \times \pi \sigma^2 v = \pi \sigma^2 v n \quad \text{— (1)}$$

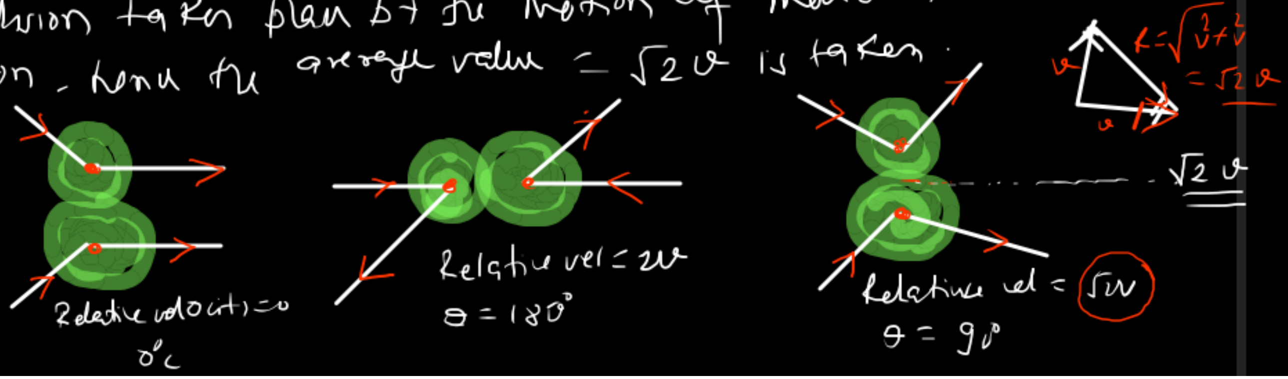
∴ No. of collisions made by molecule 'A' with others molecules in 1 sec

$$= \pi \sigma^2 v n \quad \text{— (2)}$$

Here, all the molecules are supposed to be at rest and only molecule 'A' is moving

Let v = average speed of molecule 'A'

Since collision taken place by the motion of molecules in all possible direction. Hence the average value $= \sqrt{2}\, v$ is taken.



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Hence average velocity of colliding molecules $= \sqrt{2}\,v$

Hence No. of collisions made by molecule A with other molecules/sec

$$= \sqrt{2}\,\pi \sigma^2 v n \quad \text{—(3)}$$

∴ collisions for all the molecules with each other in 1 sec

$$= n \times \sqrt{2}\,\pi \sigma^2 v n$$

$$= \sqrt{2}\,\pi \sigma^2 v n^2 \quad \text{—(4)}$$

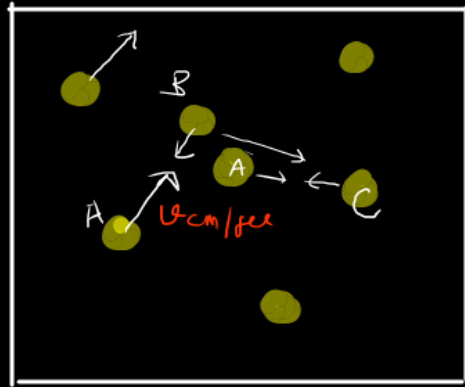
But each collision involves two molecules.

∴ collision frequency $= \dfrac{\cancel{\sqrt{2}}\,\pi \sigma^2 v n^2}{\cancel{2}\ \sqrt{2}}$

$$\therefore \quad \boxed{Z = \frac{1}{\sqrt{2}}\,\pi \sigma^2 v n^2}$$

Mean free Path (λ)

"The average distance travelled by a molecule between successive collisions is called mean free path."



Let, average velocity of the molecule = v cm/sec

∴ the molecule travels/covers a distance v cm in 1 sec.

In 1 sec molecule A covers a distance = v cm

Let the no. of collisions which a molecule undergoes in 1 sec = $N = \sqrt{2}\pi v \sigma^2 n$

∴ then the mean free path (λ) = $\frac{v}{N}$.

where σ = molecular diameter.

$$\therefore \lambda = \frac{\cancel{v}}{\sqrt{2}\pi \cancel{v} \sigma^2 n} = \frac{1}{\sqrt{2}\pi \sigma^2 n} \quad \text{—(1)}$$

Also from Ideal gas equation

$$PV = nRT$$
$$= n N_0 k T$$

$$\therefore P = \left(\frac{n N_0}{V}\right) kT$$
$$= \frac{N_A}{V} kT$$

$$P = \rho kT$$
$$\rho = \frac{P}{kT} \quad \text{—— (a)}$$

$$P \propto n$$

Mean free path =
$$\boxed{\lambda = \frac{1}{\sqrt{2}\pi\sigma^2 n} = \frac{1}{\sqrt{2}\pi\sigma^2 \frac{P}{kT}} = \frac{kT}{\sqrt{2}\pi\sigma^2 P}}$$

k = Boltzmann const $= \frac{R}{N_0}$

$R = N_0 k$

ρ = no. density = No. of molecules per unit volume

n = no. of mols

N_0 = Avogadro's No

N_A = Total no. molecules $= n N_0$

$\rho = \frac{\text{total no. of molecules}}{\text{volume}} = \frac{N_A}{V}$

ρ = Number density of molecules