

KINETIC THEORY OF A GASES

ASSUMPTIONS

- Size of gas molecules is negligible in comparison to intermolecular distance (10^{-9} m).
- Molecules of given gas are all identical; Spherical. and perfectly elastic point mass.
- Volume of Molecules is negligible in Comparison to the volume of the gas.
- Density of gas is Constant at all points of the. container.
- Molecules obey Newton Law's. of Motion, but as a Whole, their motion is isotropic, ie any molecule ⚡ Can move randomly in all possible directions with all possible velocities.
- ✓→ Time spent in a collision between two molecules is negligible in Comparison to time between successive collisions. The No of collision per unit volume in a gas remains constant.
- No attractive or repulsive force acts between gas. Molecules
- ✓→ Molecules constantly Collide with the walls of container due to which their momentum changes. The change in momentum is transferred. to the walls of the container due to which Pressure is exerted by gas molecules on the wall of the container.

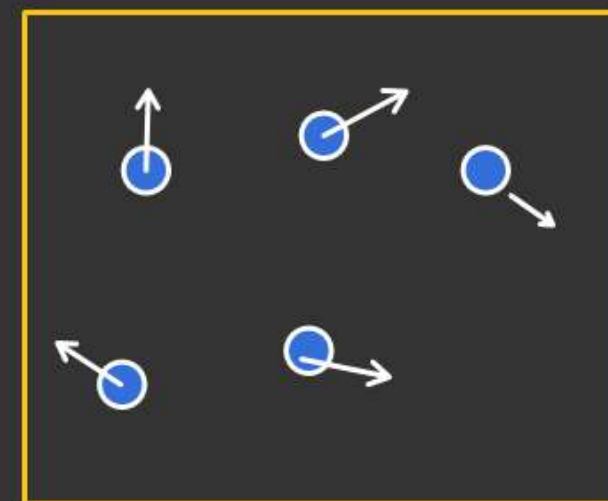
$$PV = \frac{1}{3}(Nm) v_{rms}^2$$

$$P = \frac{1}{3} \left(\frac{Nm}{V} \right) v_{rms}^2$$

$$N = (6.02 \times 10^{23})$$

m = mass of each molecule.

$$P = \frac{1}{3} \rho v_{rms}^2$$



$$\begin{array}{l} W \\ \Downarrow \\ \text{Weight} \\ \text{of gas} \end{array} \Leftarrow (nM) = \begin{array}{c} \text{Total no of} \\ \text{Molecules} \end{array} \times m$$

$$\cancel{n}M = \begin{array}{c} \Leftarrow \\ (\cancel{n} \cdot N) \end{array} \times m$$

$$M = mN$$



R.M.S Velocity

$$V_{rms} = \sqrt{\overline{V^2}}$$

$$= \sqrt{\frac{v_1^2 + v_2^2 + \dots + v_n^2}{n}}$$

$$P = \frac{1}{3} \rho v_{rms}^2$$

$$v_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3KT}{m}}$$

K.T.C

$$PV = \frac{m}{M} RT$$

$$P = \left(\frac{\rho RT}{M} \right)$$

$$\frac{P}{\rho} = \frac{RT}{M}$$

$$N_K = R$$

$$mN = M$$

$$\left(\frac{R}{M} = \frac{K}{m} \right)$$

$$v_{rms} \propto \sqrt{T}$$

$$\propto \frac{1}{\sqrt{M}}$$

If temp is constant.
then v_{rms} is independent of pressure

$$\left(\frac{P}{\rho} = c \right) \Rightarrow \text{if } T = \text{Constant}$$

Most probable Speed.

Speed which is possessed by maximum fraction of gas molecules.

Ex:-

1, 2, 2, (3, 3, 3), 4, 5, 6

$$V_{mp} = \underline{3 \text{ m/s.}}$$

$$V_{mp} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{3}}$$

Ex: Avg Speed

$$v_{avg} = \left(\frac{v_1 + v_2 + \dots + v_n}{n} \right)$$

$$v_{avg} = \sqrt{\frac{8P}{\pi \rho}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{\pi m}}$$

$$v_{rms} > v_{avg} > v_{mp}$$

$$v_{avg} = 0.92 v_{rms}$$

$$v_{mp} = 0.82 v_{rms}$$

K.T.G

• Avg. translational K.E = $\frac{1}{2} m \underline{v_{rms}^2}$ (m = mass of each molecule)

• Avg translational K.E per molecule = $\frac{1}{2} m \left(\frac{3KT}{m} \right) = \frac{3}{2} KT$

• Avg translational K.E per mole = $\frac{1}{2} M \left(\frac{3RT}{M} \right) = \frac{3}{2} RT$

• Avg translational K.E for n mole = $\frac{3}{2} nRT$

• Avg translational K.E per unit volume = $\frac{1}{2} \rho v_{rms}^2$
 $= \frac{1}{2} \rho \left(\frac{3P}{\rho} \right)$
 $= \frac{3}{2} P$

(*) Avg translational K.E for V Volume

$= \frac{3}{2} PV$

Mean free path

$$\lambda = \left(\frac{\text{Total distance travelled by gas molecule b/w two successive collision}}{\text{Total no of collision}} \right)$$

$$\lambda = \frac{1}{\sqrt{2} \pi d^2 n}$$

d = diameter of gas molecules

n = no of molecules per unit volume

$$\lambda \propto T$$

$$\lambda \propto \frac{1}{d^2}$$

$$\lambda \propto \frac{1}{P}$$

$$PV = NKT$$

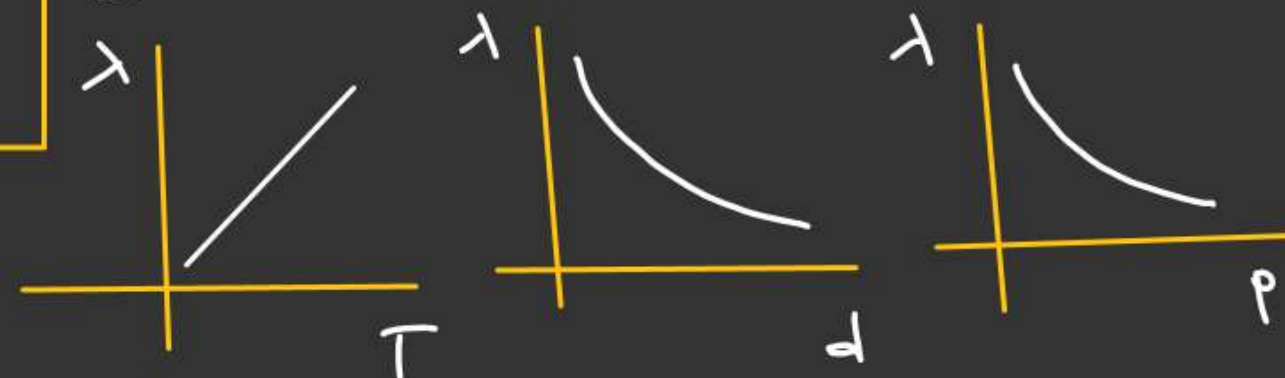
$$P = \left(\frac{N}{V} \right) KT$$

$$\Downarrow$$

$$\approx$$

$$\frac{P}{KT} = \approx$$

$$\lambda = \frac{1}{\sqrt{2} \pi d^2 \left(\frac{KT}{P} \right)}$$



Q.1: Collision frequency

$$f = \pi d^2 v_{avg} n$$

Q.2

$$\underline{\text{Mean free time}} = \frac{1}{f} = \frac{1}{\pi d^2 v_{avg} n}$$

Q.2Law of Equipartition of Energy

It states that Energy possessed by gas
per molecule per degree of freedom is $\frac{1}{2}kT$
or per mole per degree of freedom is $\frac{1}{2}RT$
irrespective of type of degree of freedom.

$$U = \frac{1}{2}kT \quad \begin{array}{l} \text{per molecule} \\ \text{per degree of freedom} \end{array}$$

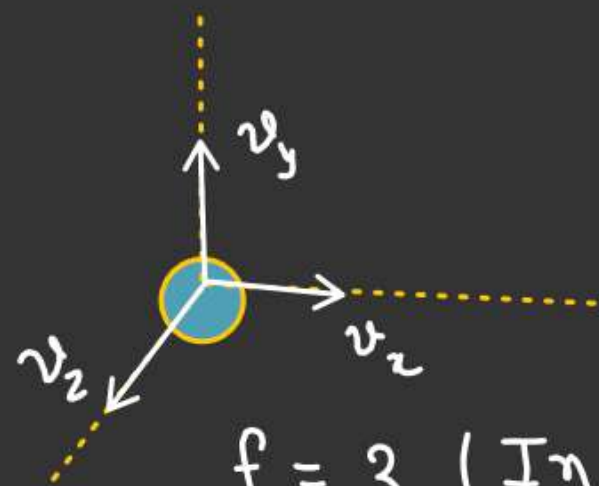
$$U = \frac{f}{2}kT \quad f = \text{degree of freedom}$$

$$U_T = \frac{f}{2}RT \times n$$

K.T.G

Degree of freedom :- [Possible no of motion a gas molecule can have]

Mono atomic



$$\frac{1}{2} m v_x^2 = \frac{1}{2} m v_y^2 = \frac{1}{2} m v_z^2 = \frac{1}{2} kT \quad \checkmark$$

$f = 3$ (In the form of translational K.E)

$$U = \frac{3}{2} RT \quad (\text{Per mole})$$

$$U = \frac{3}{2} nRT \quad (\text{for } n \text{ mole})$$

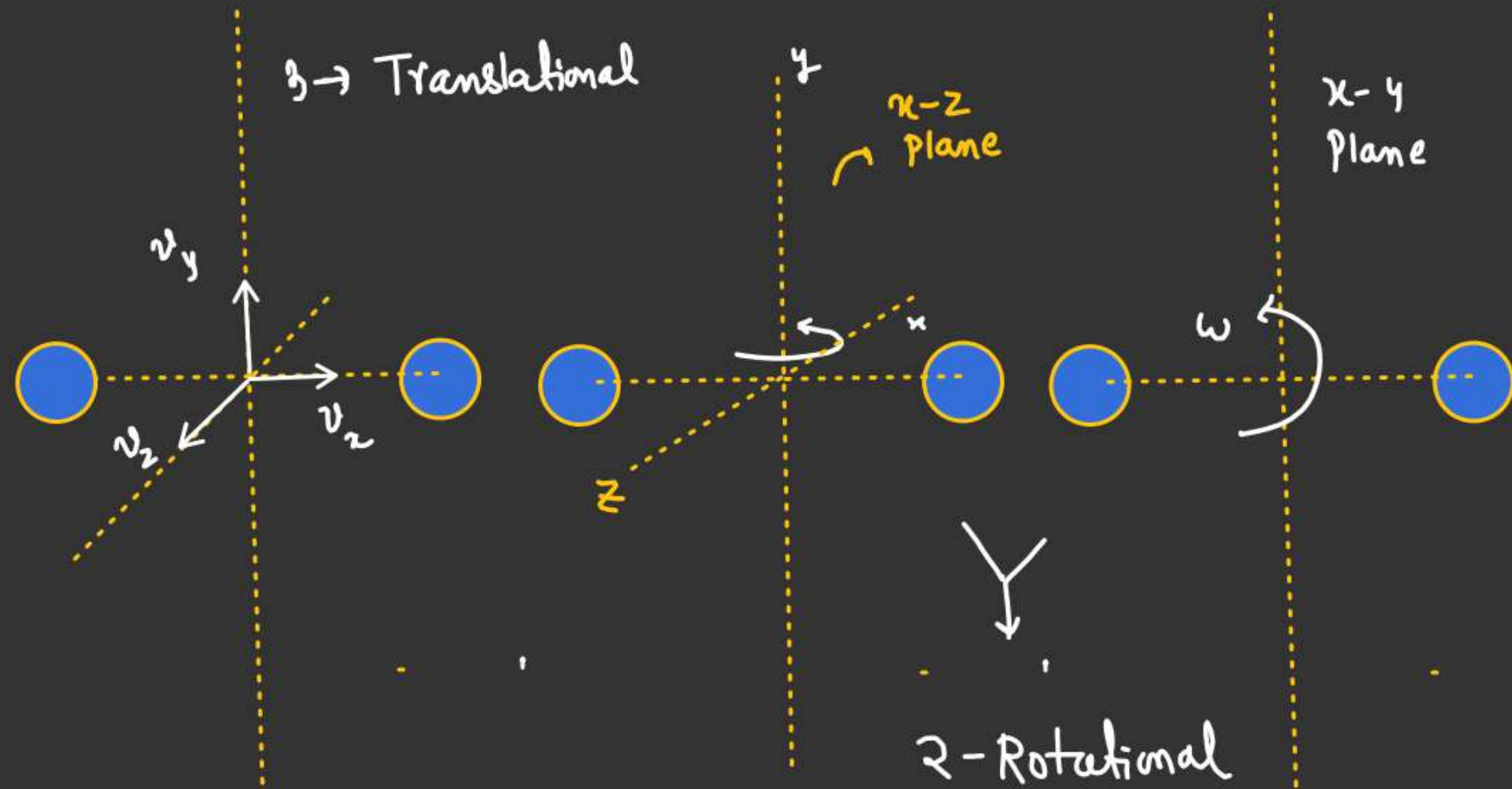
$$C_v = \frac{1}{n} \frac{dU}{dT} = \frac{3}{2} R$$

$$C_v = \frac{1}{n} \frac{dU}{dT}$$

$$C_v = \frac{3}{2} R$$

$$C_p = C_v + R = \frac{5}{2} R$$

$$\gamma = \frac{C_p}{C_v} = \frac{5}{3}$$

Diatomic

At Normal temp.

$$f_{\text{dia}} = 5$$

$$U = \frac{5}{2} nRT$$

$$\frac{1}{n} \frac{dU}{dT} = \frac{5}{2} R$$

$$C_v = \frac{5}{2} R$$

$$C_p = \frac{7}{2} R$$

$$\gamma = \frac{7}{5}$$

At higher temperature

Molecules oscillates about their mean position

So,

$$f_{\text{dia}} = 3 + 2 + 2$$

↓ ↘ ↘
translational Rotational Vibrational

$$f_{\text{dia}} = 7$$

$$U_T = \frac{7}{2} nRT$$

$$\frac{1}{n} \frac{dU_i}{dT} = \frac{7}{2} R$$

$$C_V = \frac{7}{2} R, C_P = \frac{9}{2} R \quad \gamma = 9/7$$

K.T.G $(C_p)_{\text{mix}}, (C_v)_{\text{mix}}, (\gamma)_{\text{mix}}$ ΔT is in temp if ΔQ amount given to the container.

$$\Delta Q = \Delta U + \cancel{\Delta W}^0$$

↓

Insulated n_1 (Mono) n_2 (Dia) ΔQ 

$$\frac{C_p}{C_v} = \gamma$$

$$C_p - C_v = R$$

$$C_p = \frac{R\gamma}{\gamma-1}$$

$$C_v = \frac{R}{\gamma-1}$$

$$(n_1 + n_2)(C_v)_{\text{mix}} \Delta T = n_1(C_v)_{\text{mono}} \Delta T + n_2(C_v)_{\text{dia}} \Delta T$$

$$(C_v)_{\text{mix}} = \frac{n_1(C_v)_{\text{mono}} + n_2(C_v)_{\text{dia}}}{n_1 + n_2} = \left[\frac{\frac{n_1 R}{\gamma_{\text{mono}} - 1} + \frac{n_2 R}{(\gamma_{\text{dia}} - 1)}}{n_1 + n_2} \right]$$

$$(C_p)_{\text{mix}} = \frac{n_1(C_p)_{\text{mono}} + n_2(C_p)_{\text{dia}}}{n_1 + n_2} = \left[\frac{\frac{n_1 R \gamma_{\text{mono}}}{\gamma_{\text{mono}} - 1} + \frac{n_2 R \gamma_{\text{dia}}}{\gamma_{\text{dia}} - 1}}{n_1 + n_2} \right]$$

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$$\gamma_{\text{mix}} = \frac{(C_p)_{\text{mix}}}{(C_v)_{\text{mix}}} = \frac{n_1 (C_p)_{\text{mono}} + n_2 (C_p)_{\text{dia}}}{n_1 (C_v)_{\text{mono}} + n_2 (C_v)_{\text{dia}}}$$

Case of dissociation

$K\%$ of moles of diatomic dissociated.

$$(C_v)_{\text{mix}} = \frac{\left(\frac{K}{100} \times n\right) \times 2 (C_v)_{\text{mono}} + n \left(1 - \frac{K}{100}\right) (C_v)_{\text{dia}}}{\left(n + \frac{nK}{100}\right)}$$

Moles of Mono $\leftarrow n_1 = \left(\frac{K}{100} \times n\right) \times 2$

$(C_p)_{\text{mix}} = \checkmark$

Moles of diatomic $n_2 = \left(n - \frac{K}{100} \times n\right)$
 $= n \left(1 - \frac{K}{100}\right)$

$\gamma_{\text{mix}} = \checkmark$

Total no of Moles after dissociation $= \left(n + \frac{nK}{100}\right)$