

## 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.

K.T.G

$$\rho V = \frac{1}{3} (N m) v_{rms}^2$$

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

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

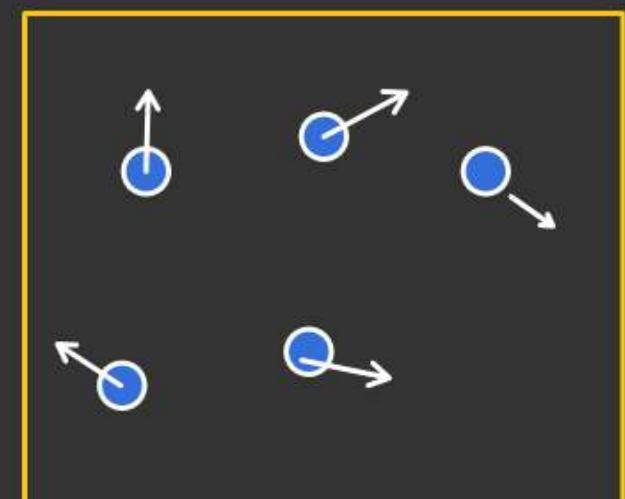
$m$  = mass of each molecule.

$$W \leftarrow (n M) = \text{(Total no of Molecules)} \times m$$

$$\downarrow \\ \text{Weight of gas} \quad \cancel{M} = \cancel{(N \cdot m)} \times m$$

$$M = m N$$

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





## R.M.S Velocity

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

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

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

$$NK = R$$

$$mN = M$$

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

## K.T.G

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

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

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

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

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

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

$$\left[ \frac{P}{\rho} = c \right] \Rightarrow \text{if } T = \text{constant}$$

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

Most probable Speed.

Speed which is possessed by maximum fraction of gas molecules.

Ex:-

1, 2, 2, 3, 3, 3, 4, 5, 6

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

$$V_{mp} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2kT}{m}}$$

Avg Speed

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

$$V_{avg} = \sqrt{\frac{8P}{\pi M}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8kT}{\pi m}}$$

$$V_{rms} > V_{avg} > V_{mp}$$

$$V_{avg} = 0.92 V_{rms}$$

$$V_{mp} = 0.82 V_{rms}$$

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

(\*) Avg translational K.E for  $V$  Volume

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

Mean free path

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

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

$d$  = diameter of gas molecules

$n$  = no of molecules per Unit Volume

$$\begin{aligned} \lambda &\propto T \\ \lambda &\propto \frac{1}{d^2} \\ \lambda &\propto \frac{1}{P} \end{aligned}$$

$$PV = NKT$$

$$P = \frac{(N/V)KT}{n}$$

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

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



Collision frequency

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

Mean free time

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

Ans:Law of Equibpartition of Energy

It State 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.

$$U = \frac{1}{2}KT \quad \begin{matrix} \text{per molecule} \\ \text{per degree of freedom} \end{matrix}$$

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

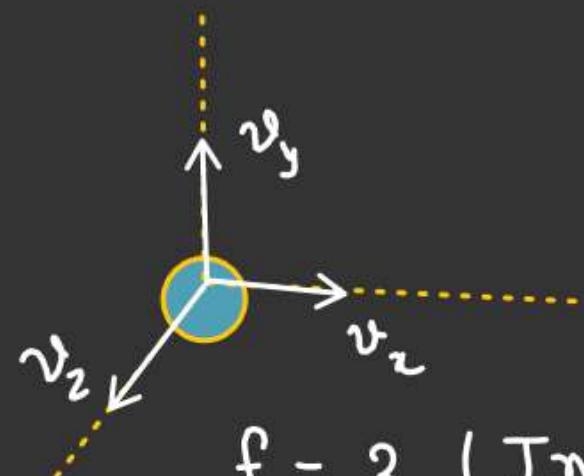
$$\frac{U}{T} = \frac{f}{2}RT \times n$$

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

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

### Mono atomic

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



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

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

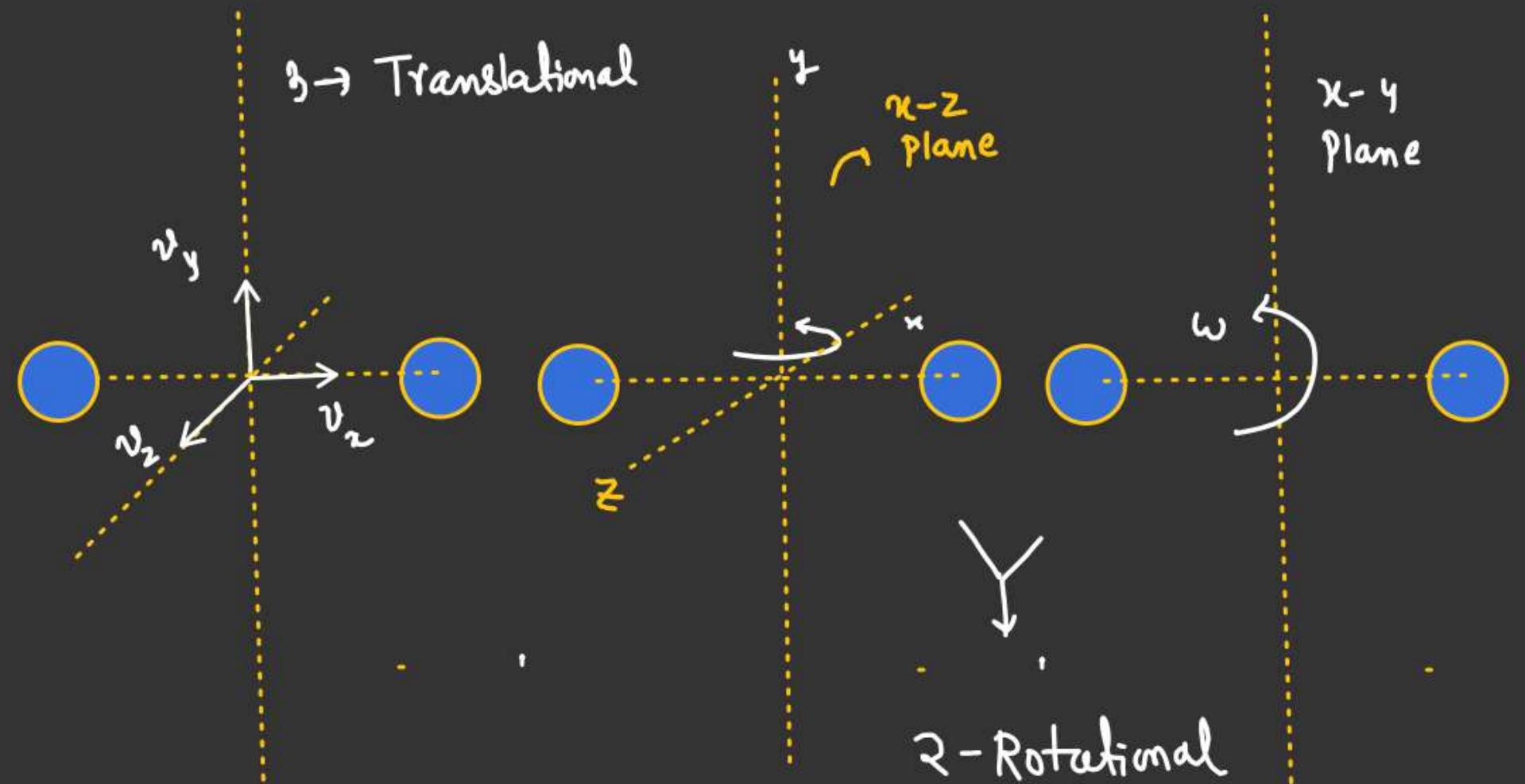
$$U = \frac{3}{2}nRT \text{ (for n mole)}$$

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

$$C_P = C_V + R = \frac{5}{2}R$$

$$\gamma = \frac{C_P}{C_V} = \frac{5}{3}$$

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

Diatom

At Normal  
temp.

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

$$U = \frac{5}{2} n R T$$

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

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

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

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

At higher temperature

Molecules oscillates about their mean position

So,

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

+ translational      Rotational      Vibrational

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

$$U_T = \frac{7}{2} n R T$$

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

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

K.T.G $(C_p)_{mix}, (C_v)_{mix}, (\gamma_{mix})$ 

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

$$C_p - C_v = R$$

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

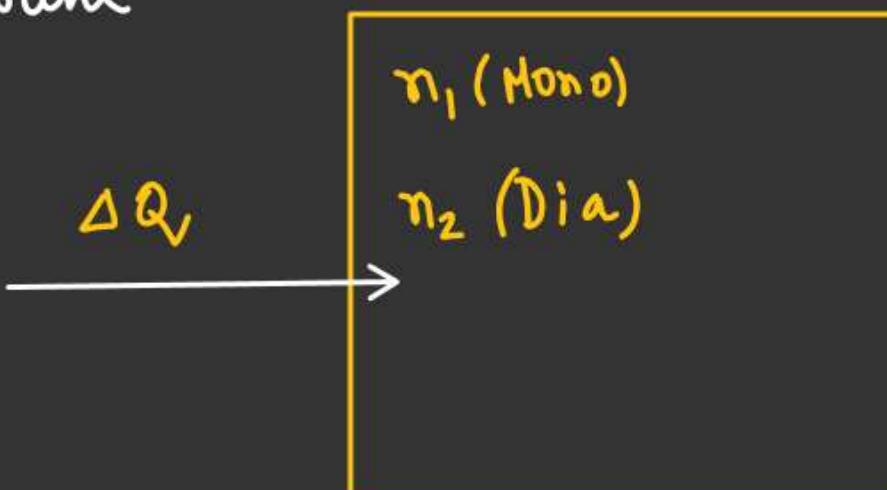
$$C_v = \frac{R}{\gamma-1}$$

$\Delta T$  rise in temp if  $\Delta Q$  amount given to the container.

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

↓

Insulated  
↓



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

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

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

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

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

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

## Case of dissociation

n - Moles  
of dia.

dissociation  
→

Mono ( $n_1$ )  
+  
Dia ( $n_2$ )  
↓

K% of moles of diatomic  
dissociated.

$$\text{Moles of Mono} \leftarrow n_1 = \frac{K}{100} \times n \times 2$$

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

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

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

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

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