

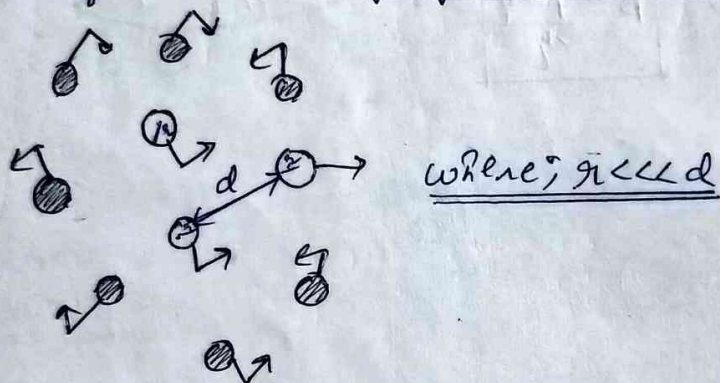
## - KINETIC THEORY OF GASES -

(i) Gases are made up of tiny particles consisting of molecules, atoms or even ions!

> KTG: a model of molecular behaviour which confirms the observed behaviour of an ideal gas

### > ASSUMPTIONS OF KTG:-

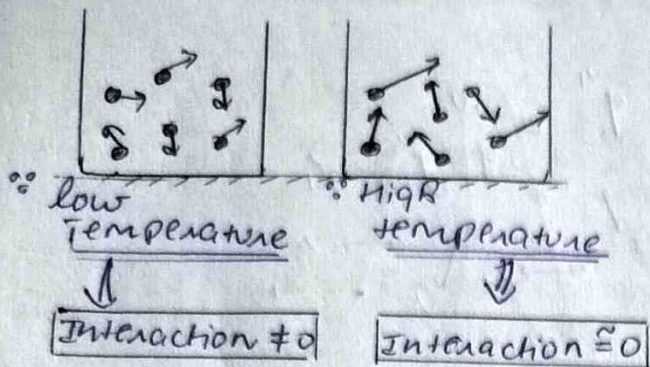
- (i) There are very large no. of molecules  
(ii) Volume of mol. is negligible as compared with vol. of gas.



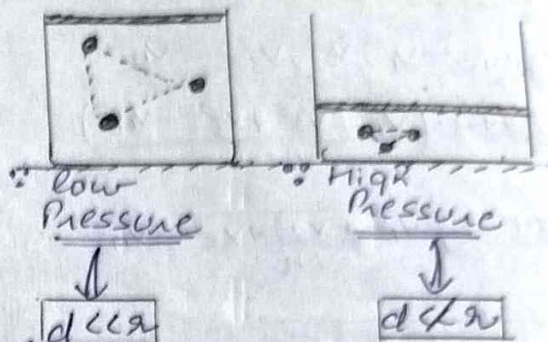
- (iii) All mol. are identical, perfectly elastic & hard sphere.  
(iv) Molecules move in all directions randomly.  
"equally likely motion along x, y, z axis"  
(v) mol. do not exert force on one another or walls of container.  
(vi) The collisions b/w molecules or with wall are perfectly elastic.  
(vii) Mol. obey Newton's law of motion.  
(viii) There is absolute uniformity in all properties of gas throughout container.



(I)



(II)



"FOLLOWS RTA ASSUMPTIONS"

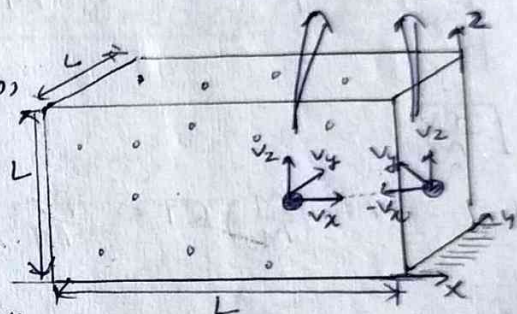
> PRESSURE OF IDEAL GAS:-

"Pressure exerted by Gas is due to collisions of Gas molecules on walls of container!"

$$\Delta p = (-mv_x) - (mv_x) \\ \Rightarrow -2mv_x$$

$$F = \frac{dp}{dt} = \frac{|\Delta p|}{\Delta t} = \frac{2mv_x}{2L/v_x} \Rightarrow \frac{mv_x^2}{L}$$

Before Collision      After Collision



"change in momentum in y and z-axis is 0"

$$\boxed{F = \frac{mv_x^2}{L}} \Rightarrow F_{net} = \frac{\sum mv_x^2}{L} = \frac{M}{L} \sum v_x^2 \Rightarrow \boxed{F_{net} = \frac{M}{L} \sum v_x^2}$$

"due to randomness of molecules,  $v_x^2 = v_y^2 = v_z^2 = \frac{1}{3} v_{net}^2$ "

Hence:

$$\boxed{F_{net} = \frac{1}{3} \frac{M}{L} \sum v^2}$$

$$F_{net} = \frac{1}{3} \frac{MN}{L} \left( \frac{\sum v^2}{N} \right)$$

$$\Rightarrow \text{Pressure} = \frac{F}{A} = \frac{F}{L^2} = \frac{1}{3} \left( \frac{MN}{L^3} \right) \frac{\sum v^2}{N}$$

$$\Rightarrow \frac{1}{3} \rho \frac{\sum v^2}{N} \text{ where } \rho = \frac{\text{Mass}}{\text{vol}} = \frac{MN}{L^3}$$

$$\text{Hence: } \boxed{P = \frac{1}{3} \rho \left( \frac{\sum v^2}{N} \right)} \rightarrow \text{mean square speed!}$$

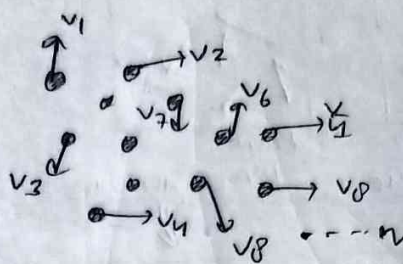


## > ROUTE MEAN SQUARE SPEED :-

> Square:  $v_1^2, v_2^2, v_3^2 \dots v_n^2$

> Mean:  $\left( \frac{v_1^2 + v_2^2 + v_3^2 \dots v_n^2}{n} \right)$

> Root:  $\sqrt{\frac{v_1^2 + v_2^2 + v_3^2 \dots v_n^2}{n}}$



$$V_{rms} = \sqrt{\frac{\sum_{i=1}^n v_i^2}{n}}$$

Also,

$$V_{rms} = \left[ \frac{\int v^2 dN}{\int dN} \right]^{1/2} \text{ or } \left( \frac{N_1 v_1^2 + N_2 v_2^2 \dots}{N_1 + N_2 \dots} \right)^{1/2} \text{ or } \sqrt{\frac{3PV}{M}}$$

NOW,

$$V_{rms} = \sqrt{\frac{3PV}{M}}$$

$$PV = nRT \Rightarrow PV = \left( \frac{M}{M_0} \right) RT \Rightarrow \frac{PV}{M} = \frac{RT}{M_0} \text{ where } M_0 \text{ is molar mass of gas!}$$

$$V_{rms} = \sqrt{\frac{3RT}{M_0}}$$

$$V_{rms} \propto \sqrt{T} \text{ where } 3, R, M_0 \text{ are constants}$$

> TEMP. of Gas is a measure of Avg. K-E of its molecules!  
or kinetic interpretation of TEMP.

## > KINETIC ENERGY OF IDEAL GAS :-

$$K_1^0 = \frac{1}{2} m v_1^2 \quad \text{--- (1)}$$

$$> K_{total} = \sum K_1^0 = \sum \left( \frac{1}{2} m v_1^2 \right) = \frac{m}{2} \sum v_1^2$$

$$\text{Also, } V_{rms} = \sqrt{\frac{\sum v_1^2}{N}} \Rightarrow \sum v_1^2 = N V_{rms}^2 \quad \text{--- (2)}$$

$$K = \frac{m}{2} (N V_{rms}^2)$$

$$K = \frac{1}{2} M N V_{rms}^2$$

$$K = \frac{1}{2} M_{gas} V_{rms}^2$$

$$\text{Also, } V_{rms} = \sqrt{\frac{3PV}{M}}$$

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





## TRANSLATIONAL KINETIC ENERGY OF 1 MOL:

$$E = \frac{K}{N} = \frac{K}{n N_A} = \frac{\frac{3}{2} n R T}{n N_A} = \frac{3}{2} \left( \frac{R}{N_A} \right) T$$

$\downarrow$   $\downarrow$   $\downarrow$   
 K.E of one mol. total molecules total moles

$$\boxed{E = \frac{3}{2} K T}$$

Where K is Boltzmann Constant  
 $K = 1.388 \times 10^{-23} \text{ J/K}$

∴ This means that Mol. can have speed less than  $v_{rms}$  or greater than  $v_{rms}$

### > MAXWELL EQ:-

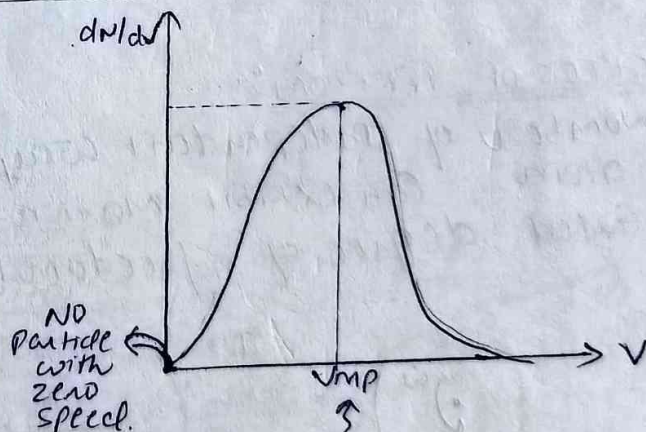
Maxwell derived an eq. giving distribution of Mol. in diff. speeds

∴ If  $dN \rightarrow$  No. of molecules with speed b/w  $v$  and  $v+dv$  then;

$$\boxed{dN = 4\pi N \left( \frac{m}{2\pi kT} \right)^{3/2} v^2 e^{-mv^2/2kT} dv}$$

$$\boxed{v_{mp} = \sqrt{\frac{2KT}{m}} = \sqrt{\frac{2RT}{M_0}}}$$

$\uparrow$   $\uparrow$   
 mass of molecule molar mass



The speed at which  $dN/dv$  is Max. is called Most Probable speed.

### ∴ Area under Curve:

$$\text{Area} = \int y dx = \int \left( \frac{dN}{dv} \right) dv = \int dN = N$$

∴ Area under Curve gives No. of molecules.

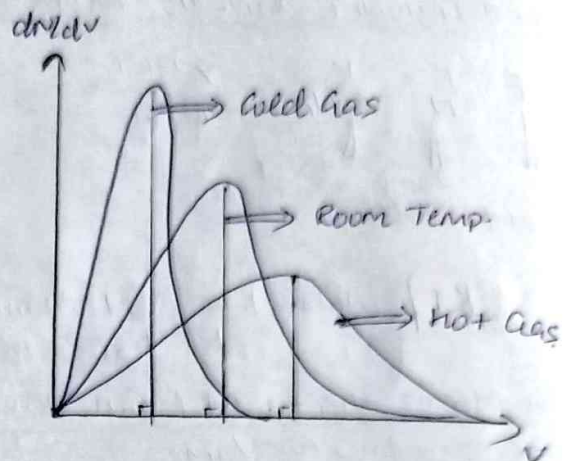


### > Features of Graph:-

(iii), At higher Temp. Mol. have more Energy & Curve is broader

(ii), At lower Temp, Mol. have less energies Curve is narrow & sharp

∴ Area under each Curve is to total No. of Mol. Hence it remains same.



### > According to Maxwell distribution:-

$$V_{avg} = \sqrt{\frac{3RT}{\pi M}} = \sqrt{\frac{3KT}{\pi M}} = 0.92 V_{rms}$$

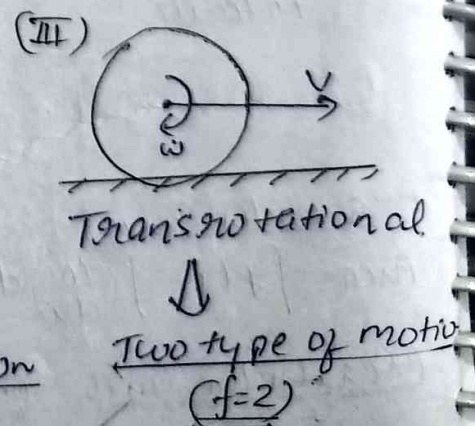
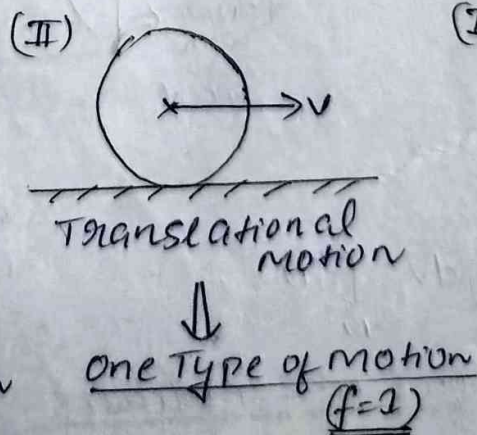
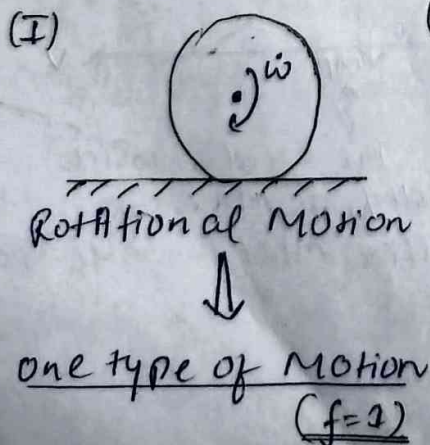
$$V_{avg} = 0.92 V_{rms}$$

Hence:

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

### > DEGREES OF FREEDOM:-

The Number of Independent ways in which a mol. or atom can exhibit motion or have energy is called degree of freedom!





> Such Independent possible motions:-

- (i) Translational
  - (ii) Rotational
  - (iii) Vibrational
- } so, there are three types of degree of freedom!

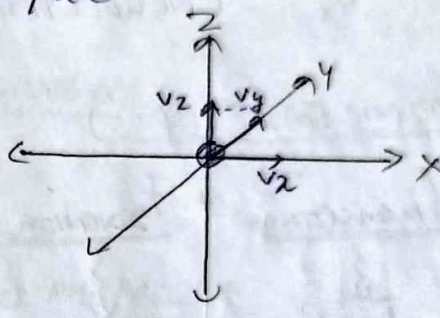
> TRANSLATION DEGREE OF FREEDOM:-

The Max. No. of Translational degree of freedom can be three. so;

$$[f=3]$$

> Corresponding energy

$$\frac{1}{2}mv_x^2, \frac{1}{2}mv_y^2, \frac{1}{2}mv_z^2$$

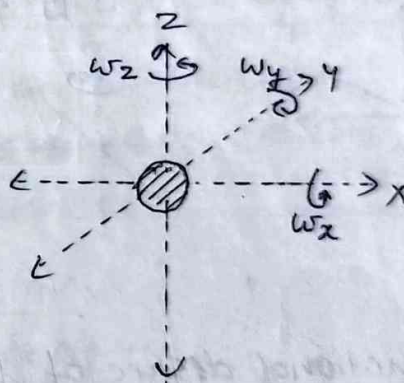


> ROTATIONAL DEGREE OF FREEDOM:-

Max. No. of rotational degree of freedom can be three;

$$\frac{1}{2}I\omega_x^2, \frac{1}{2}I\omega_y^2, \frac{1}{2}I\omega_z^2 \text{ are}$$

Corresponding energy!



> VIBRATIONAL DEGREE OF FREEDOM:-

Their number depend on atoms in molecule and their arrangement.

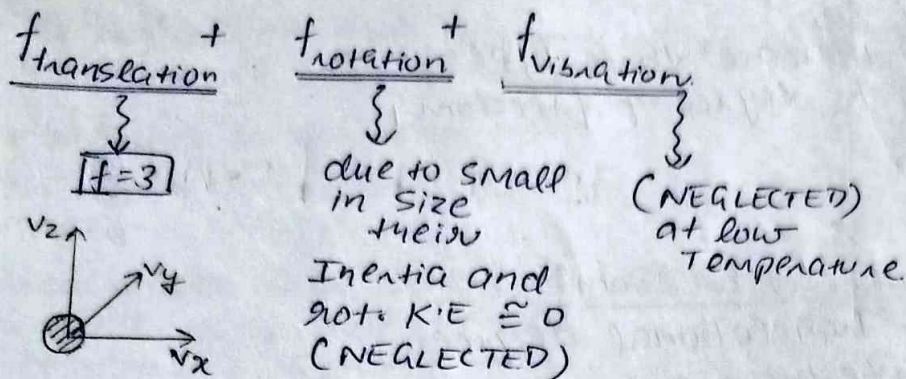
These degrees of freedom are considered at high temp. only.

At Room Temp. only translational and rotational degree of freedom are taken.

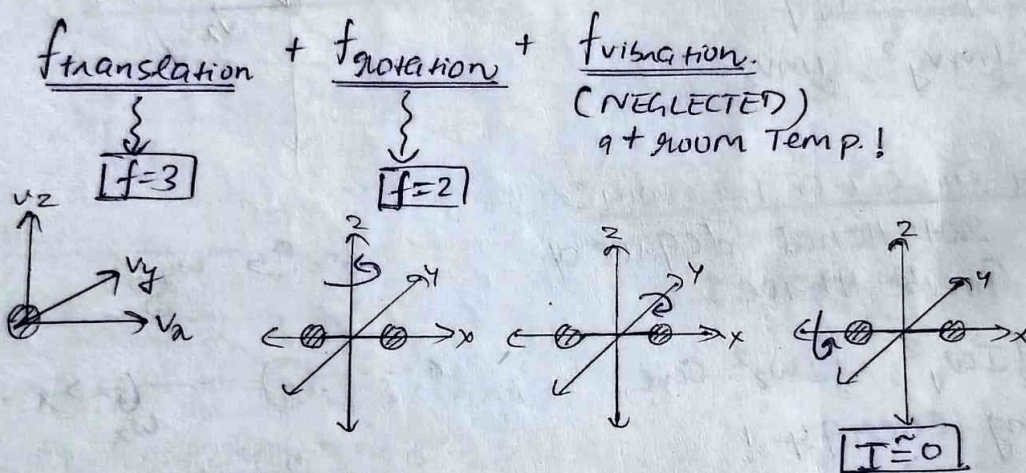




## > MONOATOMIC GAS: ( $f=3$ )



## > DIATOMIC GAS: ( $f=5$ )



### NOTE:-

If vibrational degree of freedom are taken into Account. at very high Temp.

$f_{\text{vibration}} = 2$  in diatomic molecule

→ KINETIC ( $\frac{1}{2} \mu v^2$ );  $\mu$  is reduced mass!

CORRESPONDING ENERGY

→ POTENTIAL ( $\frac{1}{2} k x^2$ );  $k$  is force constant.

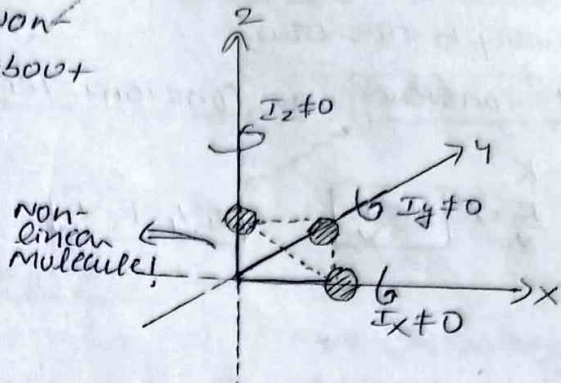


## > TRIATOMIC & POLYATOMIC:-

∴ A non-linear mol. has non-zero moment of inertia about any axis.

$$\underbrace{f_{\text{translation}}}_{[3]} + \underbrace{f_{\text{rotation}}}_{[3]}$$

$$[f=6]$$



∴ due to Complexity vibration is not studied.

## > LAW OF EQUIPARTITION OF ENERGY:-

The Total energy of an ideal Gas molecule is distributed equally among all of its degree of freedom

Avg. E of Mol. in a Gas associated with each degree of freedom is  $\boxed{\frac{1}{2}KT}$  ∴ K is Boltzmann's Constant.  
∴ T is Absolute Temperature

$$\left. \begin{aligned} > \frac{1}{2}KT \rightarrow \text{for molecule / degree of freedom} \\ > \frac{1}{2}RT \rightarrow \text{for mole / degree of freedom} \end{aligned} \right\}$$

## > INTERNAL E OF A GAS:-

$$U = \underbrace{\frac{f}{2}}_{\text{degree of freedom.}} \underbrace{n}_{\text{no. of moles}} \underbrace{RT}_{\text{Absolute Temp. of Gas.}}$$

> Also,  $\boxed{kN_A = R}$  ∴

$$\boxed{U = \frac{f}{2} n (kN_A) T}$$



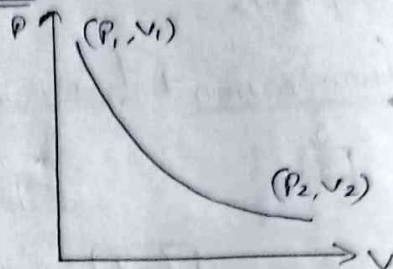
## > BOYLE'S LAW:-

According to this law;

$PV = \text{Constant}$  at Constant Temperature

$$PV = K$$

$$P = \frac{K}{V} \Rightarrow \boxed{P \propto \frac{1}{V}} \quad \boxed{P_1 V_1 = P_2 V_2}$$

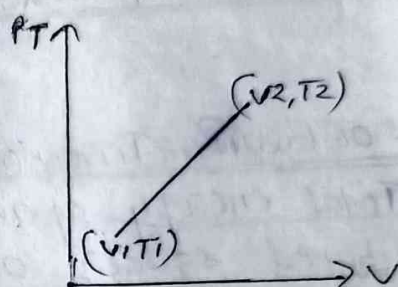


## > CHARLES LAW:-

$V \propto T$  at Constant Pressure

$$V = KT \Rightarrow \frac{V}{T} = \text{Constant}$$

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

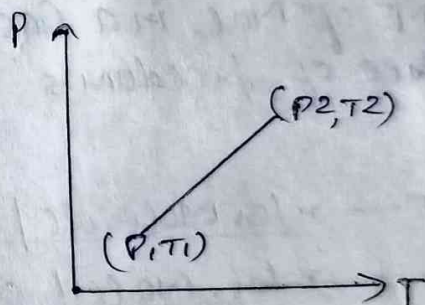


## > GAY-LESSAC'S LAW:-

$P \propto T$  at Constant Volume

$$P = KT \Rightarrow \frac{P}{T} = \text{Constant}$$

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$



## > AVOGADRO LAW:-

Equal vol. of all Gases under same conditions of Temp. and Pressure contain equal number of molecules.

At same Pressure equal volumes  $V$  of diff Gases containing  $N_1, N_2$  molecules of Mass  $M_1, M_2$

$$PV = \frac{N_1 M_1 V_{rms}^2}{3} \quad \text{--- (1)}$$

$$PV = \frac{N_2 M_2 V_{rms}^2}{3} \quad \text{--- (2)}$$

$\therefore$  from eq (1) and (2) :-

$$M_1 N_1 V_{rms}^2 = M_2 N_2 V_{rms}^2$$



At Same Temp. their Avg. K.E of translation is equal.

$$\text{So, } \frac{1}{2} m_1 v_{1rms}^2 = \frac{1}{2} m_2 v_{2rms}^2$$

> from eq 3 and 4 :-

$$\boxed{N_1 = N_2}$$

> DALTON'S LAW OF PARTIAL PRESSURE :-

The total pressure exerted by a No. of Non-reacting Gases when taken together in a container is equal to sum of their Partial Pressure

$$\boxed{P_1 + P_2 + P_3 \dots P_n = P}$$

> MEAN FREE PATH :-

Avg. distance travelled by mol. b/w two successive collisions

$$l = l_1 + l_2 + l_3 \dots l_4$$

By experiments;

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

where;

$d \rightarrow$  diameter of molecule

$n \rightarrow$  No. of mol. / unit volume

$$\star \boxed{l \propto \frac{1}{\sqrt{n}}}$$

