VISUAL PHYSICS

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SHORT NOTES

CHAPTER

Kinetic Theory of Gases

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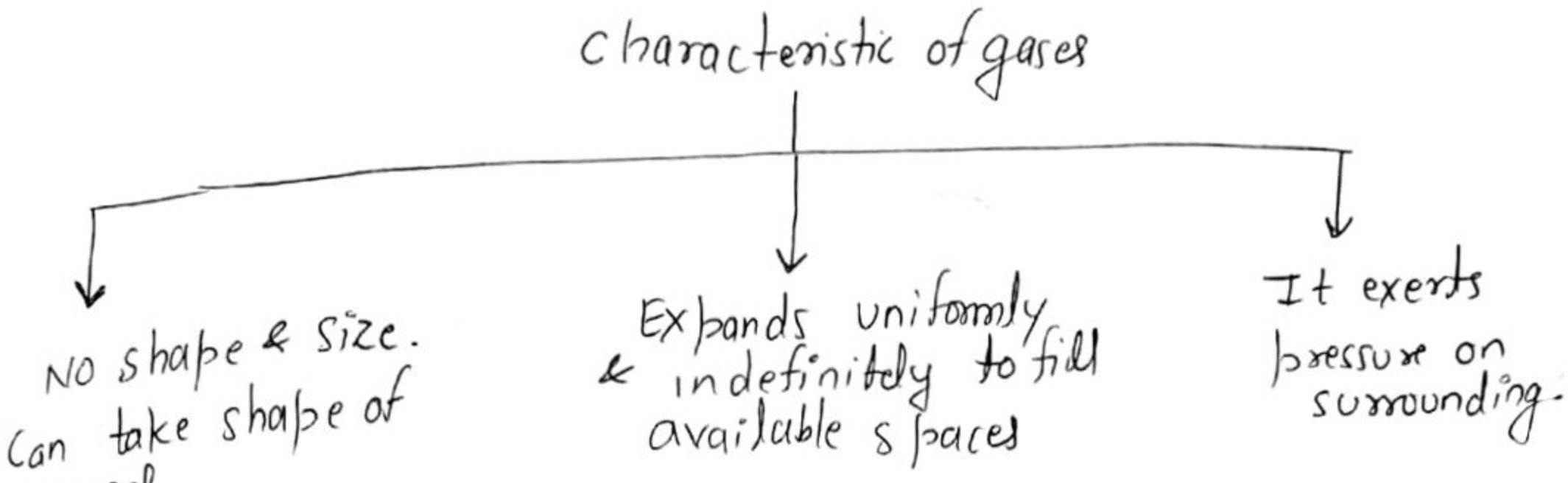
KINETIC THEORY of GASES



Assumptions of kinetic Theory of Gases:

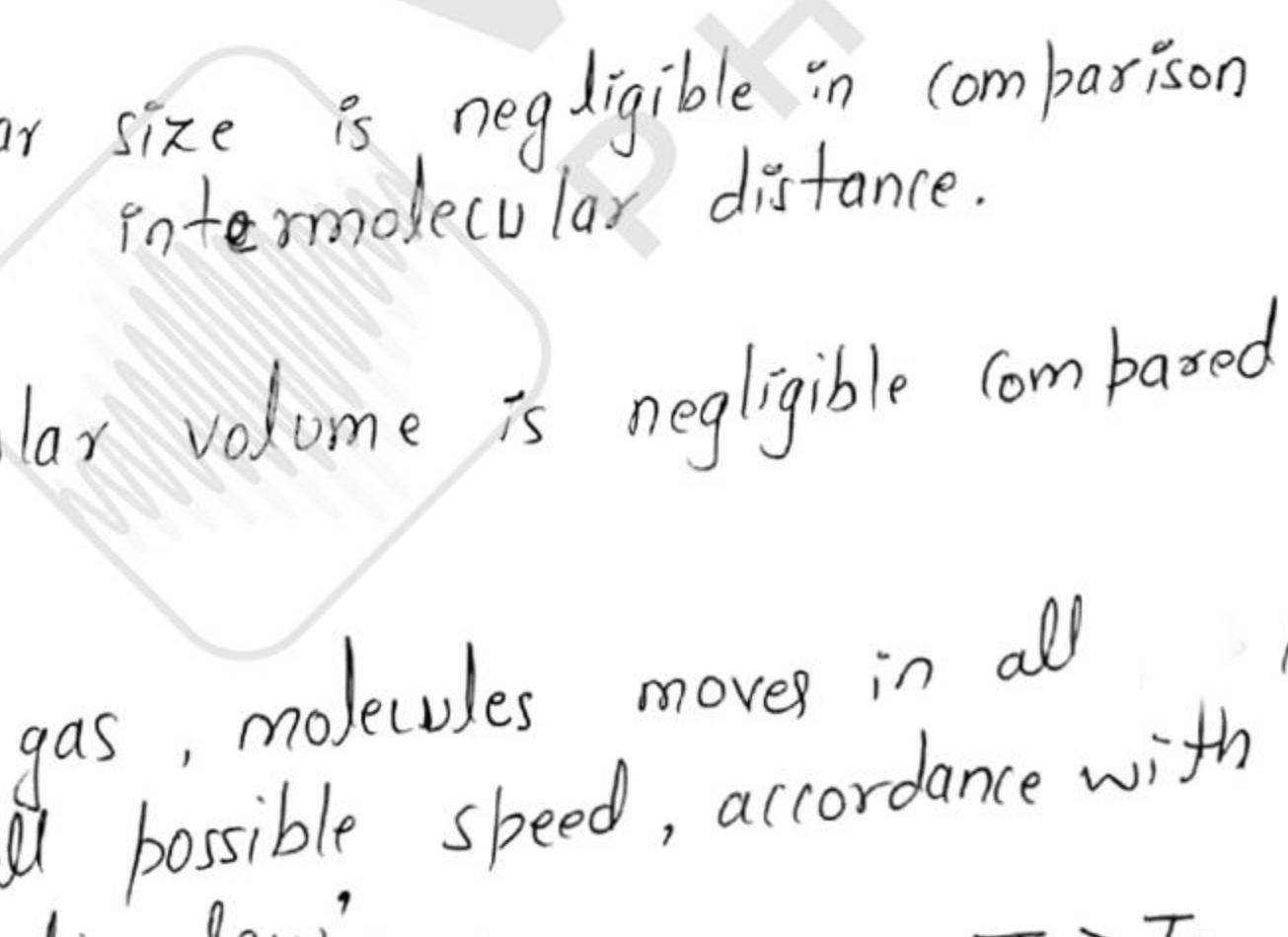
→ Every gas made up of small particles called molecules. For a gas it is identical but different from another gas.

→ molecules are elastic, spherical & rigid. (perfectly elastic point mass)

→ Molecular size is negligible in comparison to the intermolecular distance.

→ molecular volume is negligible compared to volume of gas

→ In a gas, molecules moves in all possible directions with all possible speed, accordance with 'Maxwell's distribution law'.



→ Maximum molecules moves with most probable speed

→ Collission between molecules & molecule & wall are perfectly elastic

→ Molecules moves in a staight line with constant speed between successive collisions.

→ The number of collisions per unit volume in a gas remains constant.

→ No attractive or repulsive force acts between gas molecules.

→ Gravitational attraction among molecules is ineffective due to extremely small masses.

→ Density of a gas is constant at all points of the container

→ Molecules constantly collide with the wall of container, and this results in pressure by gas molecules on wall.

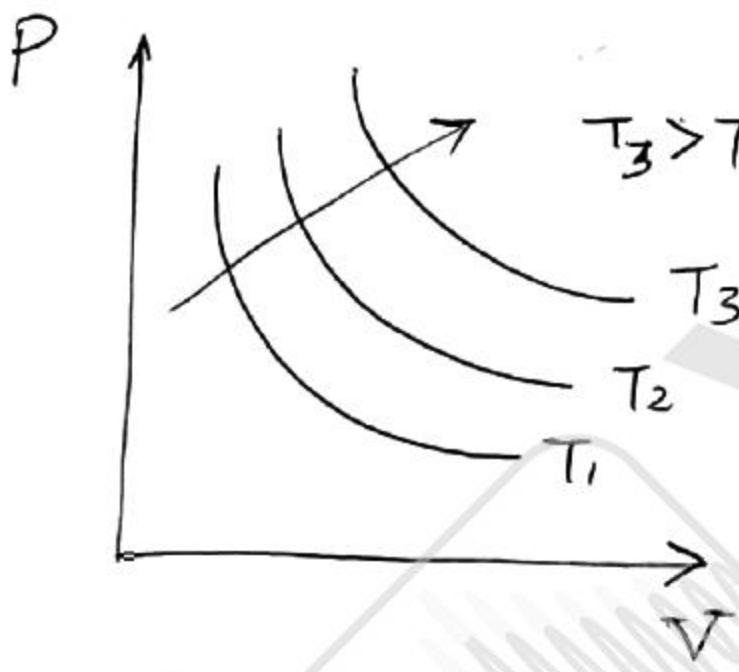
GAS LAWS

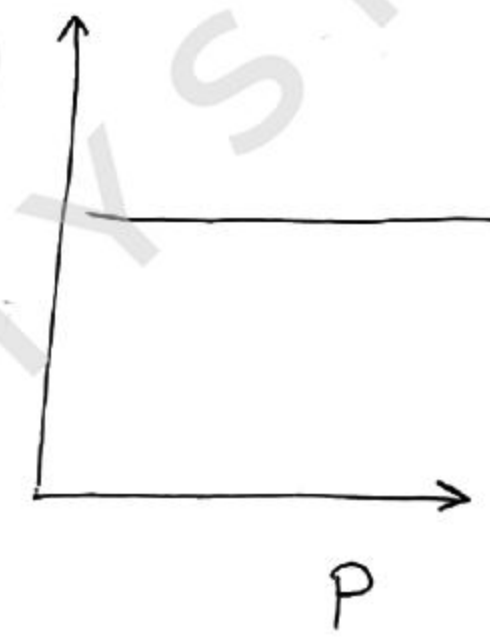
Boyle's law:

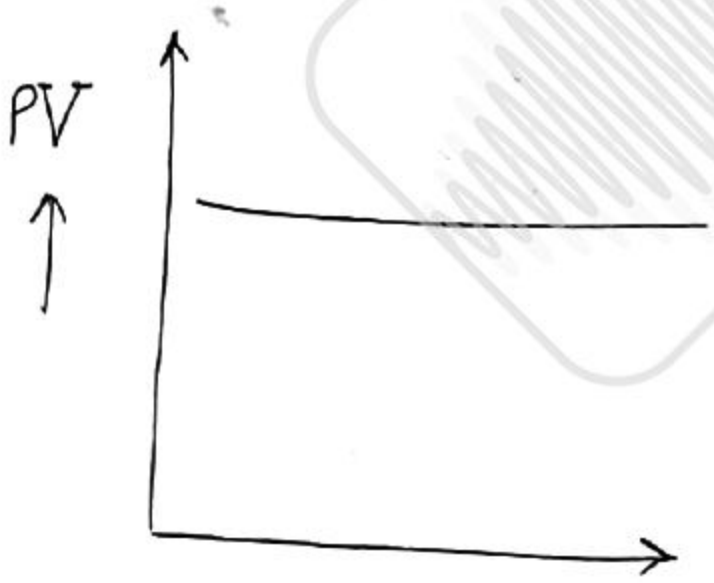
$$P \propto \frac{1}{V}$$ → for constant Temperature of gas in given situation (moles)

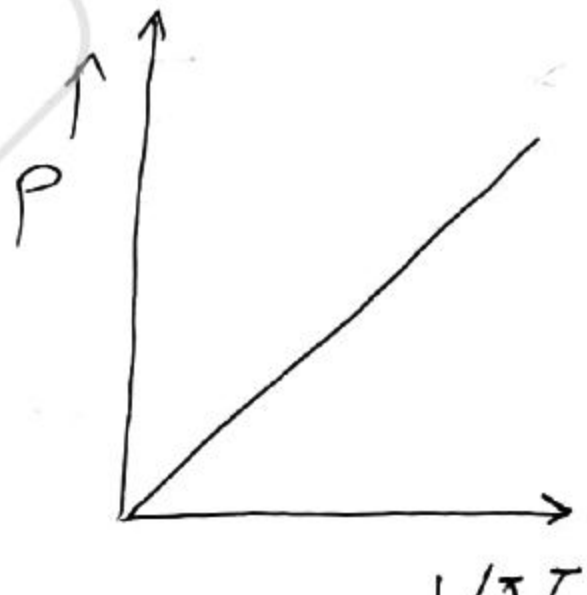
$$\Rightarrow PV = \text{constant}$$

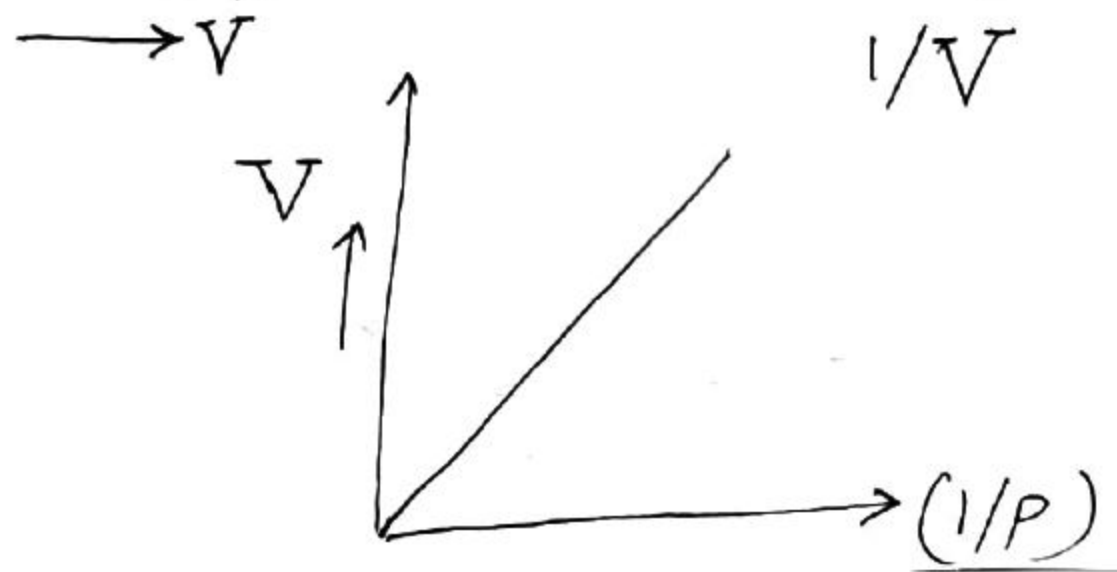
for constant mass & Temperature we get graphs as:





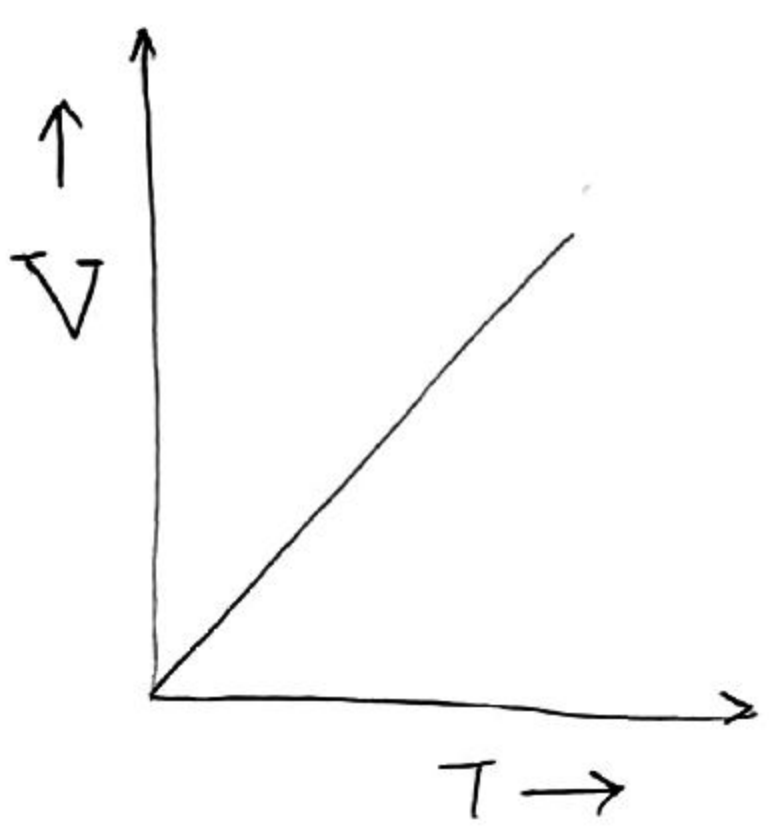


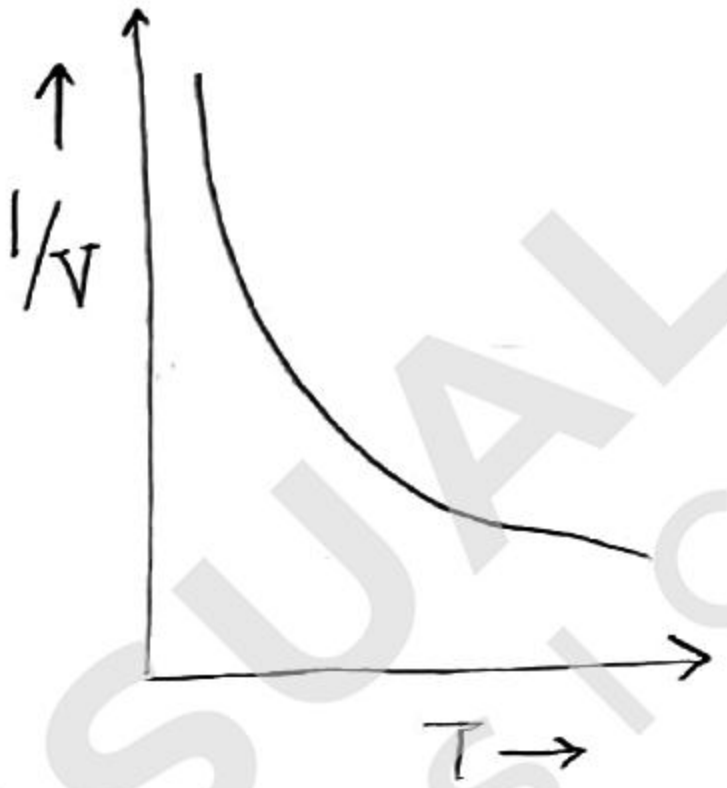


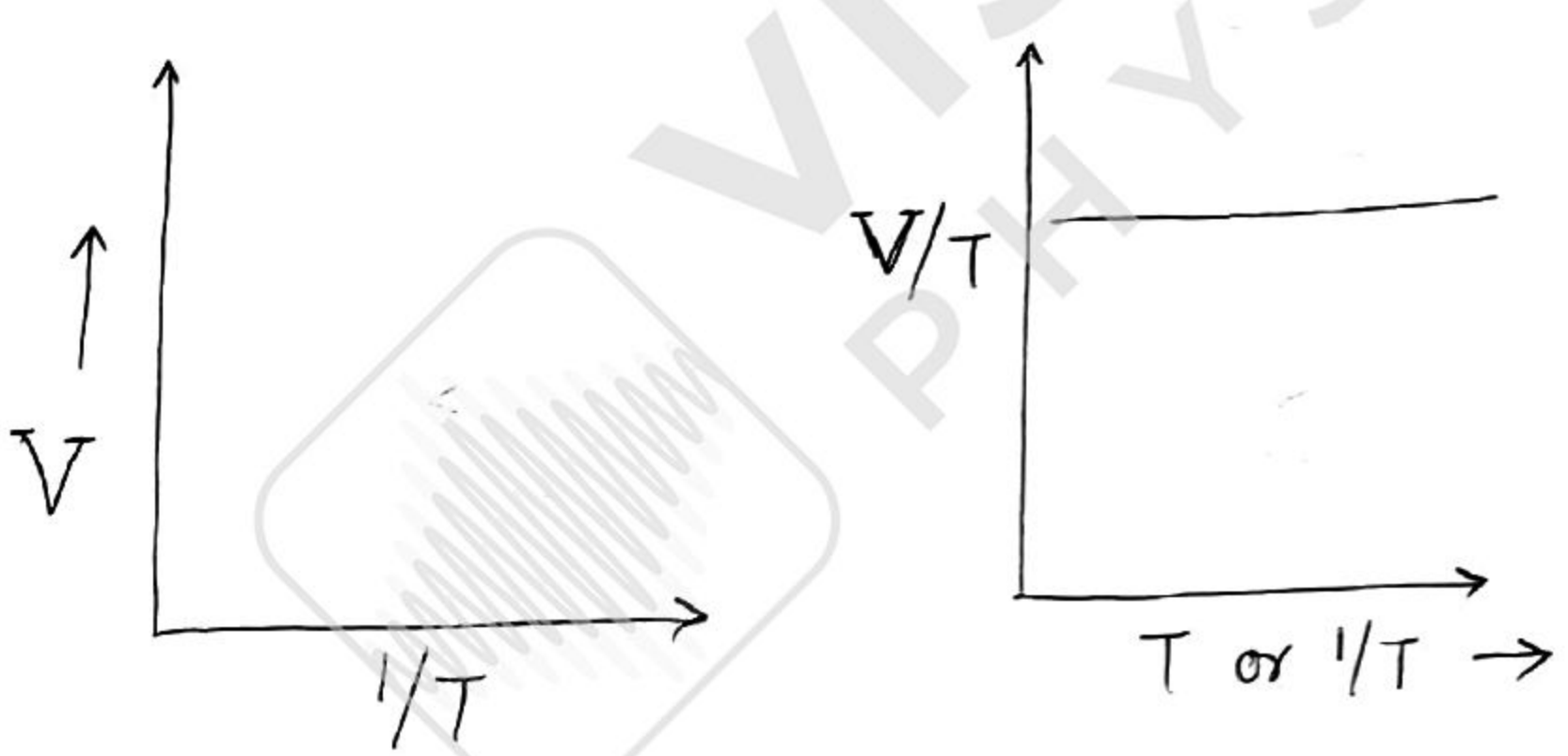


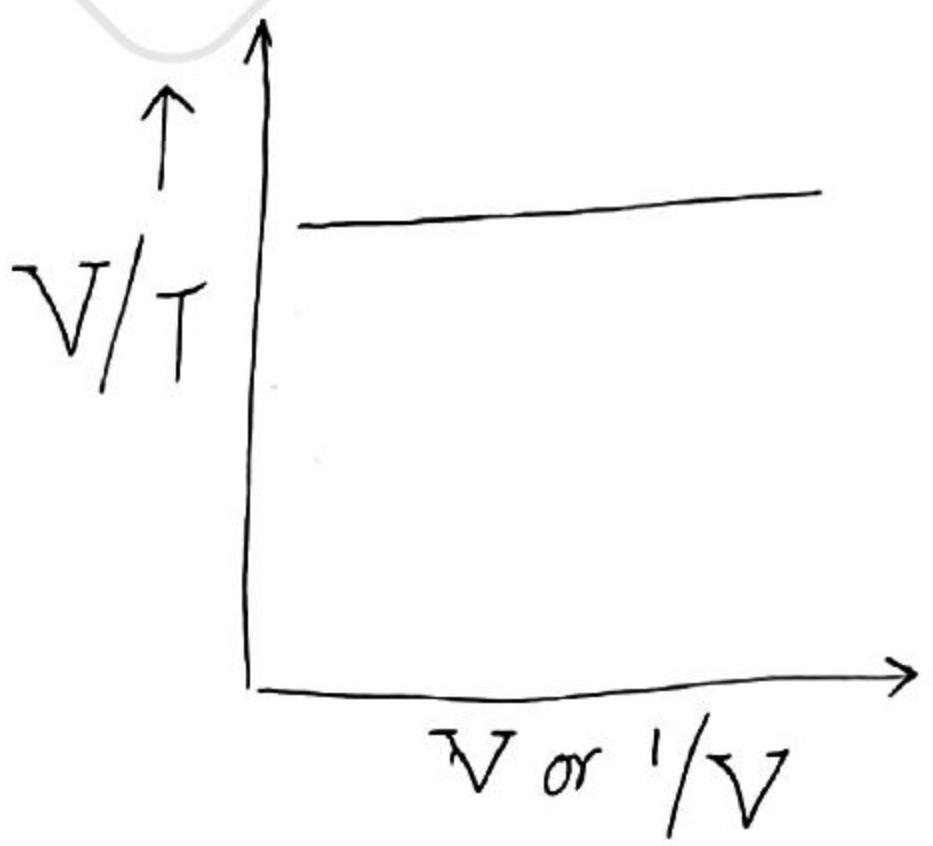
Charle's law:

$V \propto T$ → for constant pressure and moles





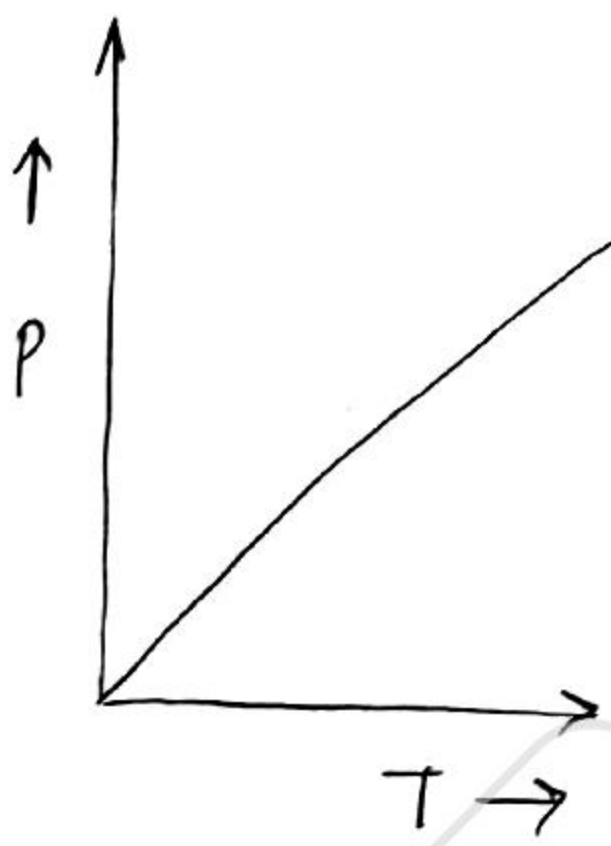


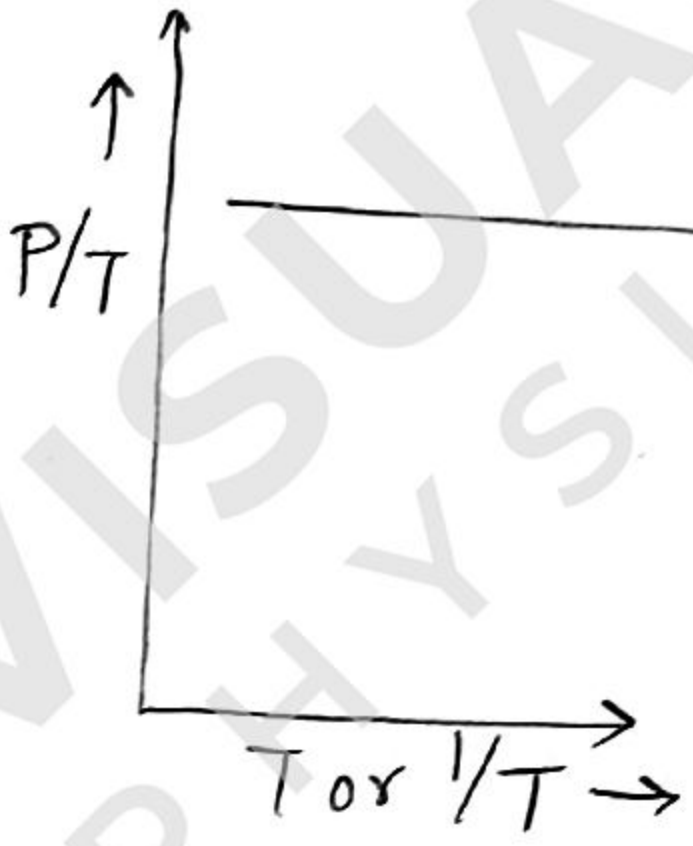


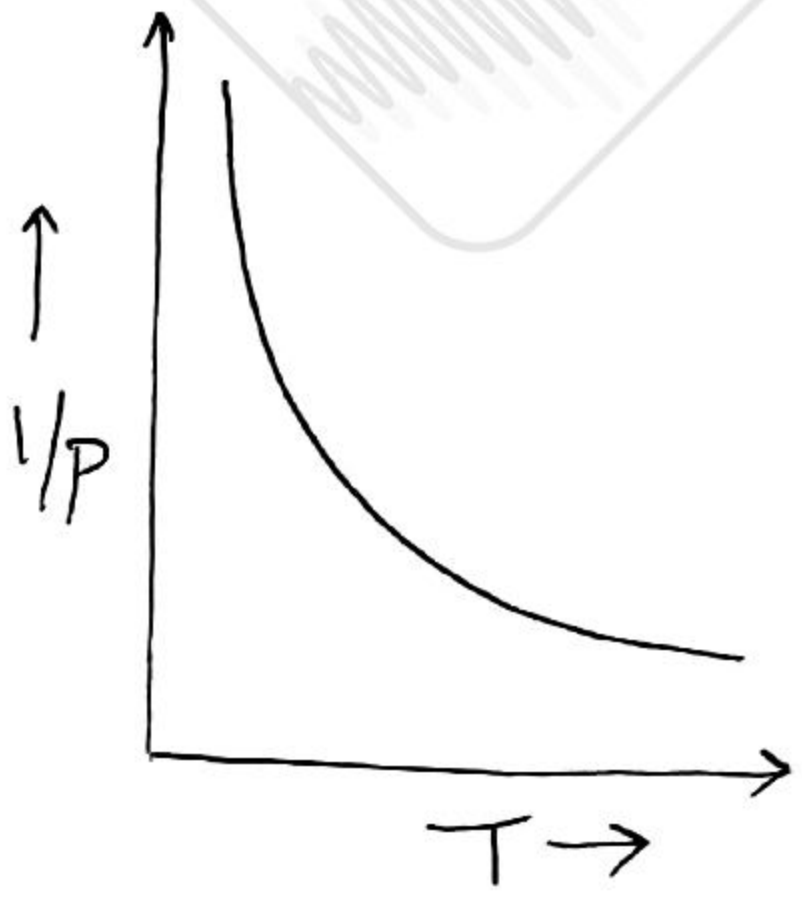
Gay-Lussac's law:

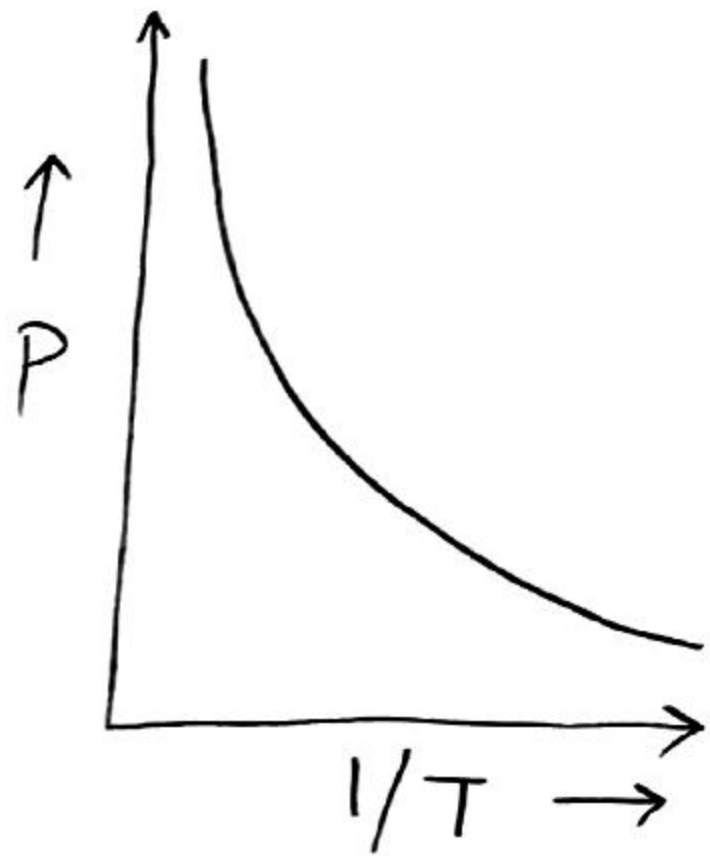
$$\boxed{P \propto T} \rightarrow \text{for constant volume and mole}$$

$$\boxed{\frac{P}{T} = \text{constant}}$$









Avogadro's Law:

Equal Volume of all the gases under similar conditions of temperature and pressure contain equal number of molecules.

$$N_A = 6.023 \times 10^{26} \text{ mole/kg}$$

$$N_A = 6.023 \times 10^{23} \text{ mole/gram}$$

↑ Avogadro's number.

★

→ At STP or NTP ($T = 273k$ and $P = 1 atm$)
22.4 L of eas gas has 6.023×10^{23} molecules

IDEAL GAS EQUATION:

→ Gas that strictly obeys gas law is called perfect or ideal gas

→ All real gases are not perfect gases.

→ At extremely low pressure and high Temperature gases like hydrogen, nitrogen & helium are nearly perfect gases.

$$PV = nRT$$ → ideal gas equation

P → Pressure
V → Volume
n → number of moles
R → Universal gas Constant
T → Temperature

$$R = 8.31\ J/mol\,k$$

$$k = \frac{R}{N_A}$$

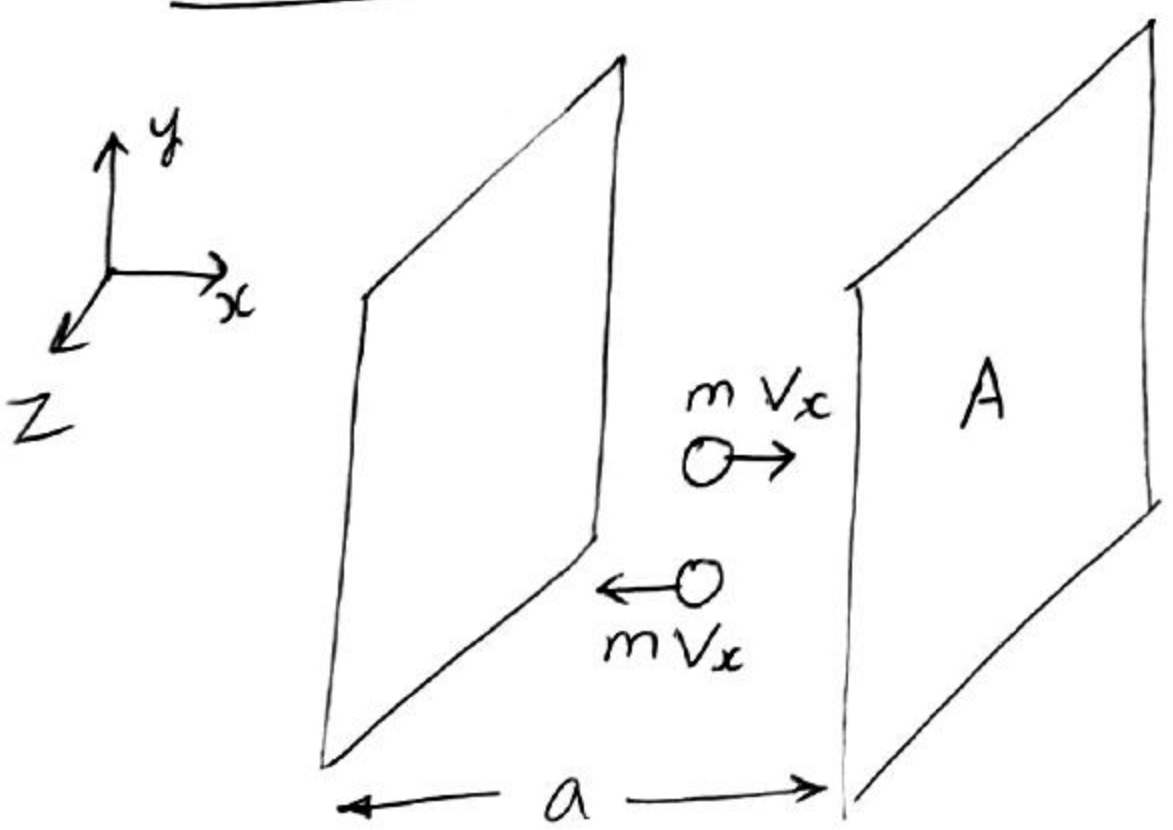
R → Avogadro's number
N_A → $6.023 \times 10^{23}\ mol^{-1}$
k → boltzmann's Constant

$$k = 1.38 \times 10^{-23}\ J/K$$

$$\gamma = \frac{R}{M}$$

R → Specific gas Constant
M → Molar mass of given gas

Pressure of an Ideal gas:



A → Area of wall

V_x → Velocity component in x direction

a → seperation between walls

$t = \frac{2a}{V_x}$ → time between successive collisions on same wall

→ So number of collisions per second $= \frac{1}{t} = \frac{V_x}{2a}$

→ momentum change in successive collisions $= 2mV_x$

So, change in momentum per selond $= (2m)V_x \times \left(\frac{V_x}{2a}\right)$

Force exerted in x-direction = f_x

$\Rightarrow f_x = \frac{mV_x^2}{a}$ → force because of one molecules

F_x = Net fore in x-direction $= \Sigma f_x = m\frac{\Sigma V_x^2}{a}$

$$P_x = \text{pressure} = \frac{F_x}{A} = \frac{m}{A\,a}\,\Sigma V_x^2 = \frac{m}{V}\,\Sigma V_x^2$$

So net pressure

$$P_x + P_y + P_z = \frac{m}{V}\left[\Sigma V_x^2 + \Sigma V_y^2 + \Sigma V_z^2\right]$$

As $P_x = P_y = P_z = P$

$$\boxed{3P = \frac{m}{V}\,\Sigma\,(V_x^2 + V_y^2 + V_z^2)}$$

$$P = \frac{m}{3V}\,\Sigma\,(V_x^2 + V_y^2 + V_z^2)$$

As net speed, $V = \sqrt{V_x^2 + V_y^2 + V_z^2}$

$$\Rightarrow V^2 = V_x^2 + V_y^2 + V_z^2$$

$$P = \frac{m}{3V}\,\Sigma V^2$$

as $V_{rms}^2 = \dfrac{V_1^2 + V_2^2 + \cdots V_N^2}{N} = \dfrac{\Sigma V^2}{N}$

$$\rightarrow \Sigma V^2 = N\,V_{rms}^2$$

$$\boxed{P = \frac{m}{3V}\,N\,V_{rms}^2}$$

as $mN = M$ = total mass of gas

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

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

$\rho \rightarrow$ density of gas $= \frac{M}{V}$

$\rightarrow$ $v_{rms}^2 \propto T \Rightarrow \boxed{P \propto \frac{(mN)T}{V}}$

for constant m, N, T

$\boxed{P \propto 1/V}$

for constant V & T

$\boxed{P \propto (mN)}$ $\rightarrow$ increasing mass of gas increases pressure.

and also for constant V, m & N

$\boxed{P \propto T}$

Various Speeds of Gas Molecules

1. Root mean square speed:

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

↳ molar mass

↳ mass of one molecules

2. Most probable speed:

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

3. Average speed:

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

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

$: V_{rms} : V_{avg} : V_{mp} = \sqrt{3} : \sqrt{2.5} : \sqrt{2}$

kinetic energy of ideal gas :

→ for one molecule :

$$\frac{1}{2} m v_{rms}^2 = \frac{1}{2} m \left(\frac{3KT}{m}\right) = \boxed{\frac{3}{2} kT}$$

as $v_{rms} = \sqrt{\frac{3kT}{m}}$

→ for 1 mole or M mass

$$= \frac{1}{2} M v_{rms}^2 = \frac{1}{2} M \left(\frac{3RT}{M}\right) \boxed{= \frac{3}{2} RT}$$

✡

⇒ kinetic energy per molecules do not depend on mass of the molecules but only on Temperature.

Degree of freedom:

* Minimum number of variables required to completely specify the state of system.

→ Translational degree of freedom (maximum) = 3 (x, y, z direction)

→ Rotational degree of freedom (maximum) = 3

→ Vibrational degree of freedom → depends on atoms arrangement.

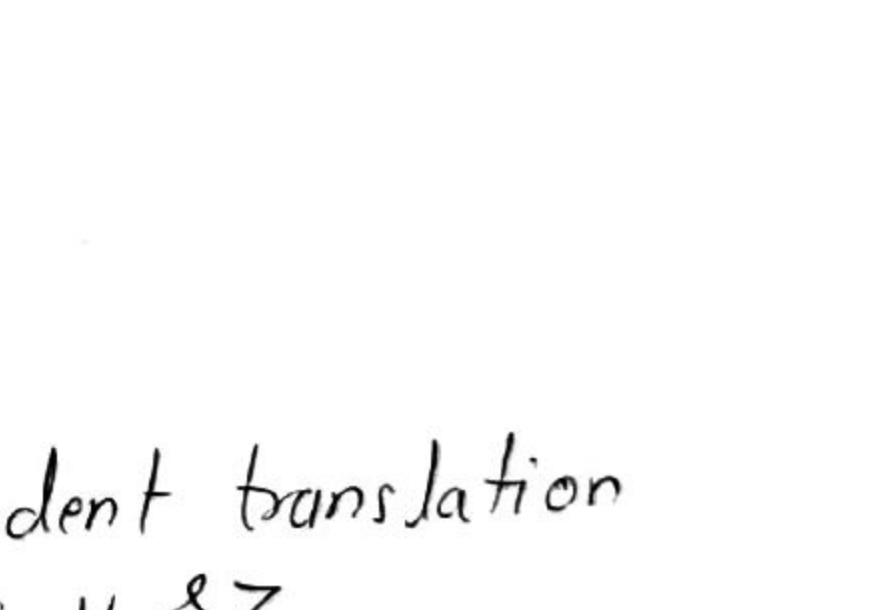
* At room temperature only translational and rotational degree of freedom are taken into account.

1. monoatomic gas:

(3) → as three independent translation motion along x, y & z

2. Diatomic gas:

(5) → 3 translational
2 rotational



3. Triatomic :

(6) → 3 translational
→ 3 rotational.

At high temperature vibration degree of freedom is also considered

So for diamtomic → (7)

- 3 translational
- 2 rotational
- (2) (Vibrational)
  - ★ a vibration gives 2 degree of freedom

Law of Equipartition of Energy :

★ In thermal equilibrium, total energy is equally distributed amongst its various degrees of freedom.

per degree of freedom energy = $\frac{1}{2}kT$

k → Boltzman's constant

Specific heat Capacity of Gases

→ Specific heat of gas at constant volume (c_v)

$$S_v = \frac{(\Delta Q_c)}{m \Delta T}$$ → heat at constant volume

$$\boxed{C_v = \frac{\Delta Q_c}{n \Delta T}}$$

→ Specific heat of gas at constant pressure (C_p)

$$S_p = \frac{\Delta Q_p}{m \Delta T}$$ → heat at constant pressure

$$\boxed{C_p = \frac{\Delta Q_p}{n \Delta T}}$$

$n \rightarrow$ no. of moles

$C_p, C_v \rightarrow$ molar specific heat capacity
or molar heat capacity.

Mayer's formula

for Constant volume

$W = 0$ = work done by gas

$$\rightarrow \boxed{(\Delta Q)_v = \Delta V = n C_v \Delta T}$$