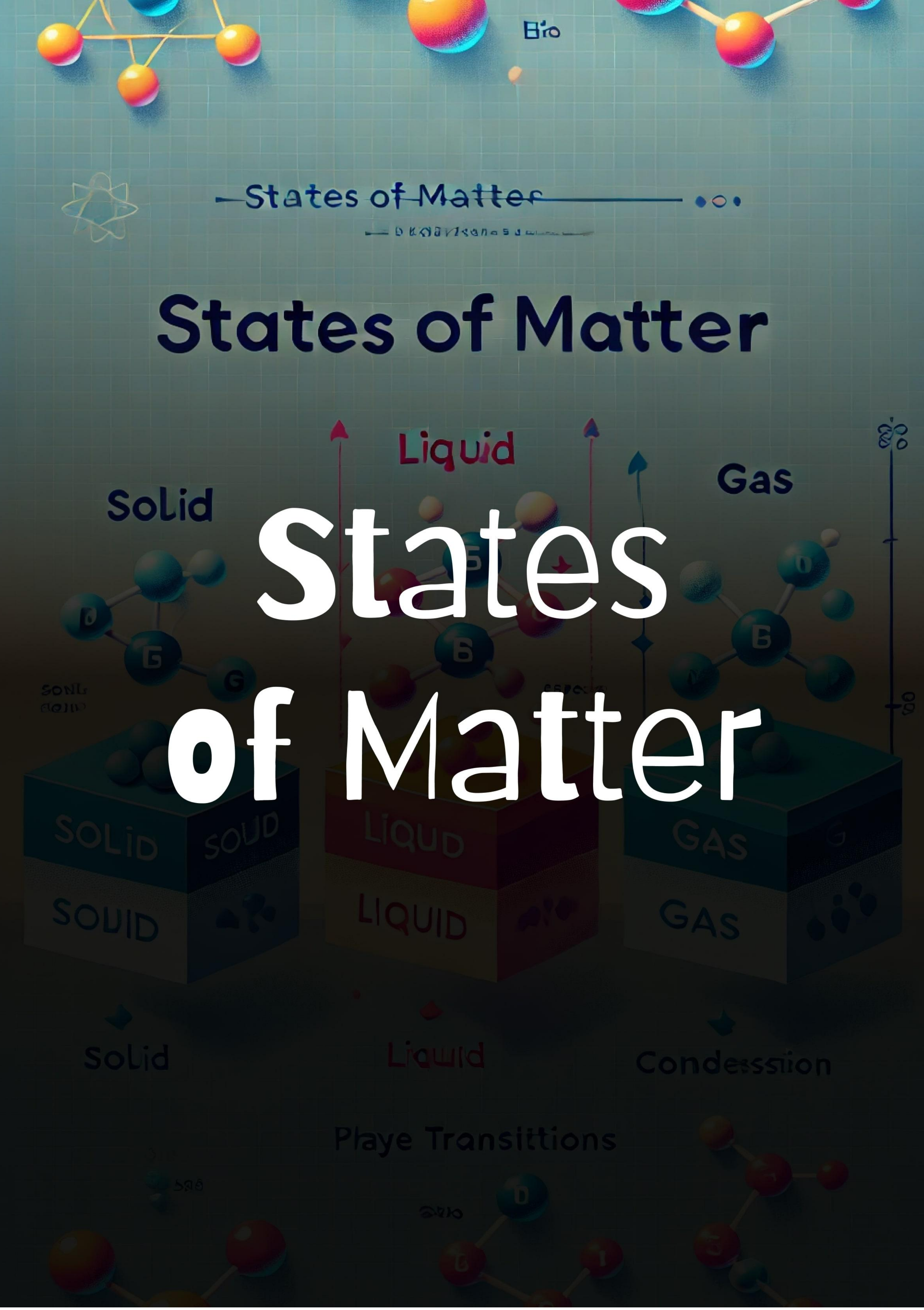


States of Matter

States of Matter

- Matter - having mass and occupying space.

① Solid state
② Liquid state ✓
③ Gaseous state. ✓

- The states of matter depends on two factors
① Intermolecular Forces. (Vanderwaal's Forces)
② Thermal energy. (Measure of KE)

- Vanderwaal's Forces:
① London Forces / Dispersion Forces — (non polar molecules - CO_2, Cl_2)
② Dipole - Dipole interaction. — (polar molecules - HCl, SO_2, HBr)
③ Dipole - Induced dipole. ← (Polar - non polar molecule - HCl + Cl_2)

- Interaction energy:

① London $\propto \frac{1}{r^6}$

③ Dipole - induced dipole $\propto \frac{1}{r^6}$

② Dipole - Dipole $\propto \frac{1}{r^3}$ (stationary) $\propto \frac{1}{r^6}$ (rotating)

- Thermal energy: (K.E) T.E $\propto$ T, K.E $\propto$ T
Due to motion.

- The states of matter is the result of balance between Inter molecular Forces and Thermal energy.

- If T.E is dominant,
Solid → Liquid → Gas ✓

- If IMF is dominant,
Gas → Liquid → Solid

- **Gas laws :**

Gas laws inter relate the measurable properties of gases.
(P, V, T and n)

① **Boyle's law**

n, T constant.

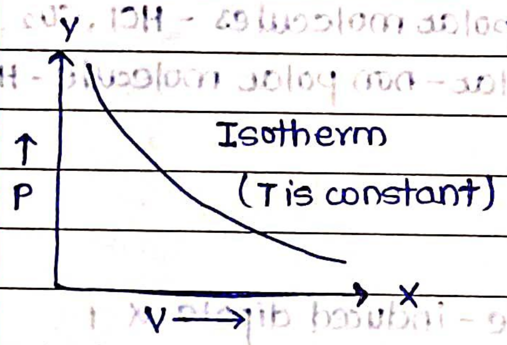
$V \propto \frac{1}{P}$

$PV = \text{constant}$ ($PV = K$ — depends on n and T also on units of P and V.)

$P_1V_1 = P_2V_2$

① Graphs:

a)



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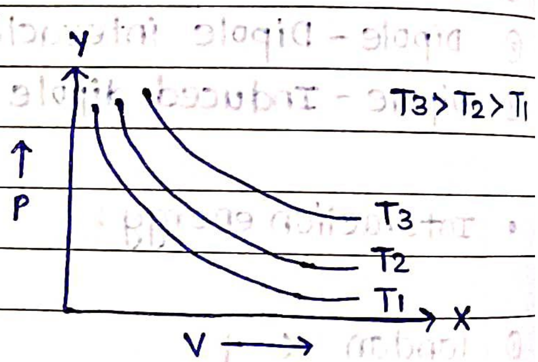

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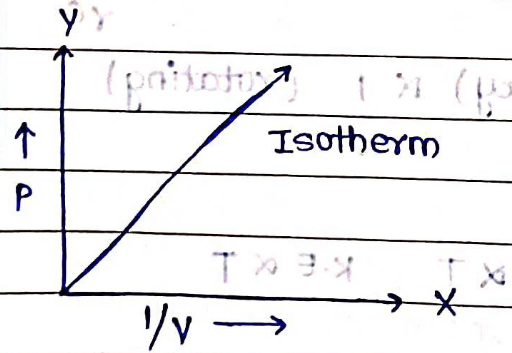

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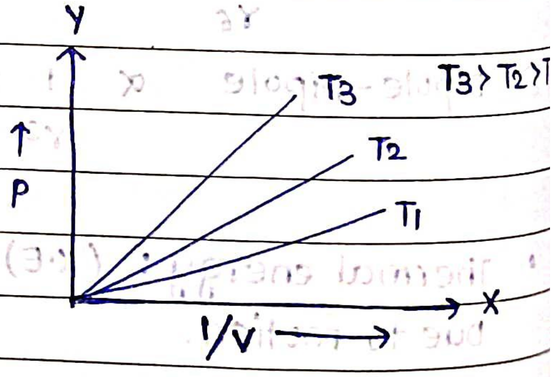

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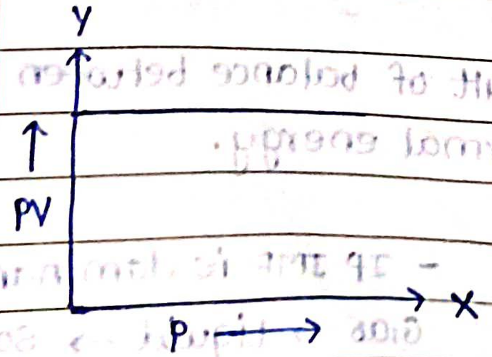
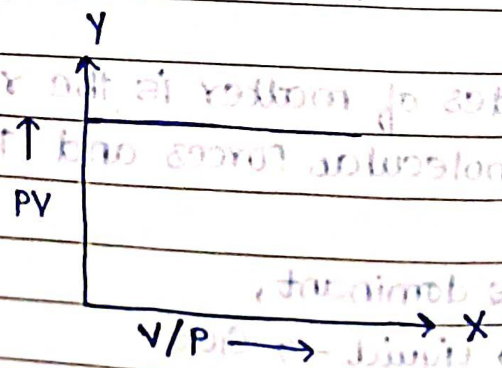




② Charle's law :

P, n constant.

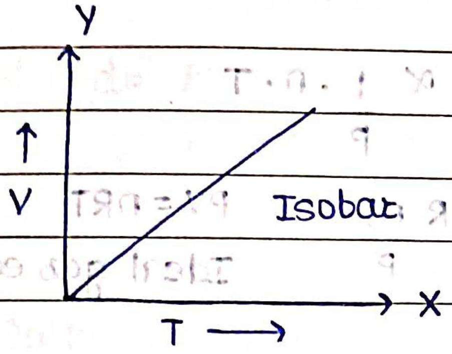
$V \propto T$

$\frac{V}{T} = K$ —— depends on p and n and units of volume.

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ —— T must be taken in kelvin only.

• Graphs :

a)



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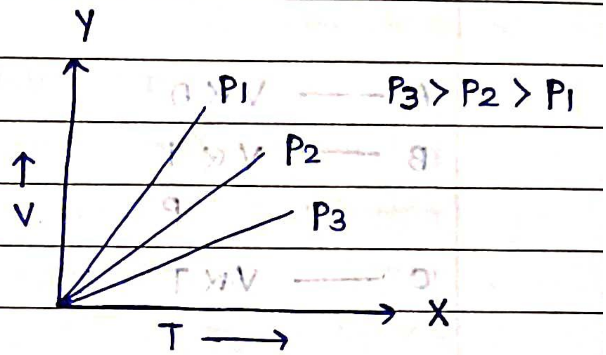

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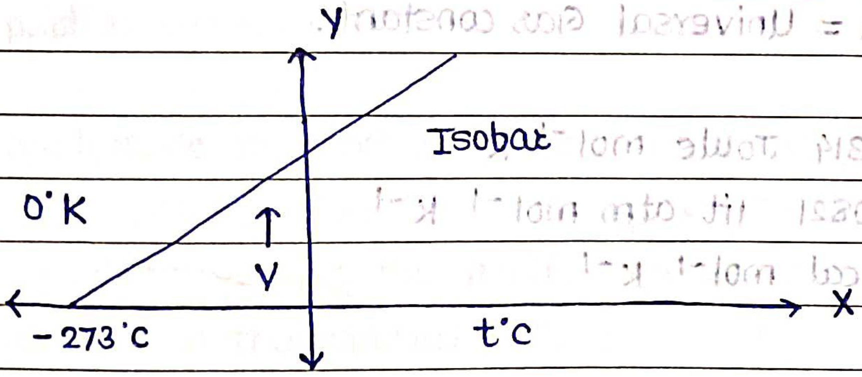

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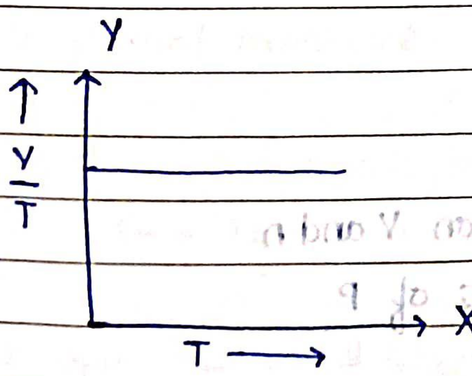

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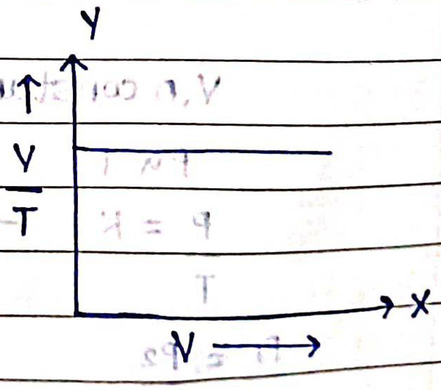


⑧ Avagadro's law :

P, T constant

$V \propto n$

$\frac{V}{n} = K$ —— depends on P and T and units of V.

$\frac{V_1}{n_1} = \frac{V_2}{n_2}$

The gas which strictly obeys A B C is known as Ideal gas.

- Ideal gas equation :

A —— $V \propto n$

B —— $V \propto \frac{1}{P}$

C —— $V \propto T$

$\therefore V \propto \frac{1}{P} \cdot n \cdot T$

$V = R\frac{nT}{P}$

$PV = nRT$ Ideal gas equation

R = Universal Gas constant.

$R = 8.314$ Joule $mol^{-1} K^{-1}$

$R = 0.0821$ lit atm $mol^{-1} K^{-1}$

$R = 2$ cal $mol^{-1} K^{-1}$

④ Gay Lussac's law :

V, n constant.

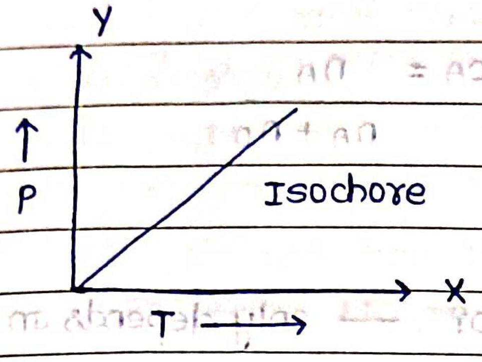
$P \propto T$

$\frac{P}{T} = K$ ⟵ depends on V and n and units of P

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

- Graphs :

a)



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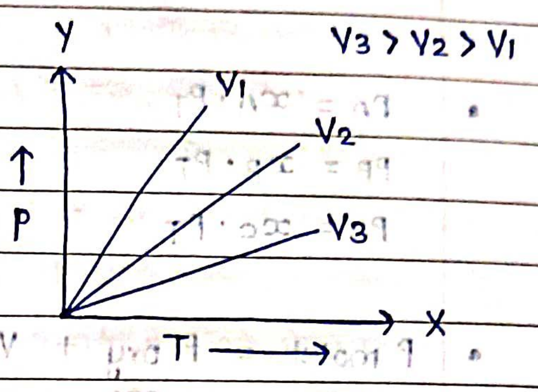


- Density of Ideal gas :

$$d = \frac{PM}{RT}$$

- Combined gas law :

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

If $n_1 = n_2$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

- Dalton's law of partial pressures :

- applicable to mixture of non-reducing gases
- The total pressure exerted by a gaseous state mixture is equal to sum of the partial pressures of all the gases present in the mixture.
- The pressure exerted by an individual gas in the mixture is partial pressure.

A, B and C — 3 gases

$$P_T = P_A + P_B + P_C$$

- On applying Ideal gas equation,

$$P_T = \frac{n_TRT}{V} \qquad P_A = \frac{n_ART}{V} \qquad P_B = \frac{n_BRT}{V} \qquad P_C = \frac{n_CRT}{V}$$

- $n_T = n_A + n_B + n_C$

- $P_A = x_A \cdot P_T$ $\qquad$ $x_A = \dfrac{n_A}{n_A + n_D}$

  $P_B = x_B \cdot P_T$

  $P_C = x_C \cdot P_T$

- P moist gas = P dry gas + V.P of H_2O or Avg. Tension — only depends on Temp

  V.P ∝ T

- Graham's law :

  The rate of diffusion or effusion of a gas is inversely proportional to molecular mass / density of gas at constant P and T.

  - Diffusion - The spontaneous intermixing of gases.
  - effusion - The diffusion of a gas from high P to low P through a 'orifice'

$$r \propto \frac{1}{\sqrt{M}} \quad \text{or} \quad r \propto \frac{1}{\sqrt{\rho}}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{\rho_2}{\rho_1}} \qquad (P, T) - \text{constant}$$

① If P constant
T variable

$$r \propto \frac{\sqrt{T}}{\sqrt{M}} \qquad \frac{r_1}{r_2} = \sqrt{\frac{T_1 \times M_2}{T_2 \times M_1}} = \sqrt{\frac{T_1 \times \rho_2}{T_2 \times \rho_1}}$$

② If T constant
P variable

$$r \propto \frac{P}{\sqrt{M}} \qquad \frac{r_1}{r_2} = \frac{P_1}{P_2}\sqrt{\frac{M_2}{M_1}} = \frac{P_1}{P_2}\sqrt{\frac{\rho_2}{\rho_1}}$$

$$r = \frac{\text{vol. of gas diffused / effused}}{\text{time taken}} = \frac{V}{t}$$

$$\frac{r_1}{r_2} = \frac{V_1}{t_1} \times \frac{t_2}{V_2}$$

$$r = \frac{\text{distance travelled by gas}}{\text{time taken}} = \frac{d}{t}$$

$$\frac{r_1}{r_2} = \frac{d_1}{t_1} \times \frac{t_2}{d_2}$$

$$r = \frac{\text{no. of moles of gas diffused / effused}}{\text{time taken}} = \frac{n}{t}$$

$$\frac{r_1}{r_2} = \frac{n_1}{t_1} \times \frac{t_2}{n_2}$$

- KTG:

- A gas consists of large number of tiny identical particles called atoms / molecules.
- There is no force of attraction b/w the particles.
- The vol. occupied by gas molecules is negligible as compared to total volume of gas.
- The particles are always in constant and random motion.
- Particles move in all possible directions in straight lines. During their motion, they collide with other and with walls of container.
- Collisions of gas molecules are perfectly elastic.
- K.E and speed always changes.

  $\approx 10^{-9}$ sec
- Avg K.E ∝ Absolute Temperature.
- $PV = \frac{1}{3} mnc^2$ (kinetic gas equation)

P $K.E = \frac{3}{2} RT$ (Average K.E of 1 mol. of gas)

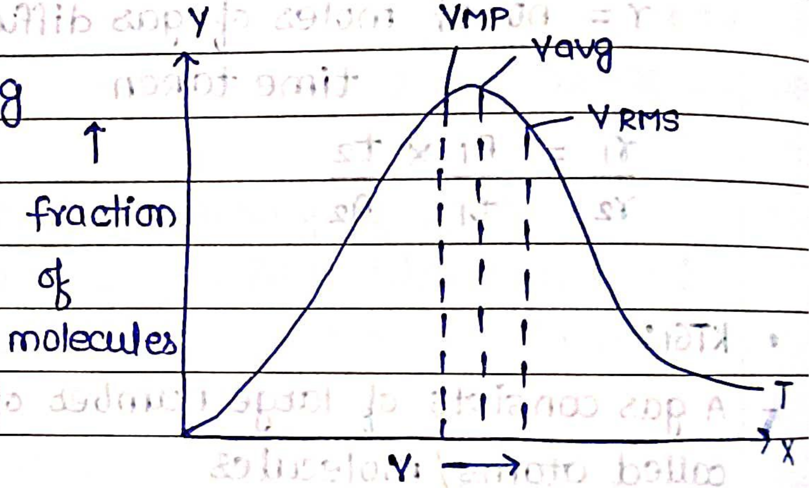
$K.E = \frac{3}{2} nRT$ (Average K.E of n mol. of gas)

$K.E = \frac{3}{2} K_b T$ (Average K.E of one gas molecule)

K_b = Boltmann constant $= \frac{R}{N_A}$

- Maxwell - Boltzmann velocity distribution curve :

- The molecules possesing very low velocities and very high velocities are found to be less.



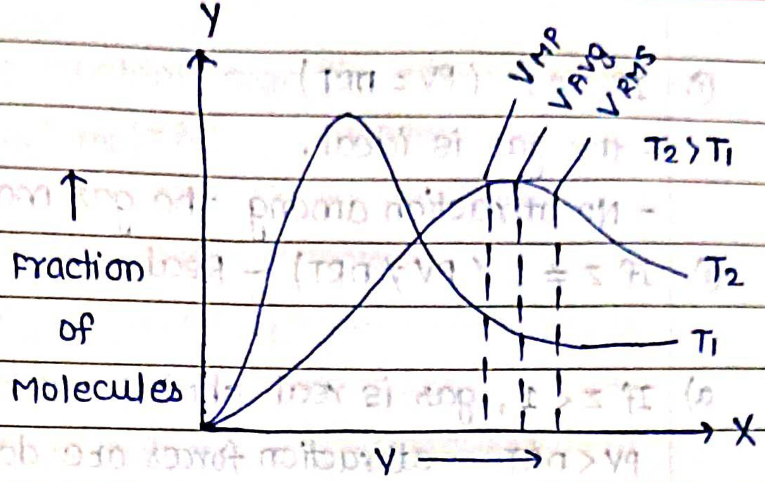
- VMP - velocity possessed by maximum fraction of the molecules

$$V_{MP} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2PV}{M}} = \sqrt{\frac{2P}{\rho}}$$ (For 1 mole of ideal gas)

$$V_{Avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8PV}{\pi M}} = \sqrt{\frac{8P}{\pi \rho}}$$

$$V_{RMS} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}}$$

- On Increasing 'T' graph shifts to right side.
- Peak becomes broader.



- Molecules possesing Higher velocities increases.
- 'M' increases velocity decreases.
- Area under the graph (Total no. of molecules) remains same.
- Density will be highest at High pressure and low temperature
- $V_{MP} < V_{Avg} < V_{RMS}$

- Deviation of a gas from ideal behaviour:

Ideal gas	Non-ideal (Real) gas
- Do obeys KTG	- Does not obey KTG
- Vol. occupies by gas molecules is negligible	- Volume occupied by gas molecules is significant.
- No attraction forces among the gas molecules.	- There is attraction or repulsion force.
- Obeys ideal gas $PV = nRT$	- Obeys vanderwaal's gas $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$
- Very low P and very high temp.	

- Compressibility factor (z):

$$z = \frac{PV}{nRT}$$

It gives the nature of gas.

① If $Z = 1$ ($PV = nRT$)

- the gas is ideal.
- No attraction among the gas molecules.

② If $Z \neq 1$ ($PV \neq nRT$) – Real.

a) If $Z < 1$, gas is real shows –ve deviation from ideal behaviour.
$PV < nRT$ – attraction forces are dominating.

b) If $Z > 1$, gas is real shows +ve deviation from ideal behaviour.
$PV > nRT$ – Repulsion forces are dominating.

- Vanderwaal's Gas equation :

- Derived from ideal gas equation by correcting P and V terms

Vanderwaals Gas equation, $(P + \Delta P)(V + \Delta V) = nRT$

ΔP – pressure correction

ΔV – Volume correction

① Pressure correction.

Due to molecular attractions,

$$P_{Real} < P_{Ideal}$$

$$P_{Ideal} = P_{Real} + \Delta P$$

ΔP – the pressure reduced due to molecular attraction

$$\Delta P = \frac{an^2}{V^2}$$

$\Delta P \propto$ colliding molecules.

$\propto$ molecules attracting the colliding molecules

$$\Delta P \propto \frac{n^2}{V^2} \qquad \Delta P = \frac{an^2}{V^2}$$

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a = vanderwaal's constant signifies attraction forces.
units of a = atm lit^2 mol^{-2}

② Volume correction

$$V_{gas} = V_{container} - nb$$

nb – vol. occupied by gas molecules is significant (excluded volume)

b – vanderwaal's constant
signifies size of molecules.
Units : lit mol^{-1}

Now, Vanderwaal's Gas equation

$$\left(P + \frac{an^2}{V^2}\right)(V-nb) = nRT$$

- b = excluded volume per mol.

excluded vol due to 1 molecule $= 4 \times \frac{4}{3} \times \pi r^3$

Volume of each gas molecule $= \frac{4}{3} \times \pi r^3$

Volume of 1 mol of molecules $= 4 \times \frac{4}{3} \times \pi r^3 \times N_A = b$

- For gases like CO_2, CH_4, SO_2 :-

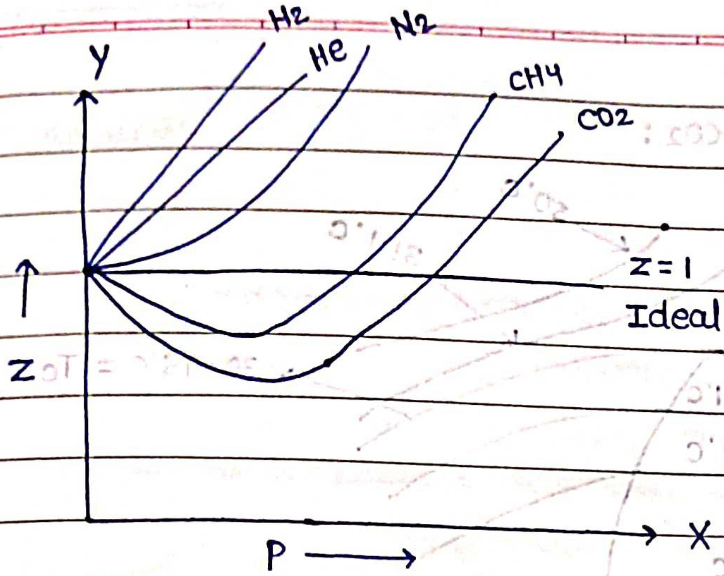
- Size is more
- a is more (attraction).
- For 1 mol,

Low P	High P
- V is very high	- V is very low
- b is negligible.	- b is not negligible.
- $\frac{a}{V^2}$ is not negligible.	- $\frac{a}{V^2}$ is neglibible.
- $\left(P+\frac{a}{V^2}\right)(V) = RT$	- $P(V-b) = RT$
$\frac{PV}{RT} = 1 - \frac{a}{VRT}$	$\frac{PV}{RT} = 1 + \frac{Pb}{RT}$
$\therefore Z < 1$	$\therefore Z > 1$
$Z = 1 - \frac{a}{VRT}$	$Z = 1 + \frac{Rb}{RT}$
- Real, -ve deviation	- Real, +ve deviation.

- For gases like H_2, He and N_2 :-

- size is very less.
- a is low.

Low P	High P
- V is very high	- V is low
- b is negligible	- $\frac{a}{V^2}$ is negligible.
- $\frac{a}{V^2}$ is negligible	- b is not negligible.
- $PV = RT$	- $P(V-b) = RT$
$\frac{PV}{RT} = 1$	- $\frac{PV}{RT} = 1 + \frac{Pb}{RT}$
$\therefore Z = \frac{V_{Real}}{V_{ideal}}$	- $(\therefore Z > 1)$ +ve deviation.



- Liquification of gases : (Depend upon T and P)

① Critical temp (Tc) - The temp above which a gas can't be liquified what ever the pressure is applied.

$$T_c = \frac{8a}{27Rb}$$ (Vanderwaal's constant)

$T_c \propto a$

Liquified easily if 'a' is more.
Higher the a value (Tc value), Higher the tendency to liquify

② Critical pressure (Pc) :
The pressure applied at Tc to liquify the gas.

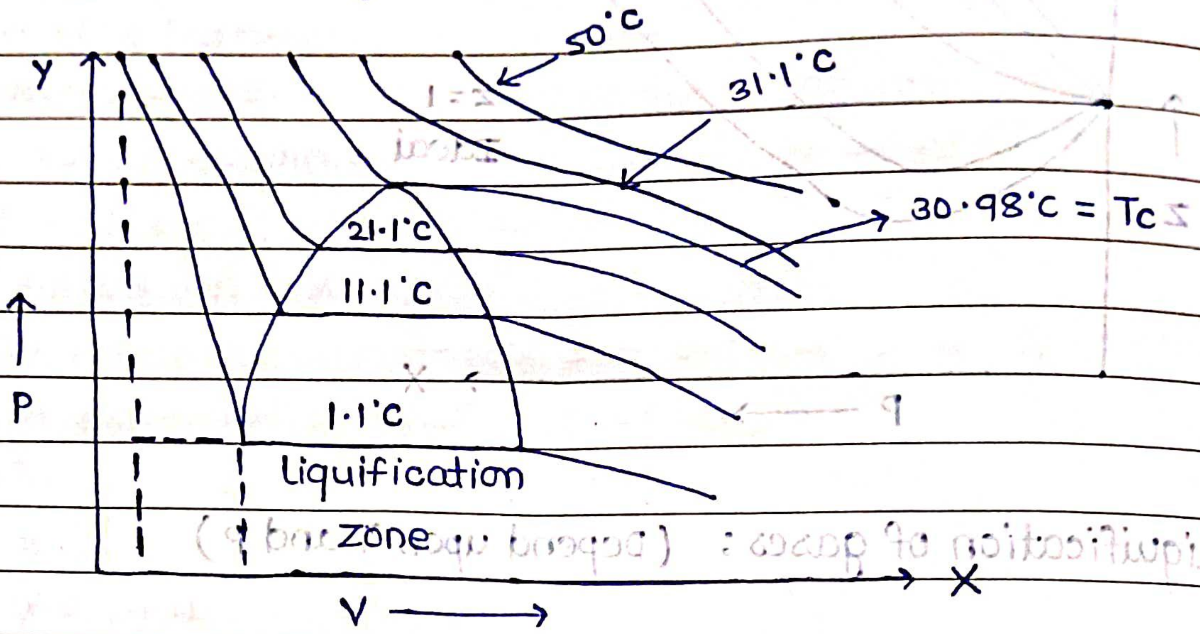
$$P_c = \frac{a}{27b^2}$$

③ Critical volume (Vc) :
The volume occupied at Tc and Pc

$$V_c = 3b$$

- $z < 1$ at critical condition for 1 mol of gas. $\left(z = \frac{3}{8}\right)$

- Andro - isotherm of CO_2 :



- Vapour pressure :
- Intensive property (mass independent)
- depends on T.

  $V.P \propto T$
- Boiling point $V.P \propto \frac{1}{B.pt}$

- Boyle's Temperature $T_b = -\frac{a}{Rb}$
- It is the temperature at which real gases obey ideal gas laws over an appreciable range of pressure.

- Standard Boiling point : 99.6 °C

  Temperature at which the vapour pressure of the liquid is 1 bar.

- Normal boiling point : 100 °C

  Temperature at which the vapour pressure of the liquid is 1 atm.