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Gaseous State

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There are 11 gaseous –

H He
N O F Ne
Cl Ar
Kr
Xe
Rn

Parameters of gases :-

1. Mass :- It represented in form of no. of moles.

$$n = \frac{w}{M}$$

2. Volume :- Volume of gas = Volume of container
$1 m^3 = 10^3 L = 10^3 dm^3 = 10^6 cc = 10^6 ml$

3. Pressure :- force exerted by gaseous molecules on the wall of container.

$$P = \frac{F}{A} \quad N/m^2 \text{ or } Pa$$

Temp. ↑ K.E. ↑ P ↑ $\quad T \propto P$

760 mm of Hg = 76 cm of Hg = 1 atm = $1.01325 \times 10^5 N/m^2$
$= 1.01325 \times 10^5 Pa$
$= 1.01325$ bar

4. Temperature :- Degree of hotness.

$T(K) = T°(C) + 273.15 K$

$T(°F) = \frac{9}{5} °C + 32$

Gaseous Law :-

1. **Boyle's Law :-** At const. temp., Pressure of certain amount (i.e. no. of moles) of gas varies inversely with volume.

at const n, T

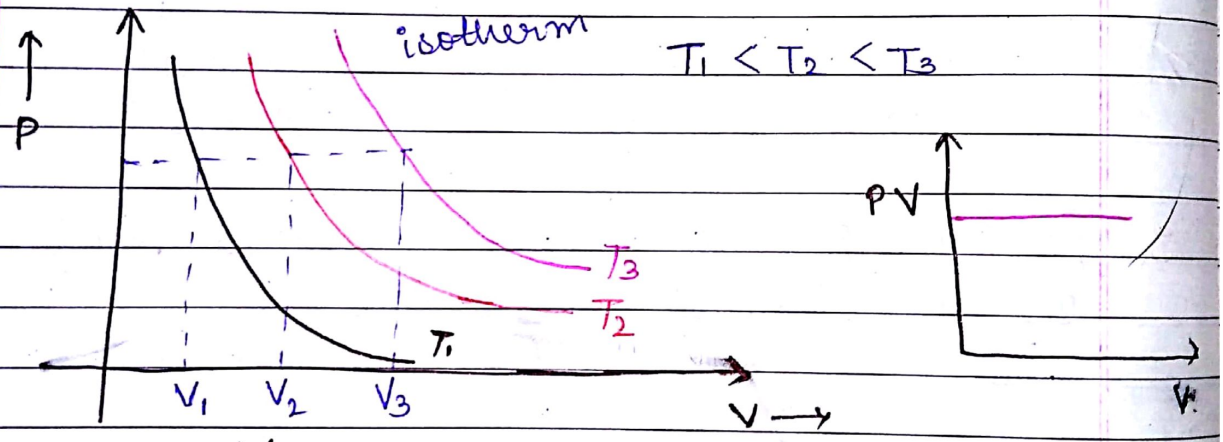
$$P \propto \frac{1}{V}$$

$$P = \frac{K}{V}$$

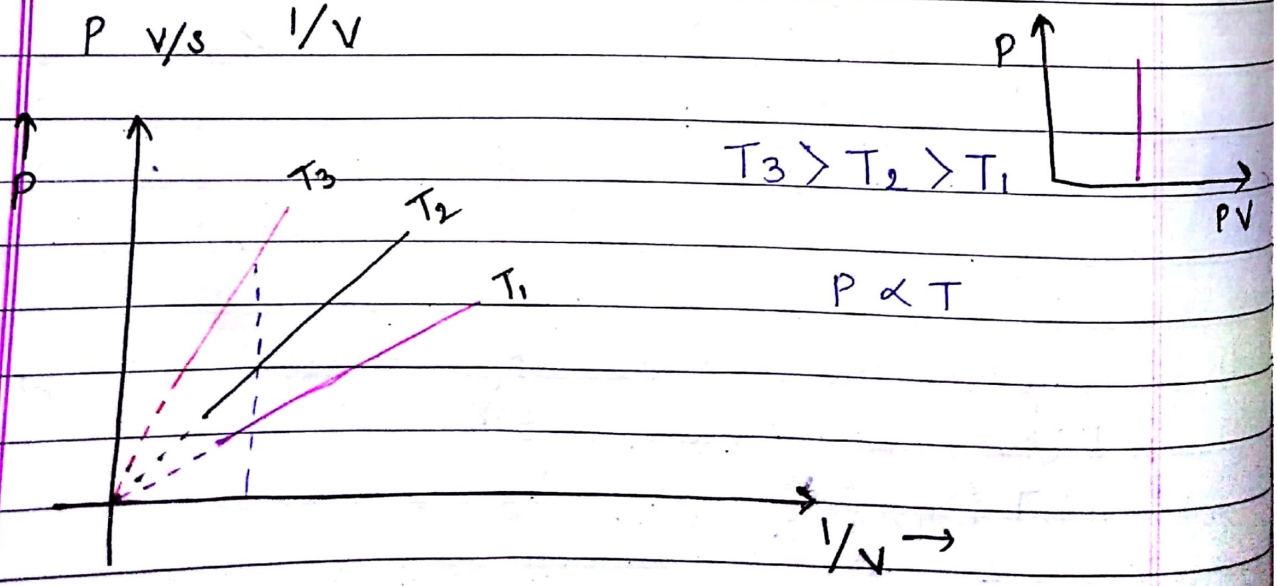
$$PV = K$$

$$P_1V_1 = P_2V_2 = P_3V_3 = - - - = \text{const.}$$

P v/s V



P v/s 1/V



2. **Charle's Law :-** At const Pressure, a fixed volume of amt. of gas varies directly with temp.

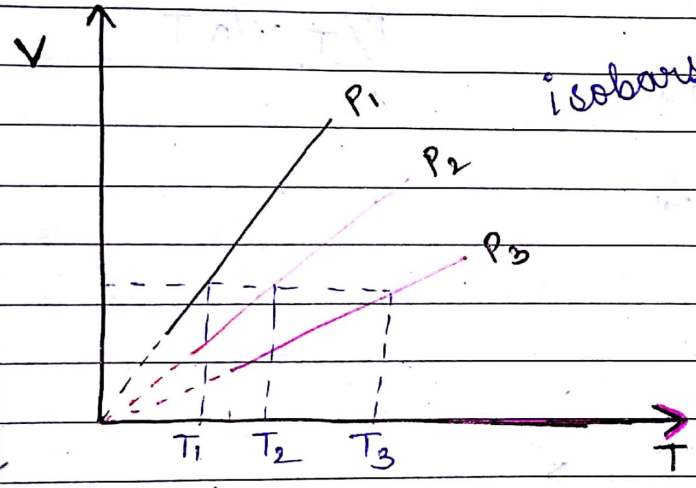
P, n = const.

$V \propto T$

$V = KT$

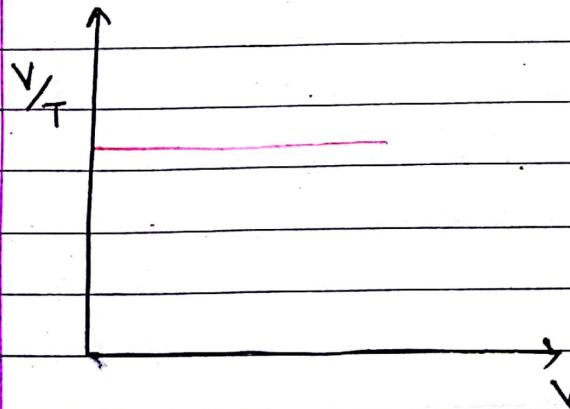
$\frac{V}{T} = K$

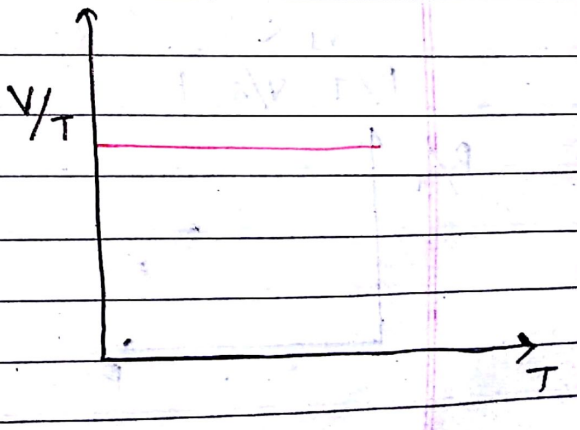
V v/s T



$P_1 < P_2 < P_3$

V/T v/s V





3. **Gay Lussac Law:** At const volume, pressure of a fixed amt. of gas varies directly with temp.

n, V = const.

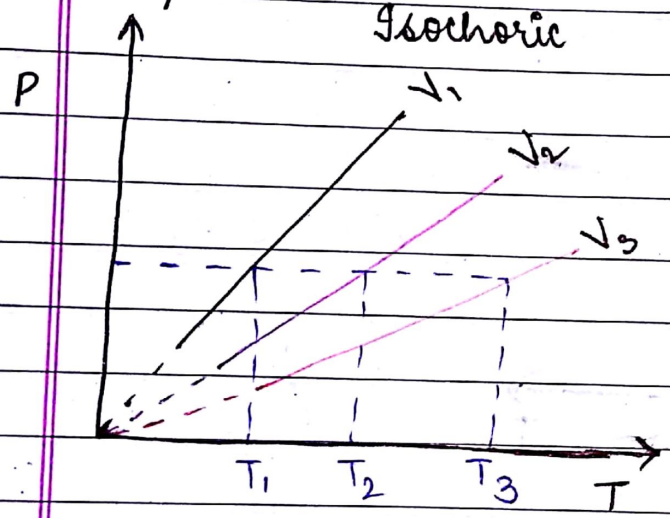
$P \propto T$

$P = KT$

$\frac{P}{T} = K$

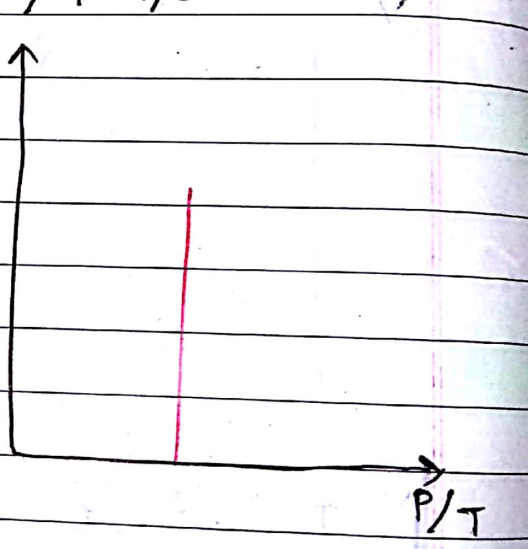
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

P v/s T

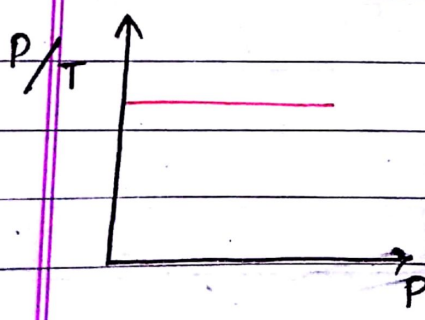


$V_1 < V_2 < V_3$

P/T v/s T



P/T v/s P



Avagadro law :- It states that equal volume of all gases contains equal no. of moles at same temp. and Pressure.

$P, T \rightarrow$ const.

$V \propto n$

$V = Kn$

Ideal gas Equation :-

27°C

1 atm
Sea level atmospheric P.
Open container

$T, n \rightarrow$ const $\quad P \propto \frac{1}{V}$ Boyle's law

$P, n \rightarrow$ const. $\quad V \propto T$ Charle's Law

closed vessel $V, n \rightarrow$ const. $\quad P \propto T$ Gay Lussac's law

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

$$P = \frac{nRT}{V}$$

$$PV = nRT$$

$R \rightarrow$ Universal Gas const.

$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$

$R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$

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

$1 \text{ cal} = 4.18 \text{ J}$

$\simeq 4.2 \text{ J}$

Relation b/w P and density (d)

$PV = nRT$

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

$PM = \frac{m}{V} RT$

$\boxed{PM = dRT}$

Ques At 27°C volume of gas is decreased by 50% when P is increased by 100% then find change in Pressure is if volume is decreased by 25%

$T \to$ const.. $P_1V_1 = P_2V_2$

$P_1 = P + 100\%\ P$

$P_1 = 2P$

$V_1 = V - 50/100\ V = V/2$

$P_2 = ?$

$\Delta P = ?$

$V_2 = V - 25/100\ V$

$= 3/4\ V$

$2P \cdot V/2 = P_2\ 3/4\ V$

$P_2 = 4/3P$

$\Delta P = 4/3P - P = 1/3P$

$\% \Delta P = \frac{4/3P - P}{P} \times 100$

$= 33.33\%$

Ques At 27°C volume of gas is increased by 100% when Pressure is decreased by 50% Find change in volumes if Pressure is decreased upto 25%.

$T \to$ const $P_1V_1 = P_2V_2$

$V_1 = 2V$

$P_1 = 1/2\ P$

$P_2 = 25/100\ P = P/4$

$P_1V_1 = P_2V_2$

$1/2P \times 2V = P/4 \times V_2$

$4V = \frac{4 \times 2}{2} V = V_2$

$\Delta V = 4V - 2V = 3V$

$\% \Delta V = \frac{4V - V}{V} \times 100$

$= \frac{3V}{V} \times 100$

$= 300\%$

ANSWT

Ques At 27°C equal masses of H_2, O_2 & CH_4 are taken then find ratio of their volume if Pressure is const.

Temp, P = const

$V \propto n$

$n_1 = \frac{m}{2}$

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$V_{H_2} : V_{O_2} : V_{CH_4} :: n_{H_2} : n_{O_2} : n_{CH_4}$

$\frac{m}{2} : \frac{m}{32} : \frac{m}{16}$

$\left(1 : \frac{1}{16} : \frac{1}{8}\right) \times 16$

$16 : \frac{16}{16} : \frac{16}{8}$

$16 : 1 : 2$

AIPMT

Ques 500 ml of a gas at 27°C is cooled upto −3°C at identical condⁿ then find new volume of gas ?

$P \rightarrow$ const

$V \propto T$

$\frac{V}{T}$ = const

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

$\frac{500}{300} = \frac{V_2}{270}$

$V_2 = \frac{270 \times 500}{300} = 450$ ml

Ques At 1 atm Pressure & 27°C density of gas is 'd' at what temp. density of gas will be 0.75d, pressure being same ?

$PM = dRT$

$dT \propto$ const.

$d_1 T_1 = d_2 T_2$

$d \times 300 = 0.75 d\, T_2$

$T_2 = \frac{300}{0.75} \times 1 = 400$ K

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Ques Density of Ne gas is maxm at
① STP
② 0°C, 2 atm
③ 1 atm, 27°C
④ 273°C, 2 atm

$PM = dRT$

$\frac{P}{T} \propto d$

$\frac{1}{1}$

Ques A balloon is filled with hydrogen at room temp. It will burst if Pressure exceeds 0.2 bar. If at 1 bar pressure the gas occupies 2.27 L. Volume upto what volume can the balloon be expanded.

$P_1V_1 = P_2V_2$

$1 \times 2.27 = 0.2\, V_2$

$V_2 = \frac{2.27 \times 10}{0.2\ \ 10}$

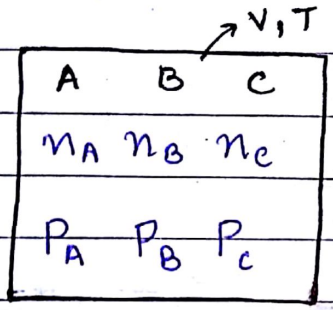
$= \frac{22.7}{2}$

$= 11.3$ L

Ques On a ship in Pacific ocean where temp. is 23.4°C. A balloon is filled with 2 L air. What the vol. of the balloon when ship reaches Indian ocean where temp is 26.1°C

Dalton's Law :- (non-reactive gases)
In a mixture of non-reactive gases, total pressure of gaseous mixture is sum of partial pressure of all gases.

O_2 + Ne = O_2 + Ne
0.2 atm 0.6 atm 0.8 atm



$P_T = P_A + P_B + P_C$

$PV = nRT$

$P_A = \frac{n_A RT}{V}$

$P_B = \frac{n_B RT}{V}$

$P_C = \frac{n_C RT}{V}$

$P_T = P_A + P_B + P_C$

$= (n_A + n_B + n_C)\frac{RT}{V}$

$P_T = \frac{n_T RT}{V}$

$\frac{P_A}{P_T} = \frac{\frac{n_A RT}{V}}{\frac{n_T RT}{V}}$

$\frac{P_A}{P_T} = \frac{n_A}{n_T} = X_A$

$P_A = X_A P_T$

$P_B = X_B P_T$

$P_C = X_C P_T$

Ques Equal masses of O_2 & ~~CH_4~~ N_2 are +nt in a container then find ratio of their Partial Pressure.

$P_{O_2} = \frac{n_{O_2} RT}{V}$

$P_{N_2} = \frac{n_{N_2} RT}{V}$

$\frac{P_{O_2}}{P_{N_2}} = \frac{n_{O_2}}{n_{N_2}} = \frac{m/32}{m/28} = \frac{28}{32} = \frac{7}{8}$

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Ques In a container, equal masses of He, O_2 & N_2 are ~~then~~ ~~+nt~~ then find fraction of partial ~~part~~ Pressure ~~ert~~ exerted by O_2?

$\frac{P_{O_2}}{P_T}$

~~$P_{He} = n_{He} RT$~~

$$n_{He} = \frac{m}{4}$$

$$n_{O_2} = \frac{m}{32}$$

$$n_{N_2} = \frac{m}{28}$$

4 | 32, 28
4 | 8, 7
2 | 2, 7
1, 7

$$n_T = \frac{m}{4} + \frac{m}{32} + \frac{m}{28}$$

$$= m\left(\frac{32 \times 7 + 28 + 32}{32 \times 28}\right)$$

$$= m\left(\frac{224 + 28 + 32}{32 \times 28}\right)$$

$$\frac{P_{O_2}}{P_T} = X_{O_2}$$

$$= \frac{m/32}{m\,\frac{284}{32 \times 28}} = \frac{28}{284}$$

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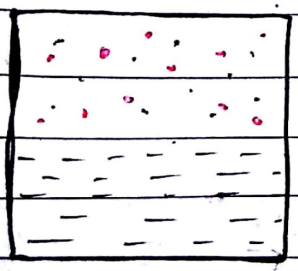


$P_{dry\ gas} = P_{Total} - aqueous\ Tension$

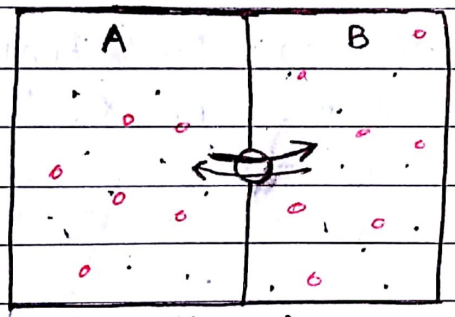
Pressure of saturated water vapours is called aq. Tension

Graham's Law of diffusion and effusion :-

When 2 or more gases are allowed to mix in a container then due to random motion of gaseous molecules intermixing of gases takes place is k/n as diffusion.

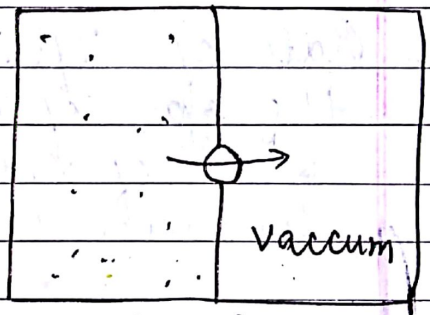
* Lighter molecules diffuse faster than heavier molecules.

→ when gas particles are allowed to move out through a pin hole towards low pressure region, process is k/n as effusion. Gaseous particles move from higher conc^n to lower conc^n.



diffusion

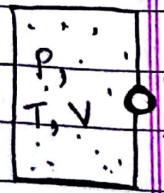
Pext. = const.



Effusion

Pext. = vary

Law :- At const. Pressure and temp., rate of diffusion/effusion is inversely proportion to square root of density.



at const P & T

$$r \propto \frac{1}{\sqrt{d}}$$

$$r \propto \frac{1}{\sqrt{V.D.}}$$

$$r \propto \frac{P}{\sqrt{T.M}} \cdot A$$

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

$$r = \frac{l \text{ diffused gas}}{t} = \frac{V \text{ diffused gas}}{t} = \frac{n \text{ diffused gas}}{t}$$

IIT

Ques If He & CH_4 are allowed to diffused in a gaseous container at 27°C & 1 atm then ratio of rate of diffusion of He & CH_4

(1) 2 (2) ~~2.5~~ 0.25 (3) 0.5 (4) 4

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

$$\frac{r_{He}}{r_{CH_4}} = \sqrt{\frac{M_{CH_4}}{M_{He}}} = \sqrt{\frac{16}{4}} = \sqrt{4} = 2$$

Ques Rate of diffusion of SO_2 gas is 2 times the rate of diffusion of a gas X. then M.wt of X at STP.

Let rate of diff. of X be → r_X

$$r_{SO_2} = 2\, r_X$$

$$\sqrt{\frac{M_{W_X}}{M_{W_{SO_2}}}} = \frac{r_{SO_2}}{r_X} = 2$$

$$\sqrt{\frac{M_{W_X}}{64}} = 2$$

$$\frac{\sqrt{M_{W_X}}}{8} = 2$$

$$\sqrt{M_{W_X}} = 16$$

$$M_{W_X} = 256$$

$$\begin{array}{r} 16 \\ \times 16 \\ \hline 96 \\ 16\times \\ \hline 256 \end{array}$$

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Ques Which gas diffuse faster at same T & P

(1) He $\sqrt{4} = 2$ (2) SO_2 $\sqrt{64} = 8$ (3) CO_2 $\sqrt{44} = 6.$ (4) N_2 $\sqrt{28} = 5.$

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

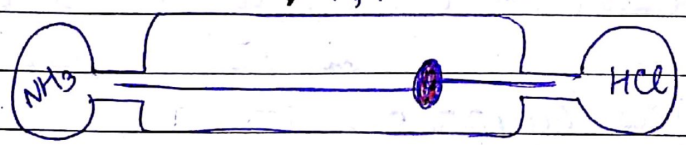
$\sqrt{M} \downarrow \; r \uparrow$

(1) H_2 $\sqrt{2} = 1.$ (2) H_2S $\sqrt{34} = 5.$ (3) O_2 $\sqrt{32} = 5.$ (4) Cl_2 $\sqrt{71} = 8.$

IIT

Ques 2 bottles of ammonia ($\sqrt{17}$) & hydrogen chloride ($\sqrt{36.5}$) are connected through a tube and opened simultaneously. Then white rings are ammonium chlorides are formed at :-

(1) at centre of tube
(2) near hydrogen chloride bottle
(3) near ammonia bottle
(4) no white rings are formed



$r \propto \frac{1}{\sqrt{M}}$ $\quad r = \frac{l_{diff.}}{t}$

Ques At const temp, rate of diffusion of gas A & B is directly proportional to

(1) $\left(\frac{P_A}{P_B}\right)\left(\frac{M_A}{M_B}\right)^{1/2}$ (3) $\left(\frac{P_A}{P_B}\right)\left(\frac{M_B}{M_A}\right)^{1/2}$

(2) $\left(\frac{P_A}{P_B}\right)^{1/2}\left(\frac{M_A}{M_B}\right)$ (4) $\left(\frac{P_B}{P_A}\right)^{1/2}\left(\frac{M_B}{M_A}\right)$

$r \propto \frac{P}{\sqrt{TM}}$ A $\qquad r \propto \frac{P}{\sqrt{M}}$

$$\frac{r_A}{r_B} = \frac{P_A}{P_B}\sqrt{\frac{M_B}{M_A}} = \left(\frac{P_A}{P_B}\right)\left(\frac{M_B}{M_A}\right)^{1/2}$$

Kinetic Molecular Theory of Gases :-

Assumptions

- Gaseous particles (atom / molecules) are very small & identical in size.
- Volume of gaseous particles is very small compare to space b/w them so these gaseous particles are considered as point mass
- There is no force of attraction b/w gaseous particles so their motion is random.
- Due to random motion, particles collides with each other and this collision is perfectly elastic i.e. no loss of energy during collision.
- Gaseous ~~g~~ exerts pressure ~~b/c~~ due to collision b/w gaseous particle & wall of container.
- K.E. of gaseous particles $\propto$ absolute Temp.

Kinetic gas equation :-

$$PV = \frac{1}{3} mNu^2$$

N → no. of molecules
m → mass of gas molecule
u → v_{rms}

$$= \frac{2}{3} N \left(\frac{1}{2} mu^2\right)$$

$\frac{1}{2}mu^2$ → K.E. of a gas molecules

$$= \frac{2}{3} N \cdot e$$

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

E_K → avg. K.E. of gas

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

$$E_K = \frac{3}{2} nRT \qquad PV = nRT$$

For $n = 1$ mole

$$E_K = \frac{3}{2} RT$$

↳ K.E. of NA molecules

→ K.E. of one molecule

$$E_K = \frac{3}{2} \frac{R}{N_A} T$$

$$K.E. = \frac{3}{2} KT$$

$$K = \frac{R}{N_A} \quad \text{Boltzman's const.}$$

$\frac{8.314}{6.02 \times 10^{23}} = 1.38 \times 10^{-23}$

$$K = 1.38 \times 10^{-23} \, JK^{-1}$$

$$ML^2T^{-2}K^{-1}$$

Velocity of Gaseous molecules :-

1. Average velocity $= \frac{n_1u_1 + n_2u_2 + \cdots + n_nu_n}{n_1 + n_2 + \cdots + n_n}$

$$v_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8PV}{\pi M}}$$

2. Root mean square speed $= \sqrt{\frac{n_1u_1^2 + n_2u_2^2 + \cdots + n_nu_n^2}{n_1 + n_2 + \cdots + n_n}}$

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}}$$

3. Most Probable Speed : It speed of max^m gaseous molecules

$$v_{MP} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2PV}{M}}$$

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$V_{MP} : V_{avg} : V_{rms} = \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}}$

AIPMT $= \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$

JEE Mains 2013 $= 1 : 1.128 : 1.224$

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Ques A gas is ~~cooled~~ from 27°C is heated upto 927°C then its averaged velocity is

① $\sqrt{\frac{927}{27}}$ of earlier value

② same

③ halved

④ doubled

$V \propto \sqrt{T}$

$\frac{V_{27°C}}{V_{927°C}} = \sqrt{\frac{300}{1200}}$

$\frac{V_{27°C}}{V_{927°C}} = \frac{1}{2}$

$V_{927°C} = 2 V_{27°C}$

$V_{av_1} = \sqrt{\frac{8RT}{\pi M}}$

$\sqrt{\frac{8R \times 300}{\pi M}}$

$V_{av_2} = \sqrt{\frac{8R \times 1200}{\pi M}}$

$= 2 V_{av_1} \sqrt{4}$

$= 2 V_{av_1}$

927
273
1200

Ques Ratio of root mean square root speed of H_2 at 50K & O_2 at 800K

$V = \sqrt{\frac{3RT}{M}}$

$V = \sqrt{T}$

$\frac{V_{H_2}}{V_{O_2}} = \sqrt{\frac{8}{32}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

$$v \propto \sqrt{\frac{T}{M}}$$

$$\frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{T_{H_2}}{M_{H_2}} \times \frac{M_{O_2}}{T_{O_2}}}$$

$$= \sqrt{\frac{80}{2} \times \frac{32}{80} \frac{16}{16}} = \sqrt{\frac{16}{16}}$$

$$= \frac{1}{1}$$

Ques write ↑ order of root mean square speed of H_2, O_2, CO_2, HBr

$\sqrt{2}$. $\sqrt{32}$ = 5. $\sqrt{44}$ = 6. $\sqrt{}$

= 1.

$$v = \sqrt{\frac{3RT}{M_w}}$$

$$v \propto \sqrt{\frac{1}{M_w}}$$

$v \downarrow$ $M \uparrow$

$$HBr < CO_2 < O_2 < H_2$$

Ques At what temp. rms speed of methane is same as that of oxygen at 300 K.

$$v_{rms\ CH_4} = v_{rms\ O_2}$$

$$\sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3RT}{M_w}}$$

$$\sqrt{\frac{T}{16}} = \sqrt{\frac{300}{32}}$$

$$\frac{T}{16} = \frac{300}{32} \quad 150\ K = 150\ K$$

Ques Ratio of rms of H_2, O_2, SO_2 at 300 K

$$v_{H_2} : v_{O_2} : v_{SO_2}$$

$$\left(\frac{1}{\sqrt{2}} : \frac{1}{\sqrt{32}} : \frac{1}{\sqrt{64}}\right) \times \sqrt{64} \Rightarrow \sqrt{32} : \sqrt{2} : 1$$

$$4\sqrt{2} : \sqrt{2} : 1$$

Ques At const Pressure, root mean square ~~root~~ speed of a gas ~~vas~~ varies with density as

(1) d (2) d^{-1} (3) $d^{1/2}$ (4) $d^{-1/2}$

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{d}}$$

$$PV = nRT$$

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

$$PM = \frac{W}{V}RT$$

$$PM = dRT$$

$$\boxed{\frac{P}{d} = \frac{RT}{M}}$$

Real Gases :-

- Real Gas molecule have definite volume.
- Force of attraction b/w particles is not zero.
- Real Gases behaves as ideal gases at low pressure and high temp.
- Deviation of Real Gas from Ideal behaviour can be explained by compressibility factor (Z)

$$Z = \frac{(PV)_{real}}{(PV)_{ideal}}$$

at $n = 1$ $\quad V_{real} = V_m$ → molar volume of a gas

$$Z = \frac{PV_m}{RT}$$

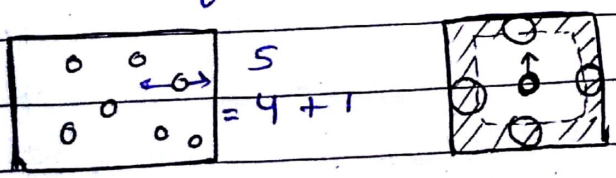
$Z = 1$ $\quad PV_m = RT$ → real gas behave as ideal gas

$Z \neq 1$ $\quad PV_m \neq RT$ → real gas behaviour.

Real Gas Equation / Vanderwaal Eq^n

$$\left(P + \underbrace{\frac{an^2}{V^2}}_{\text{corr}^n \text{ in Pressure of real gas to consider to imf}}\right)\left(V - \underbrace{nb}_{\text{Correction in Volume to consider definite vol. of molecules.}}\right) = nRT$$

(ideal Pr. → P_{real}; ideal Vol. → V_{real})



$n=1$ $\left(P+\frac{a}{V^2}\right)(V-b) = RT$

$PV - Pb + \frac{a}{V} - \frac{ab}{V^2} = RT$ ($\frac{ab}{V^2} \to 0$)

$PV = RT + Pb - \frac{a}{V}$

$\frac{PV}{RT} = 1 + \frac{Pb}{RT} - \frac{a}{VRT}$

at low Pr $\frac{PV}{RT} = 1 - \frac{a}{VRT}$ $Z<1$ at low Pr. Real Gas show -ve deviation

at high Pr $\frac{PV}{RT} = 1 + \frac{Pb}{RT}$ $Z>1$ at high Pr Real Gas show +ve deviation

Unit of a

$\frac{an^2}{V^2} = \text{Pressure}$

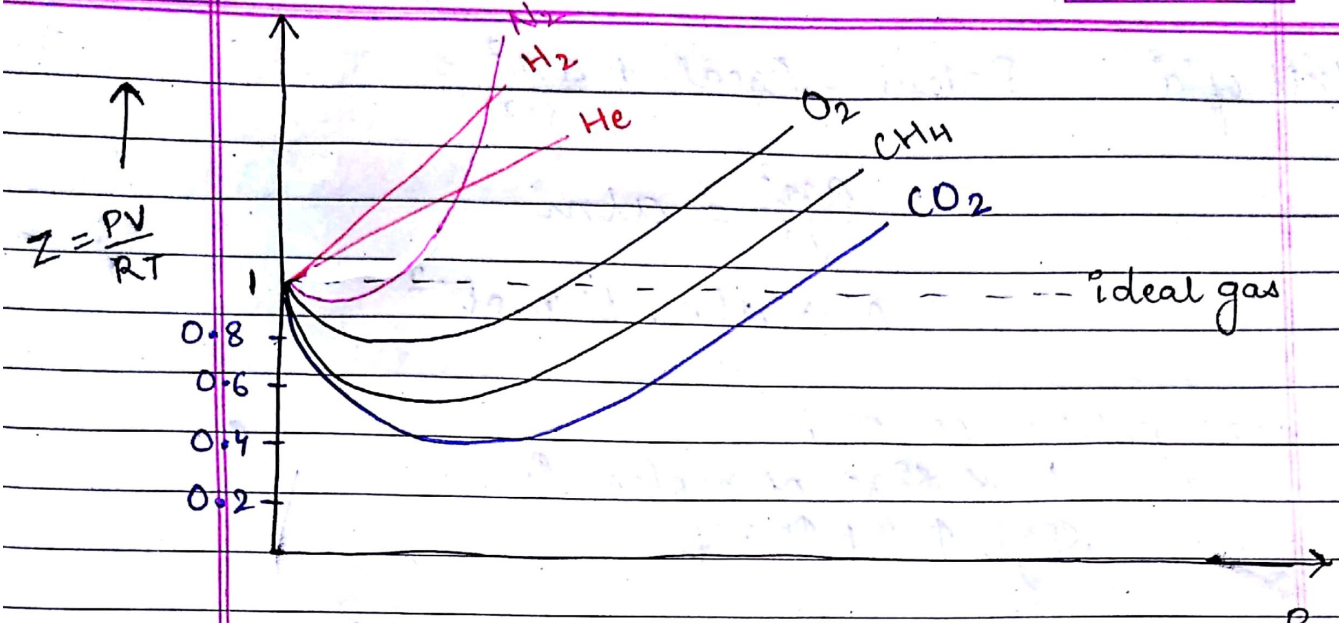
$a = \frac{P \times V^2}{n^2} = \frac{N/m^2 \times L^2}{mol^2}$

$= \frac{N L^2}{m^2 mol^2}$

Unit of b

Volume $= nb$

$b = \frac{V}{n} = \frac{L}{mol} = L\,mol^{-1}$



→ CO_2 can be liquified easily.

→ H_2 & He can't be liquified at very high Pressure.

– ve deviation ↑ liquification ↑

Significance of 'a' :-

$a \propto imf$

liquification of a gas $\propto imf \propto a$

$a \uparrow imf \uparrow$ liquification ↑

For Polar molecule :-

$a_{H_2O} > a_{NH_3}$ dipole-dipole att^n

polar > nonpolar

$a_{NH_3} > a_{CH_4}$

for non polar molecule :- $imf \propto Mw$

$a_{CO_2} > a_{C_2H_4}$ $a_{C_2H_6} > a_{CH_4}$

Unit of 'a' $P_{ideal} = P_{real} + \frac{an^2}{V^2}$

$\frac{an^2}{V^2} = atm$

$a \rightarrow atm\ L^2\ mol^{-2}$

Significance of b

b ∝ size of molecule

Size ↑ b ↑ V ↓

Unit of 'b' $V_{ideal} = V_{real} - nb$

$nb = L$

$b \Rightarrow L\ mol^{-1}$

Ques which of the following gas can be liquified easily?

① He × ② N_2 × ③ CH_4 (non polar) ④ NH_3 → ~~non~~ polar

① H_2 (2) ② O_2 (32) ③ N_2 (28) ④ Cl_2

① CH_4 ② C_2H_6 ③ C_3H_4 ④ C_5H_{12} Mw ↑

Ques Under which of the following cond^n gas shows min^m deviation from ideal behaviour.

① 473 K, 2 atm ② 5 :

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Ques which of following terms represent correction factor in pressure
① RT ② $(RT)^{-1}$ ③ $V-b$ ④ $P+\frac{a}{V^2}$

Liquification of gases :-
High Pressure, low Temp. → which are easily liquify

Critical Temperature :- (T_c)
The min. temp above which a gas cannot be liquify.

$$T_c = \frac{8a}{27Rb}$$

ideal gas :- $a = 0 \quad T_c = 0$
↳ can't be liquify.

Critical Pressure : (P_c)
During liquification of gas, pressure at T_c is called critical Pressure.

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

Critical Volume (V_c) :-
Volume at critical temp. c/a critical volume.

$$V_c = 3b$$

Condⁿ for Liquification :- $T < T_c$ $P > P_c$

$$Z = \frac{P_c V_c}{RT_c} = \frac{a/27b^2 \times 3b}{R \times \frac{8a}{27Rb}} = \frac{3}{8}$$

$$P_c V_c = \frac{3}{8} RT_c$$