'KINETIC THEORY OF GASES (K.T.G)'

Assumption about K.T.G

|i| → Gasses consist of large no. of small particle. Wich is called molecules, each Molecules of gas is identical & behave as a solid, Rigid, elastic Sphere.

*|ii| → Collision b/w Gas molecule & container wall is perfectelly elastic (Momentum & Energy both are conserved) (Energy loss = 0)

*|iii| → Size of Gas molecule is negligible (10^{-24} kg) that's why effect of Gravity is not consider. It means density of gas Molecule is same energy.
Exemplar

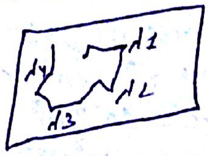
A/R AIIMS |iv| → Size of Gas Molecule is negligible that's why It occupied complete volume of container (vol of gas = vol. of container)

|v| → There is no attractive or, Repulsive between gas molecules.

*|vi| → Time b/w two successive collision & contact time during collision ($1 : 10^{-8}$).

|vii| → Average distance b/w two successive collision is called mean free path.

$$\langle \lambda \rangle = \frac{\lambda_1 + \lambda_2 + \cdots \lambda_N}{N}$$



$$= \frac{\text{total distance in 'N' collision}}{\text{No. of collision.}}$$

Gas equation ⇒

AIIMS 2016

$$\boxed{PV = \mu RT}$$

Press. of gas ← P

V ← vol. of gas = vol. of container

μ → No. of Moles $\frac{M}{M_W}, \frac{N}{N_A}$

R → universal gas const. $R = 8.31 \frac{J}{mole}, \frac{2\,cal}{mol}$

T ← Temp. of Gas.

|II| →

P (unit) :→ $\frac{N}{m^2}$, $\frac{D}{cm^2}$, pa, bar, atm pr, mm of Hg column, Torr.

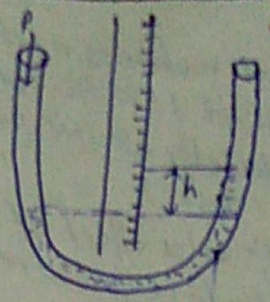
$1 \frac{D}{cm^2} = 10^{-2} \frac{N}{m^2}$ | 1 pascal (pa) = 1 N/m^2

1 bar = $10^5 N/m^2$ | 1 atm pr. = $10^5 N/m^2$

760 mm of Hg column
or,
76 cm of Hg column
or,
0.76 m " "
] = 1 atm pr. = $10^5 N/m^2$

m = mass of one Molecule
M = Mass of gas = m.N
M_W = Molecular wt = m N_A
N = total no. of Molecule
K = Boltzman const = R/N_A
= 1.38×10^{-23} J/K

Pressure measurment :→

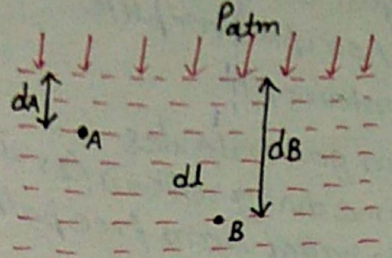


$$\boxed{P = hd_l g}$$

$$\boxed{h = \frac{P}{d_l g}}$$

$$P = 1\,atm \begin{cases} \to h_{Hg} = \dfrac{P_{atm}}{d_{Hg}\, g} = 0.76\,m \\ \to h_{H_2O} = \dfrac{P_{atm}}{d_{H_2O}} = \dfrac{10^5}{10^3 \times 10} = 10\,m \end{cases}$$

$$\boxed{* \ 10\,m \text{ Water column} = 1 \text{ atm pressure.}}$$



$$\boxed{P_A = P_{atm} + d_A d_l g}$$

$$\boxed{P_A = P_{atm} + d_B d_l g}$$

|II|→ V = volume of gas = volme of container.

*unit → m^3, cm^3 (c.c), liter, ml

$1\,c.c = 10^{-6} m^3$

$1\,liter = 10^3 cm^3 = 10^{-3} m^3$

$1\,ml = 10^{-3} lit = 1\,c.c = 10^{-6} m^3$

|III|→ μ = No. of moles $= \frac{M}{M_W} = \frac{N}{N_A}$

M = mass of gas = mN

M_W = Mol. wt of gas = mN_A

N = no. of molecules

m = mass of 1 gas molecule.

IV→ R = gas constant

= 8.31 J/mole K

= 1.98 cal/molK

≃ 2 cal/mole K.

|V|→ T = Tempm. of gas

unit → S.I. $\boxed{K}$, °C, °F, °R, Ra

n = molecular density $= \frac{\text{no. of molecule}}{\text{vol.}}$

$$\boxed{n = \frac{N}{V}}$$

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

$$\boxed{\rho = mn}$$

Diff. form of Gas equation

$$\boxed{PV = \mu RT}$$

$\mu = \frac{M}{M_W}$

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

$P = \left(\frac{M}{V}\right) \frac{RT}{M_W}$.

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

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

$P = \frac{\rho TK}{m}$

$\mu = \frac{N}{N_A}$

$P = \frac{N}{N_A} RT$

$PV = NKT$

$$\boxed{\frac{R}{N_A} = K = \text{Boltzman const}}$$

*

$PV = \mu RT$

$PV = NKT$

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

$P = \frac{\rho TK}{m}$

***

condn	P	T	V
NTP	1atm	0°c = 273.15K	22.4 lit
STP	1 atm	0.01°c = 273.16K	22.4 lit
S.A.T.P	1atm	25°c	24.2 lit

2.

'GAS LAW'

[A]→ Galusac Law
[B]→ charles law
[C]→ Boyle's law
[D]→ Dalton's partial press. mix. law
[E]→ Law of mix
[F]→ Law of Diffusion.

[A]→ **Graylusac Law** → At const. volume same quantity press is directelly propersnal to Temp.

$P = \frac{\mu R}{V} T$

$P \propto T$

$\frac{P}{T} = K_3$ → Graylusac const.

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

$K_3 = \frac{\mu R}{V} / \frac{NK}{V}$

[B]→ **charls law**:→ At const. press. for same quantity volume is directelly propersnal to temp.

$P = \mu RT$

$V = T$

$\frac{V}{T} = K_2$ → charls const.

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

$K_2 = \frac{\mu R}{P} / \frac{NK}{P}$

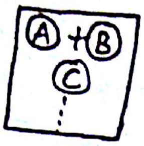
[C]→ **Boyles Law**:→ At const. temp. for same quantity press is Inversally propersnal to volume.

$PV = \mu KT = NKT$

$PV = K_1 \Rightarrow P \propto \frac{1}{V}$

K_1 = Boyles law const $= \mu RT / NKT$

[D] → **Dalton partial pressure mix. law** → In a same container at thermal eq^m condition pressure of gaseous mixture is a scalar addition of indivisual press. of gas.



$$\boxed{P_{mix} = P_A + P_B + P_C - - - -}$$

$T = c, V = c$

$$\boxed{P_{mix} = \frac{RT}{V}(\mu_A + \mu_B + \mu_C + - - - -}$$

$$\boxed{P_{mix} = \mu_{mix}\frac{RT}{V}}$$

$$\boxed{M_{mix} = M_A + M_B + M_C + - - -}$$

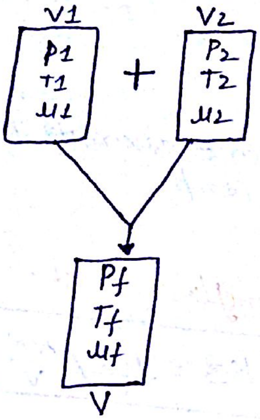
$$\rho_{mix} = \frac{M_{mix}}{V} = \frac{M_A + M_B + M_C + - - -}{V}$$

$$M\overset{m}{w}_{mix} = \frac{M_1 w_1 + M_2 \cancel{m} w_2 + - - -}{M_1 + M_2 + - - -}$$

[E] → **Law of Mixture** →

(i) → **Law of Mass conservation**

(a) →



$$\mu_1 + \mu_2 = \mu_f$$

$$\frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2} = \frac{P_fV_f}{RT_f}$$

$$\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2} = \frac{P_fV_f}{T_f}$$

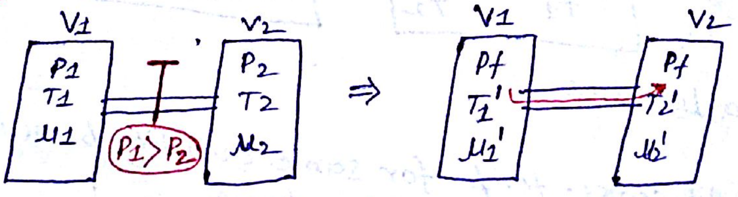
$$\# \quad T_1 = T_2 = T_f \Rightarrow \boxed{P_f = \frac{P_1V_1 + P_2V_2}{V_f}}$$

$$\# \quad V_1 = V_2 = V_f \Rightarrow \boxed{\frac{P_1}{T_1} + \frac{P_2}{T_2} = \frac{P_f}{T_f}}$$

$$\left.\begin{matrix} V_1 = V_2 = V_f \\ T_1 = T_2 = T_f \end{matrix}\right] \Rightarrow \boxed{P_f = P_1 + P_2}$$

Dalton law.

(b) →



$$\mu_1 + \mu_2 = \mu_1' \, \mu_2'$$

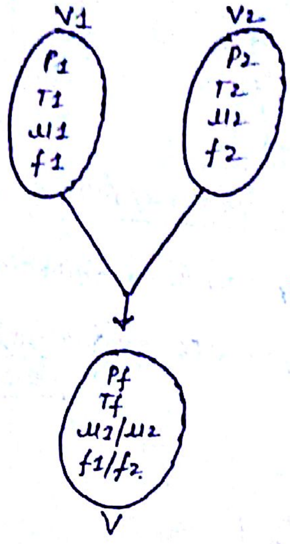
$$\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2} = \frac{P_fV_1}{T_1'} + \frac{P_fV_2}{T_2'}$$

$$\# \quad T_1' = T_2' = T_1 = T_2 \Rightarrow \boxed{P_f = \frac{P_1V_1 + P_2V_2}{V_1 + V_2}}$$

$$\# \quad V_1 = V_2 \Rightarrow \frac{P_1}{T_1} + \frac{P_2}{T_2} = \boxed{\frac{P_f}{T_1'} + \frac{P_f}{T_2'}}$$

$$\# \quad \left.\begin{matrix} V_1 = V_2 \\ T_1 = T_2 = T_1' = T_2' \end{matrix}\right] \Rightarrow \boxed{P_f = \frac{P_1 + P_2}{2}} \Rightarrow P_{avg}.$$

(iii) → Law of Energy conservation →



$$\boxed{E_i = E_f}$$

$$\mu_1\left(\frac{f_1}{2}RT_1\right)+\mu_2\left(\frac{f_2}{2}RT_2\right)=\mu_1\left(\frac{f_1}{2}RT_f\right)+\mu_2\left(\frac{f_2}{2}RT_f\right)$$

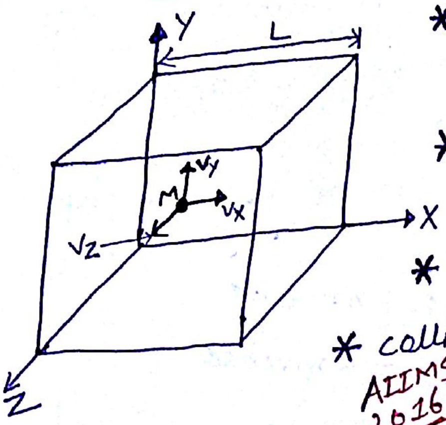
*** $$\boxed{T_f = \frac{\mu_1 f_1 T_1 + \mu_2 f_2 T_2}{\mu_1 f_1 + \mu_2 f_2}}$$

[F] → Law of Diffusion →

Rate of diffusion is Inversally propertional to the square root of Mw of gas at const Temp. & press.

** $$\boxed{r_d \propto \frac{1}{\sqrt{Mw}} \propto \frac{1}{\sqrt{\rho}} \propto V_{r.m.s}}$$

3. → Pressure exerted by gas in a container :→



* change in momentum of 1 molecule in X-direction

$\vec{\Delta p} = \vec{p_f} - \vec{p_i} = -mv_x - (mv_x) = \boxed{-2mv_x}$

* Momentum transfer to the surface in X-direction $|\vec{\Delta p}| = \boxed{2mv_x}$

* time b/w two collision $t = \frac{\text{Distance}}{\text{speed}} = \boxed{\frac{2L}{v_x}}$

* collision frequency (f_c)

AIIMS 2016

$$\boxed{f_c = \frac{1}{t} = \frac{v_x}{2L} = \frac{V_{R.M.S}}{2\sqrt{3}\,L}}$$

* Force exerted by 1 molecule in X-direction

$F_{1x} = \frac{|d\vec{p}|}{dt} = (f_c)(|d\vec{p}|) = \left(\frac{v_x}{2L}\right)(2mv_x) = \boxed{\frac{2v_x^2}{L}}$

* Force exerted by 'N' malecule in X-direction.

$$\boxed{F_x = NF_{1x} = N\left(\frac{mv_x^2}{L}\right) = \frac{Mv_x^2}{L} \quad (M = mN)}$$

* Pressure exerted by 'N' malecule in X-direction.

$$\boxed{P_x = \frac{mv_x^2}{V}, \quad P_y = \frac{mv_y^2}{V}, \quad P_z = \frac{Mv_z^2}{V}}$$

$V_x = V_y = V_z$

$$\boxed{P_x = P_y = P_z = P_{net}}$$

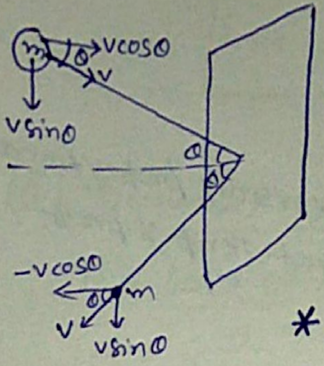
$$\boxed{P_{net} = \frac{1}{3}\left(\frac{M}{V}\right) V^2_{R.M.S}}$$

Translational K.E

$$\boxed{K.E_t = \frac{1}{2} m V^2_{r.m.s}}$$

$$\boxed{\frac{K.E_t}{P} = \frac{3}{2} V}$$

Gas molecule incident at an angle 'θ' from Normal :→



* change in momentum Due to 1 Molecule

- → $\vec{\Delta p}_{\parallel} = mv\sin\theta - mv\sin\alpha = \boxed{0}$
- → $\vec{\Delta p}_{\perp} = -mv\cos\theta - (mv\cos\theta) = -2mv\cos\theta$ $\boxed{= -2mv\cos\theta}$

* Momentum transfer to the Surface

- → $|\vec{\Delta p}_{\parallel}| = \boxed{0}$
- → $|\vec{\Delta p}_{\perp}| = \boxed{2mv\cos\theta}$

* Force duce due to 'N' Molecule

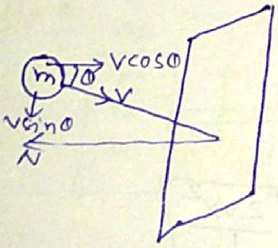
- → $\vec{F}_{\parallel} = \frac{dp_{\parallel}}{dt} = \boxed{0}$
- → $F_{\perp} = \frac{dp_{\perp}}{dt} = \left(\frac{2mv\cos\theta}{t}\right)N$

$\frac{N}{t} = n$ = no. of Molecule incident per unit time.

$$\boxed{F_{\perp} = n(2mv\cos\theta)}$$

$$* \boxed{Press = \frac{F_{\perp}}{A} = \frac{n(2mv\cos\theta)}{A}}$$

If surface is perfectelly absorbing :→



* $\vec{\Delta p}_{\parallel} = \boxed{0} - mv\sin\theta = -mv\sin\theta$

$\vec{\Delta p}_{\perp} = \boxed{0} - (mv\cos\theta) = -mv\cos\theta$

*

- → $|\vec{\Delta p}_{\parallel}| = \boxed{mv\sin\theta}$
- → $|\vec{\Delta p}_{\perp}| = \boxed{mv\cos\theta}$

*

- → $\vec{F}_{\parallel} = |dp_{\parallel}|$ $\boxed{\neq 0 \Rightarrow \text{stress}}$
- → $F_{\perp} = \frac{dp_{\perp}}{dt} = \boxed{\left(\frac{mv\cos\theta}{t}\right)N}$

$\frac{N}{t} = n$ = no of molecule incedent per unit time.

$$* \boxed{Press = \frac{F_{\perp}}{A} = \frac{n(mv\cos\theta)}{A}}$$

$$\boxed{F_{\perp} = n(mv\cos\theta}$$

Relation b/w $V_{R.M.S}$ & P, V, T

$$V_{R.M.S} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}}$$

***
***

$$\boxed{\begin{aligned} V_{RMS} &= \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{Mw}} = \sqrt{\frac{3KT}{m}} \\ V_{avg} &= \sqrt{\frac{8}{\pi}\frac{PV}{M}} = \sqrt{\frac{8}{\pi}\frac{P}{\rho}} = \sqrt{\frac{8}{\pi}\frac{RT}{Mw}} = \sqrt{\frac{8}{\pi}\frac{KT}{m}} \\ V_{M.P} &= \sqrt{\frac{2PV}{m}} = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2RT}{Mw}} = \sqrt{\frac{2KT}{m}} \\ V_{\text{sound in gaseous medium}} &= \sqrt{\frac{\gamma PV}{M}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{Mw}} = \sqrt{\frac{\gamma KT}{m}} \end{aligned}}$$

Aakash test

$\boxed{R > A > M > S}$

γ or y = sp. heat ratio

At const temp. for same gas →

$$\boxed{V_{R.M.S} > V_{avg} > V_{M.P} > V_{\text{sound in gases medium}}}$$

Factor Affecting :→

(i) → Effect of temp →

$$\boxed{V_{R.M.S} = \sqrt{\frac{3RT}{Mw}} = \sqrt{\frac{3KT}{m}}}$$

(a) → Gas same → $(M_w = c,\ m = c,\ \gamma = c)$

$$\boxed{V \propto \sqrt{T}}$$

→ $T\uparrow \Rightarrow V\uparrow$

→ $T\downarrow \Rightarrow V\downarrow$

(b) → Gas different → $V_{R.M.S} = \sqrt{\frac{3RT}{Mw}} \propto \sqrt{\frac{T}{Mw}}$

T = same = $V \propto \sqrt{\frac{1}{Mw}}$

↓

V_{max} for H_2 gas.

* $\boxed{V \propto \sqrt{T}}$

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

AIIMS

Prob :→ Atm. ⊕nt on Earth but Non on Moon Why ?

Ans → $V_{R.M.S}$ of gases at surface of earth is less than from escape velocity of earth that's why atm. ⊕nt on earth but it is more than from Vescape of moon & escape from surface of moon.

NOTE → Escape velocity Independent from mass of particle but escape temp. depend on molecular wt.

Earth

$$\boxed{V_{R.M.S} \leq V_{escape}}$$

$V_{R.M.S}$ ⇓ $8\,\frac{km}{sec}$; V_{escape} ⇓ $11{\cdot}2\,km/sec$

* Gases Ⓟnt on Earth

Moon

$$\boxed{(V)_{O_2} > V_{escape}}$$

$(V)_{O_2}$ ⇓ $4\,\frac{km}{sec}$; V_{escape} ⇓ $2{\cdot}7\,km/sec$

* Gases escape from planet.

Escape temp: → Min temp of atm at which gases escape from planet is called escape temp.

$$T \uparrow \Rightarrow V_{R.M.S} \uparrow \Rightarrow \boxed{V_{R.M.S} \geq V_{escape}} \Rightarrow \text{Gases escape from planet.}$$

$$\sqrt{\frac{3RT}{mw}} \geq V_{escape}$$

$$T \geq \frac{Mw}{3R} V_{escape}^2$$

$$* \boxed{(T_{min})_{escape} = \frac{Mw}{3R} V_{escape}^2}$$

$$* \boxed{V_{escape} = \sqrt{\frac{2GM}{R}} = \sqrt{2Rg} \propto m^0}$$

AIIMS

Ex → $\overset{Earth}{V_{escape}} = 11{\cdot}2\,km/sec$

|i| → $(T_{H_2})_{min} = \frac{2\times10^{-3}}{3\times8{\cdot}31}(11{\cdot}2\times10^3)^2 = \underline{10^4 K} = \underline{10{,}000 K}$

|ii| → $T \propto Mw \Rightarrow T_{O_2} = 16\,H_2$

$= 16\times10^4$

$= \underline{1{\cdot}6\times10^5 K}$

Effect of pressure: →

$$V_{R.M.S} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}}$$

* At const. temp. (for same gas) velo. of gas Remain unchange with pressure.

$$P = \rho\frac{RT}{mw} \qquad \frac{P}{\rho} = \frac{RT}{mw}$$

$$\boxed{\frac{P}{\rho} = \frac{RT}{mw} = const}$$

→ $P\uparrow \Rightarrow \rho\uparrow \Rightarrow P/\rho \Rightarrow const \Rightarrow V_{R.M.S} = const$

→ $P\downarrow \Rightarrow \rho\downarrow \Rightarrow \frac{P}{\rho} \Rightarrow const \Rightarrow V_{R.M.S} = const.$

Real gas eqn → * Due to finite size of real gas molecule it can not occupy complete volume container i.e volume of real gas is less than from volume of container.

"That correction in volume of ideal gas is called vollume correction.

$\boxed{\Delta V = b}$ b = volume correction or, Vander Wall co-efficient.

*$\boxed{V_{Real\ Gas} < V_{Real\ gas}}$ V = volume of container

$V_R = V - \Delta V$

*$\boxed{V_R = v - b}$

Ideal gas for 1 mole

$PV_R = (1)RT$

*$\boxed{P = \frac{RT}{v-b}}$

AIIMS

A/R

* Due to interatomic attraction force Ent b/w Real gas molecule pressure* exerted by real gas is less than from ideal gas that correction in pressure is called press. correction.

$\boxed{P_{Real\ gas} < P_{Ideal\ gas}}$

$\boxed{\Delta P = \frac{a}{V^2} = \text{Pr. correction}}$

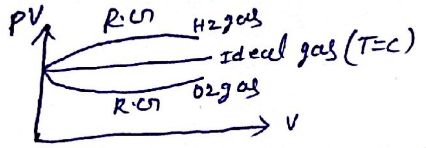
a = vanderWall pr. co.coff.

$$\boxed{\begin{aligned} a &= N \times m^4 = [M^1 L^5 T^{-2}] \\ b &= m^3 = M^0 L^3 T^0 \end{aligned}}$$

$$\boxed{\left(P_R + \frac{a}{V^2}\right)(v-b) = RT}$$

$$\boxed{\left(P_R + \frac{\mu a^2}{V^2}\right)(V - \mu b) = \mu RT}$$

Amaghat Exp:→ At 'high temp. & low press.' real gas behave as a Ideal gas.



Boyles tem(T_b) → Minm temp. of real gases at ~~which~~ Wich it behave as a ideal gas.

$\boxed{T_b = \frac{a}{Rb}}$

NOTE→ a & b depend on nature of gas i.e Why Boyles temp. is diff. for diff real gases.

Dr. Andrewz exp. or, Isothermal curve of CO_2 gas → At const. temp. on ↑ pressure of Real gas decrease & then it is liquified.

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

critical temp (T_c) • Temp. above which liquification of gas is not possible from press. is called critical temp.

$\boxed{T_c \text{ for } CO_2 = 31.15^\circ C}$

$\boxed{T_c = \frac{8a}{27Rb}}$ $\boxed{T_b = \frac{a}{Rb}}$ * $\boxed{\begin{array}{c} T_b > T_c \\ \hline T_c = \frac{8}{27} T_b \end{array}}$

critical press (P_c) → At critical temp. minm required press. for liquification of gas.

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

critical volume (V_c) :→ Vol. of 1 mole Real gas at critical press. & critical temp.

$\boxed{V_c = 3b}$ ~~[illegible]~~

* P_c, V_c, T_c is different for diff Real gas.

$\boxed{\frac{P_c V_c}{RT_c} = 3/8}$ ⟶ For 1 mole real gas.

$\boxed{\frac{PV}{RT} = 1}$ ⟶ for 1 mole Ideal gas.

NOTE → Liquification of ideal gas is not possible with pressure critical paraeten is valid only for real gases.

NOTE → Average of Even power velocity is not equal to zero. but avg. of odd power velocity is zero.