NEET - UG

NATIONAL TESTING AGENCY

Chemistry

Inorganic Chemistry
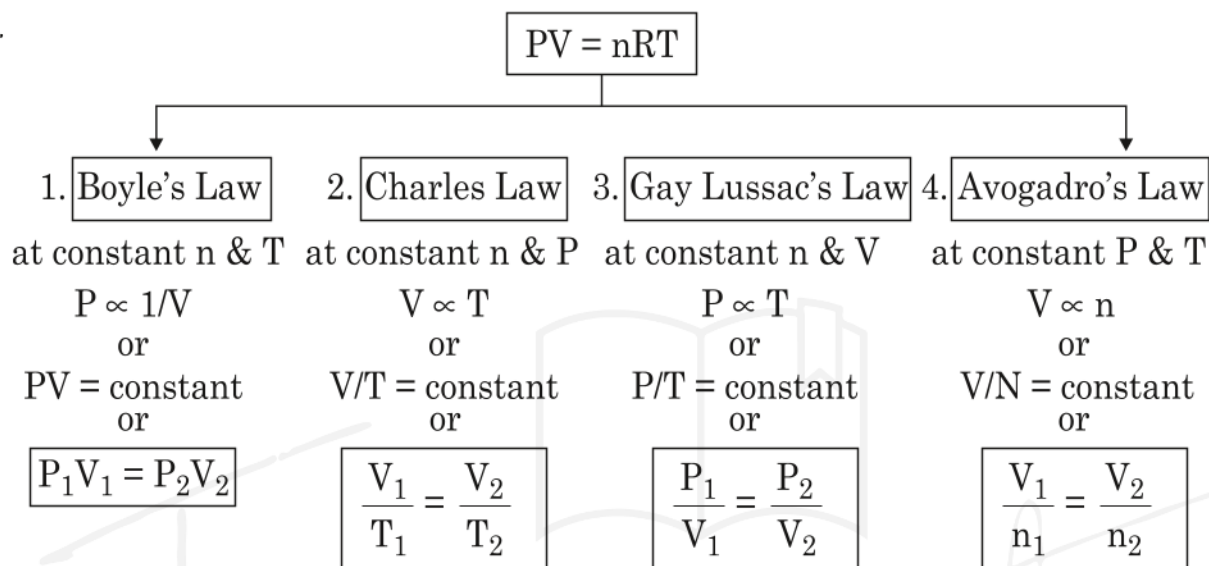
INDEX

Inorganic Chemistry

"Gaseous State"

Ideal Gas Equation

A.

$$PV = nRT$$

1. Boyle's Law	2. Charles Law	3. Gay Lussac's Law	4. Avogadro's Law
at constant n & T	at constant n & P	at constant n & V	at constant P & T
$P \propto 1/V$	$V \propto T$	$P \propto T$	$V \propto n$
or	or	or	or
PV = constant	V/T = constant	P/T = constant	V/N = constant
or	or	or	or
$P_1V_1 = P_2V_2$	$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$	$\dfrac{P_1}{V_1} = \dfrac{P_2}{V_2}$	$\dfrac{V_1}{n_1} = \dfrac{V_2}{n_2}$

$$\left(\begin{array}{l} P = \text{Pressure, } V = \text{Volume, } T = \text{Temperature} \\ n = \text{moles, } R = \text{Universal gas constant} \end{array} \right)$$

B. Pressure

$$p = hdg$$

(d = density, p = pressure)

1. 760 mm of Hg = 760 torr = 1 atm = 101325 Pascal $\left(\dfrac{N}{m^2} \right)$

   = 76 cm of Hg = 0.76 m of Hg

2. 1 atm = $\underset{(h)}{0.76 \, m} \times \underset{(d)}{13.6 \times 10^3 \, \dfrac{kg}{m^3}} \times \underset{(g)}{9.8 \, \dfrac{m}{sec^2}} = 101325 \, \dfrac{N}{m^2}$

3. 1 atm = 760 mm of Hg

   = 760 Torr.

   = 101325 Pascal (N/m^2)

   = 101325×10^5 Pa   [Since, 10^5 Pa = 1 bar]

   = 1.01325 bar

C. Volume

1. $1 \text{ cm}^3 = 1 \text{ ml} = 1 \text{ cc}$ [Since, 1 dm = 10 cm]

   $1000 \text{ cm}^3 = 1 \text{ L} = 1 \text{ dm}^3$

2. $1 \text{ m}^3 = 10^6 \text{ cm}^3 = 1000 \text{ L} = 10^3 \text{ dm}^3$

3. $R = \dfrac{PV}{nT}$

D. R = Gas Constant

   at STP, Vol. of 1 mole gas = 22.4 L

   $ST = 0°\text{C} = 273 \text{ K}$

   $SP = 1 \text{ atm}$

   $V = 22.4 \text{ Ltr}$

   $n = 1 \text{ mole}$

1. $R = \dfrac{1 \text{ atm} \times 22.4 \text{ Ltr}}{1 \text{ mole} \times 273 \text{ K}} = 0.0821 \text{ atm Ltr/mole K}$

2. $R = \dfrac{1.01325 \text{ bar} \times 22.4 \text{ Ltr}}{1 \text{ mole} \times 273 \text{ K}} = 0.083 \text{ bar Ltr/mole K}$

3. $R = \dfrac{101325 \, \dfrac{\text{N}}{\text{m}^2} \times 22.4 \times 10^{-3} \text{ m}^3}{1 \text{ mole} \times 273 \text{ K}} = 8.314 \text{ J/mole K} \quad (\text{Nm} = \text{J})$

4. In terms of Calorie,   1 Cal = 4.18 J

   $R = \dfrac{8.314}{4.18} \text{ Cal/mol K} = 1.99 \approx 2 \text{ Cal/mol K}$

   1 atm Ltr = 101.325 J

Diffusion : Effusion

* A self movement of gas particles in all direction in a system to form a homogenous mixture is called diffusion.

* Diffusion through a small hole is called Effusion (unidirection movement of particle)

A. Rate of diffusion

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

$$r \propto \frac{1}{\sqrt{d}} \Rightarrow \text{Graham's Law of diffusion}$$

d = Vapour density of gas

* Under similar conditions of temperature and pressure, relative rate of diffusion of gases is inversely proportional to square root of their vapour densities.

For A gas,   For B gas

$$r_A \times \frac{1}{\sqrt{d_A}} \qquad r_B \propto \frac{1}{\sqrt{d_B}}$$

so, $$\frac{r_A}{r_B} = \sqrt{\frac{d_B}{d_A}}$$ Complete relation $$\frac{r_A}{r_B} = \frac{P_A}{P_B}\sqrt{\frac{d_B}{d_A}}$$

1. $$\frac{r_A}{r_B} = \frac{P_A}{P_B}\sqrt{\frac{M_B}{M_A}}, \text{ Molar mass of gas.}$$

2. Rate of diffusion $$= \frac{\text{Diffused volume}}{\text{Time taken in diffusion}} = \frac{V}{t}$$

$$\frac{r_A}{r_B} = \frac{V_A}{t_A} \times \frac{t_B}{V_B} = \frac{P_A}{P_B}\sqrt{\frac{M_B}{M_A}}$$

At same T & P, $V \propto n$

$$\frac{r_A}{r_B} = \frac{n_A}{t_A} \times \frac{t_B}{n_B} = \dots$$

$$\because n = \frac{w}{m}$$

$$\Rightarrow \frac{r_A}{r_B} = \frac{w_A}{M_A t_A} \times \frac{M_B t_B}{w_B} = \frac{P_A}{P_B}\sqrt{\frac{M_B}{M_A}}, \text{ weight of gas}$$

$$\Rightarrow \frac{w_A}{t_A} \times \frac{t_B}{w_B} = \frac{P_A}{P_B}\sqrt{\frac{M_A}{M_B}} \neq \frac{r_A}{r_B}$$

Kinetic Theory of Gases

A. Speeds → 3 types

1. Most probable speed : $[R_{MP}] = \sqrt{\dfrac{2RT}{m}}$

For 1 mole of gas $RT = PV$, $R_{MP} = \sqrt{\dfrac{2RT}{m}} = \sqrt{\dfrac{2PV}{m}}$

2. Average Speed : $V_{av} = \dfrac{V_1 + V_2 + V_3 + \ldots}{n} = \sqrt{\dfrac{8RT}{\pi M}} = \sqrt{\dfrac{8PV}{\pi M}}$

3. RMS Speed : $V_{RMS} = \sqrt{\dfrac{V_1^2 + V_2^2 + V_3^2 + \ldots}{n}} = \sqrt{\dfrac{3RT}{M}} = \sqrt{\dfrac{3PV}{M}}$

$$\boxed{V_{MP} : V_{AV} : V_{RMS}}$$

$$\sqrt{\dfrac{2RT}{M}} : \sqrt{\dfrac{8RT}{\pi M}} : \sqrt{\dfrac{3RT}{M}} \qquad\qquad \boxed{V_{MP} < V_{AV} < V_{RMS}}$$

$$\sqrt{2} : \sqrt{\dfrac{8}{\pi}} : \sqrt{3}$$

$$\boxed{1 \quad : \quad 1.12 \quad : \quad 1.22}$$

Q. Calculate different types of speeds of H_2 molecules at 300 K temperature.

$$R_{MP} = \sqrt{\dfrac{2 \times 8.314 \times 300}{2 \times 10^{-3}}} = \sqrt{24.9 \times 10^5} = \sqrt{25 \times 10^5}$$

$$R_{MP} = 5 \times 10^{5/2}$$

$$V_{AV} = 1.12 \times 5 \times 10^{5/2} = 5.6 \times 10^{5/2}$$

$$V_{RMS} = 1.22 \times 5 \times 10^{5/2} = 6.1 \times 10^{5/2}$$

B. Kinetic Energy : Molar Kinetic Energy of gas $= \dfrac{3}{2} RT$ Energy/mole

$\Rightarrow$ for n moles of gas, total $KE = \dfrac{3}{2} RT \times n$ Energy

$\Rightarrow$ Average Kinetic Energy of gas molecules $= \dfrac{3}{2} \dfrac{RT}{\cdot N_A} = \dfrac{3}{2} KT$ Energy/molecular

$\Rightarrow K$ = Boltzmann constant $= \dfrac{R}{N_A}$

$\Rightarrow K = \dfrac{8.314\,\text{J}}{6 \times 10^{23}\ \text{molecules} \times \text{K}} = 1.38 \times 10^{-23}$ J/mole K.

$\boxed{KE \propto T}$

Q. Calculate Kinetic Energy of 8 g methane at 127°C and average Kinetic Energy of molecules also.

$$KE = \dfrac{3}{2} \times 8.314 \times 400 \times \dfrac{8}{16} = 24.9 \times 100 = 2490 \text{ J}$$

$$KE_{av} = \dfrac{3}{2} \times \dfrac{RT}{N_A} = \dfrac{3}{2} KT = \dfrac{3}{2} \times 1.38 \times 10^{-23} \times 400$$

$$KE_{av} = 2.07 \times 10^{-23} \times 400 = 8.28 \times 10^{-21} \text{ J/molecule K}$$

Q. A gas at a P of 5 atm is heated from 0°C to 546°C and simultaneously compressed to 1/3 rd of its original volume calculate its final P.

$$\dfrac{P_1 V_1}{n T_1} = \dfrac{P_2 V_2}{n T_2}$$

$$\dfrac{5 \times V}{273} = \dfrac{P_2 \times V}{819 \times 3}$$

$$P_2 = \dfrac{3 \times 5 \times 819}{273} = \dfrac{4095}{91} = 45 \text{ atm}$$

or $\qquad T_2 = 3T_1 \Rightarrow P_2 = 3P_1$

$$V_2 = \dfrac{V_1}{3} \Rightarrow P_2 = (3P_1)\,3 = 9P_1 = 45 \text{ atm}$$

or $\qquad \dfrac{P_1 V_1}{P_2 V_2} = \dfrac{n_1 R T_1}{n_2 R T_2} \Rightarrow \dfrac{5 \times V \times 3}{P_2 \times V} = \dfrac{273}{819} \Rightarrow P_2 = 5 \times 3 \times 3 = 45 \text{ atm.}$

Q. 100 ml of a gas A at 600 torr and 500 ml of gas B at 800 torr are placed in a 2 L flask, then calculate final P of gas mixture.

Sol. $100 \times 600 + 500 \times 800 = 2000 \times P$

$$600 + 4000 = 20P$$
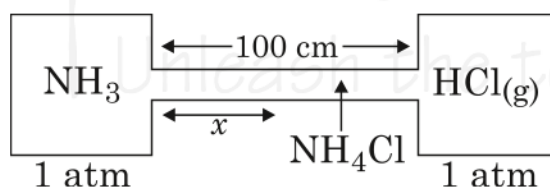
$$460 = 2P \Rightarrow P = 230 \text{ torr}$$

Boyle's law $\boxed{P_A V_A + P_B V_B + \ldots = PV}$

Q. 16 cm^3 H$_2$ gas diffuse in 20 sec. Calculate volume diffused of O$_2$ in the same time.

$$\frac{r_{H_2}}{r_{O_2}} = \frac{V_{H_2}}{V_{O_2}} = \sqrt{\frac{m_{O_2}}{m_{H_2}}}$$

$$\frac{16}{V_{O_2}} = \sqrt{\frac{32}{2}} = \sqrt{16} = 4 \Rightarrow V_{O_2} = 4 \text{ ml.}$$

Q. Condition based

$$NH_3 + HCl \longrightarrow NH_4Cl \text{ (White Fumes)}$$

Sol. $\dfrac{r_{HCl}}{r_{NH_3}} = \dfrac{P_{HCl}}{P_{NH_3}} \sqrt{\dfrac{m_{NH_3}}{m_{HCl}}} = \sqrt{\dfrac{17}{36.5}} = \dfrac{V_{HCl}}{V_{NH_3}} = \dfrac{(100-L)A}{LA}$ $L \to$ Length

$A \to$ Area

$$\frac{(100-L)}{L} = \sqrt{\frac{170}{365}} = \sqrt{\frac{34}{73}}$$

$$\frac{r_{NH_3}}{r_{HCl}} = \frac{V_{NH_3}}{t_{NH_3}} \times \frac{t_{HCl}}{V_{HCl}} = \sqrt{\frac{m_{HCl}}{m_{NH_3}}} = \frac{x \times a}{(100-x)a} = \sqrt{\frac{36.5}{17}}$$

$$\Rightarrow \frac{x}{100-x} = \sqrt{\frac{36.5}{17}} = \sqrt{\frac{73}{34}} = \sqrt{2.14} = 1.42$$

$$x = 142 - 1.42x \Rightarrow 2.42x = 142 \Rightarrow x = \frac{142}{2.42}$$

$$x = \frac{7100}{121} = 58 \text{ cm.}$$

Q. Calculate the temperature at which RMS speed of SO_2 molecules is half that of He molecules at 300 K. $\frac{1}{2}He_{(RMS)} = SO_{2(RMS)}$

Sol. $$\frac{1}{2}\sqrt{\frac{3RT_1}{m_1}} = \sqrt{\frac{3RT_2}{m_2}} \Rightarrow \frac{1}{2}\sqrt{\frac{300}{4}} = \sqrt{\frac{T_2}{64}}$$

$$\Rightarrow \qquad T_2 = \frac{300 \times 64}{4 \times 4} = \frac{4800}{4} = 1200 \text{ K}$$

Q. At masses of He and Ne are 4 and 20 amu respectively. The value of de Broglie λ of He gas at $-73°C$ is M times of that of the de Broglie λ of Ne at $727°C$. Calculate M.

$$\frac{\lambda_{He}}{\lambda_{Ne}} = M = \frac{h/m_1V_1}{h/m_2V_2} = \frac{m_2V_2}{m_1V_1} = M$$

$$\frac{20V_2}{4V} = M \qquad T_1 = 200 \text{ k} \qquad T_2 = 1000 \text{ k}$$

$$\frac{\lambda_{He}}{\lambda_{Ne}} = M = \frac{m_{Ne}V_{Ne}}{m_{He}V_{He}} = \frac{20V_{Ne}}{4V_{He}} = \frac{M_{Ne}}{M_{He}}\sqrt{\frac{T_{Ne}}{M_{Ne}}} \times \sqrt{\frac{M_{He}}{T_{He}}}$$

$$M = \sqrt{\frac{T_{Ne}M_{Ne}}{T_{He}M_{He}}} = \sqrt{\frac{1000 \times 20}{200 \times 4}} = \sqrt{25} = 5$$

$$\Rightarrow \qquad M = 5$$

⚹ Maxwell's Distribution of Speeds

A T temperature, all the molecules of a gas sample do not have same speeds and it is not possible to determine the speeds of individual molecules. On the basis of probability consideration, we can determine only the distribution of mole fractions and relative speeds.
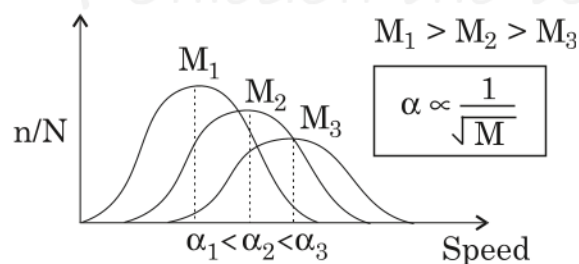
A. Graph between mole fraction and speed

α $\Downarrow$ Most probable speed
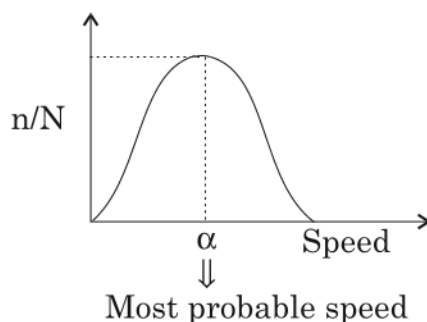
B. For a same gas at different temperature

$(T_1 < T_2 < T_3)$

$$\alpha \propto \sqrt{T}$$

$\alpha_1 < \alpha_2 < \alpha_3$
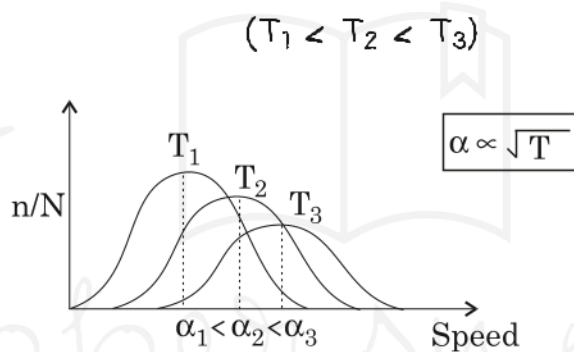
C. Different gases at a particular temperature

$M_1 > M_2 > M_3$

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

$\alpha_1 < \alpha_2 < \alpha_3$

Ideal/Real Gases

* The gases which obey gas laws and gas equation $(PV = nRT)$ at all temperature conditions and at all pressure conditions, are known as ideal gas.

* The molecules of ideal gas are assumed to be volume less with no attractive, repulsive forces between one another.

* No gas is ideal. Only the gases having very low boiling point, like H_2, He, O_2, N_2 etc. nearly behave as ideal.

Ideal Gas	Real Gas
* Obey the gas laws at all temperature and pressure conditions.	* Obey the gas laws at high temperature and low pressure conditions.
* Volume of particles is negligible.	* Volume of molecules is not negligible.
* No attractive or repulsive forces between molecules.	* Attractive forces between molecules existed at high pressure and low temperature.
* Follow the ideal gas equation $PV = nRT$	* Follow the Van der Waal equation $\left(P + \dfrac{an^2}{V^2}\right)(V - nb) = nRT$
* Hypothetical	* All gases are real.

⌗ Van der Waal Equation

Deviation from ideal gas laws.

Correction

A. Volume Correction

* Molecules of a real gas $\rightarrow$ Spherical and rigid particles having a definite volume.

* If volume of container is V, then for 1 mole gas, volume available for compression $= [V - b]$

where $b =$ non-compressible volume for 1 mole molecules.

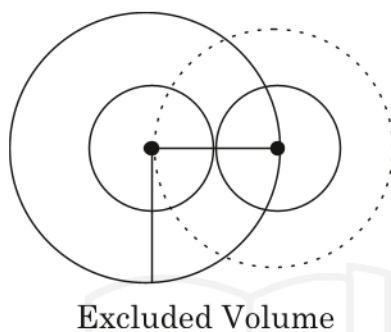$\Rightarrow$ For n moles, volume of gas $= [V - nb]$

$\Rightarrow b =$ Van der Waal constant $=$ depend on size of particle

$$\boxed{b = \frac{4}{3}\pi r^3 \times N_A \times 4} \qquad b = \text{Excluded volume}$$

$\Rightarrow b = \dfrac{4}{3}\pi(2r)^3$

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$$\Rightarrow b = \frac{4}{3}\pi \times 8r^3 = \frac{4}{3}\pi r^3 \times 8$$

For 1 molecule $= \frac{4}{3}\pi r^3 \times \frac{8}{2}$

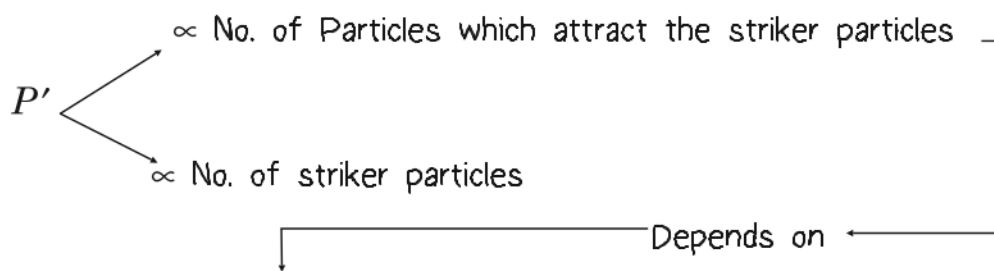Excluded Volume

Value of $b \to$ Depends on size (r)

B. Pressure Correction

$$P_{\text{ideal}} = P_{\text{observed}} + P' \qquad\qquad (P' = \text{pressure correction})$$

$P' \propto$ force of attraction between gas molecules.

$P' \propto$ No. of particles in unit volume.

P'
$\propto$ No. of Particles which attract the striker particles
$\propto$ No. of striker particles

Depends on

No. of particles in unit volume

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

$$\left.\begin{array}{l} P' \propto d \\ P' \propto d \end{array}\right] P' \propto d^2 \Rightarrow P' = ad^2 \Rightarrow \boxed{P' = \frac{an^2}{V^2}}$$

So, $\qquad P_{\text{ideal}} = P_{obs} + \dfrac{an^2}{V^2}$

Since, $P_{\text{ideal}} \, V_{\text{ideal}} = nRT$

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

For 1 mole,

$$\left[P + \frac{a}{V^2}\right][V - b] = RT$$

a, b = Van der Waal constant

$\quad b$ = size of molecule

Unit of b = In terms of volume per mole.

$a \propto$ strength of attraction between molecules (Van der Waal force of attraction)

Unit of $a \Rightarrow P' = \dfrac{an^2}{V^2}$

$$a = \frac{P'V^2}{n^2} = \frac{\text{Pressure} \times V^2}{(\text{mole})^2}$$

$$\boxed{a = \text{atm Ltr}^2 \text{ mole}^{-2}}$$

Case 1. At very low pressure means at very high volume.

For 1 mole gas,

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

Since, $\quad V >>> b$

$\therefore \qquad \left(P + \dfrac{a}{V^2}\right)V = RT \Rightarrow PV + \dfrac{a}{V} = RT$

$\Rightarrow \qquad PV = RT - \dfrac{a}{V}$

$\Rightarrow \qquad \boxed{PV = RT} \qquad \left(\because \dfrac{a}{V} \approx O\right)$

Case 2. At high temperature

T high, Kinetic Energy high, pressure will be high

↓

To maintain the constant pressure

↓

Volume ↑ = high

⇓

$$\boxed{PV = RT}$$

Q. Calculate the P exerted by 8.5 g of NH_3 contained in 0.5 L container at 300 K. For NH_3 $a = 4$ atm L^2/mol^2 and $b = 0.036$ L/mol, compare the value if the gas were considered as ideal.

$$P = \frac{nRT}{(V-nb)} - \frac{an^2}{V^2} = \frac{0.5 \times 0.0821 \times 300}{(0.5 - 0.5 \times 0.036)} - \frac{4 \times 0.25}{0.25}$$

$$P = \frac{24.63}{0.964} - 4 = 25.51 - 4 = 21.51 \text{ atm}$$

$$P_{\text{ideal}} = \frac{0.5 \times 0.0821 \times 300}{0.5} = 24.6 \text{ atm.}$$

Liquefaction of Gases

* If temperature of gas ↓, Kinetic Energy of molecules ↓, means molecular motion becomes slow and they come closer.

* Because they are unable to resist the attraction between and at a sufficient low temperature, size of voids between molecules becomes less than 10^{-5} cm and they convert into liquid state.

* Liquefaction of gases also can be achieved by increment in pressure.

* Temperature decrement is more effective than increment in pressure.

* If temperature of gas ↑ses, minimum pressure required for Liquefaction also ↑ses.

A. Critical Temperature

The temperature above which a gas cannot be liquified whatever the pressure applied.
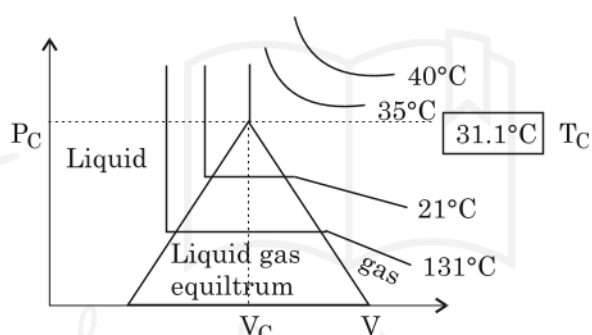
B. Critical Pressure

The minimum pressure required for Liquefaction of a gas at critical temperature conditions.

C. Critical Volume

Volume of one mole gas at critical temperature and critical pressure conditions.

PV Isotherm (CO_2)

Relation of Critical Parameters with a, b

$$V_C = 3b, \ P_C = \frac{a}{27b^2}$$

$$T_C = \frac{8a}{27Rb} \implies \boxed{T_C \propto a}$$

Compressibility Factor

$$Z = \frac{\text{Volume of 1 mole of real gas}}{\text{Volume of 1 mole of ideal gas}} \ [\text{at same T, P}]$$

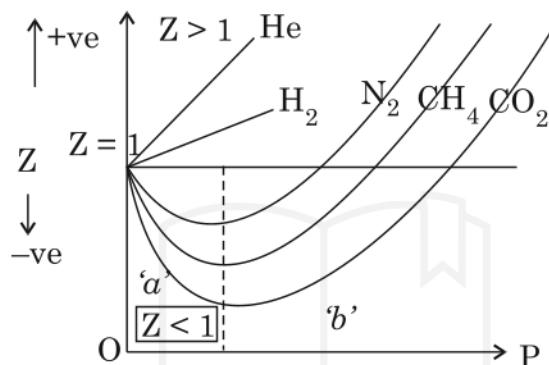$$Z = \frac{V_R}{V_I}, \qquad \left(PV = RT, \ V_I = \frac{RT}{P}\right)$$

$$\boxed{Z = \frac{V_R \times R}{RT}}$$

* **Case 1.** If $Z = 1 \implies$ Gas behaves as ideal.

* **Case 2.** If $Z > 1 \Rightarrow$ Repulsion force dominant between gas molecules.,
  For these gases, compression is difficult.

  [This condition achieved at high pressure]

* **Case 3.** If $Z < 1 \Rightarrow$ Attraction forces are dominant between gas molecules.
  In this condition, gases can easily be compressed as compared to ideal gas.

At very low pressure $\rightarrow$ All gases behave as ideal.

At Low pressure $\rightarrow Z\downarrow$, $Z = \dfrac{PV}{RT} < 1 \Rightarrow PV < RT$

Q. What will be value of Z in terms of critical parameters?

Sol. $Z = \dfrac{PV}{RT} = \dfrac{P_C V_C}{RT_C} = \left(\dfrac{a}{27b^2}\right)\dfrac{(3b)(27Rb)}{(8a)(R)}$

$Z = \dfrac{3}{8} = 0.375$

Q. The critical constant for water are 374°C, 218 atm and 0.0566 L/mol, Calculated a, b.

Sol. $b = \dfrac{V_c}{3} = \dfrac{0.0566}{3} = 0.0189$

$a = \dfrac{218 \times 27 \times (0.0566)^2}{9}$

$a = 654 \times 125 \times 10^{-6}$

$\dfrac{P_C}{T_C} = \dfrac{a}{27b^2} \times \dfrac{27Rb}{8a} = \dfrac{R}{8b}$

Q. The numerical value of a is maximum for

(a) NH_3　　　(b) O_2　　　(c) H_2　　　(d) He

Sol. (a) NH_3

Q. The value of a for gases O_2, N_2, NH_3 and CH_4 are 1.360, 1.390, 4.170 and 2.253 atm L^2 mol^{-2}. Then the gas which can most easily be liquified.

Sol. Liquefaction $\propto T_C \propto a \Rightarrow NH_3\,(a\uparrow)$.

Q. The compressibility factor of a gas is less than unit. Then

(1) $V_m > 22.4L$　　　　　(3) $V_m < 22.4\,L$

(2) $V_m = 22.4\,L$　　　　(4) $V_m = 44.8\,L$

Sol. (3) $V_m < 22.4$ L, $PV < RT \Rightarrow V = 22.4$

Q. The Van der Waal parameters of 2 gases are

	Value of 'a'	Value of 'b'
Gas A	6.5	0.056
Gas B	18.0	0.011

On their basis, which are correct?

(1) V_C of $A < V_C$ of B ✗

(2) P_C of $A > P_C$ of B ✗

(3) T_C of $A < T_C$ of B ✓

(4) Ease of liquefaction of $A > B$ ✗ (Since, $T_{C_b}\uparrow \therefore Ease_b\uparrow$)

Sol. (1) $V_C = 3b \propto b$　(3) $T_C \propto \dfrac{a}{b}$

(2) $P_C = \dfrac{a}{27b^2} \propto \dfrac{a}{b^2}$ For b, $a\uparrow b\downarrow$

$\Rightarrow$ nume $\uparrow$ of $P_{CB} > P_{CA}$