

Gas. State is characterized by following physical prop



1. Gases are highly compressible ✓
2. Gases exert pressure equally in all direction. ✓
3. Gases have much lower density than solids and liquids. ✓
4. The volume and shape of gases are fixed these assume volume and shape of container ✓
5. Gases mix completely in all proportions without any mechanical aid ✓

Boyle's Law



At const temp for a fixed amount of a gas pressure is inversely proportional to the volume

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

state 1 state 2
 P_1, V_1 P_2, V_2

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

$$PV = k$$

$$P_1V_1 = P_2V_2$$

$$PV = \text{const}$$

>> Units

Pressure

1 atm = 760 mm of Hg

= 76 cm of Hg

= 1 bar

= 760 torr

= 14.7 psi

= 100000 pa (N/m²)

Volume

1 L = 1000 ml or cc

= 1/1000 m³

= 1 dm³



Temp °C & K

27°C 300K

(27+273)



Q.

A gas is present in 10 L container at 5 atm pressure find pressure (in torr) when volume of gas is increased to 100 L at 27°C ?

$$V_1 = 10 \text{ L} , V_2 = 100 \text{ L}$$

$$P_2 = \frac{1}{2} \times 760$$

$$P_1 = 5 \text{ atm} , P_2 = ?$$

$$P_1 V_1 = P_2 V_2$$

$$P_2 = 380 \text{ torr}$$

$$10 \times 5 = P_2 \times 100$$

$$P_2 = \frac{50}{100}$$

$$P_2 = \frac{1}{2} \text{ atm}$$

Q.

If pressure of the gas is increased by 5% then find the % decrease in volume at const temp?



$$P_1 = P$$

$$P_2 = P_1 + \frac{5P_1}{100}$$

$$P_1 V_1 = P_2 V_2$$

$$P_2 = \frac{105 P_1}{100} = \frac{105 P}{100}$$

$$PV = \frac{105 P}{100} V_2$$

$$V_1 = V$$

$$V_2 = ?$$

$$V_2 = \frac{100 V}{105}$$

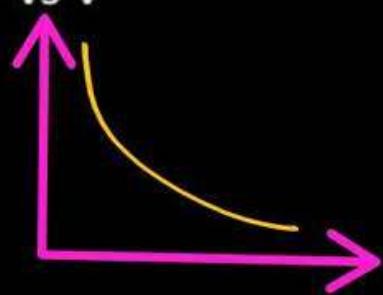
$$\% \text{ change} = \frac{|V_2 - V_1|}{V_1} \times 100$$

$$= \left(\frac{\left| \frac{100 V}{105} - V \right|}{V} \right) \times 100 = \frac{5}{105} \times 100 = \frac{500}{105}$$



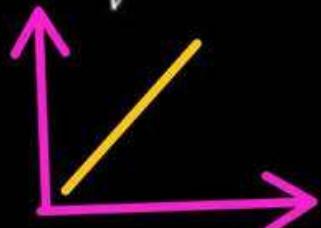
Graphs Boyles law

1. P vs V



$$PV = K$$

2. P vs $\frac{1}{V}$

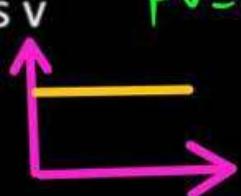


$$PV = K$$

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

$$P = K \times \frac{1}{V}$$

5. Pv vs v



$$PV = K$$

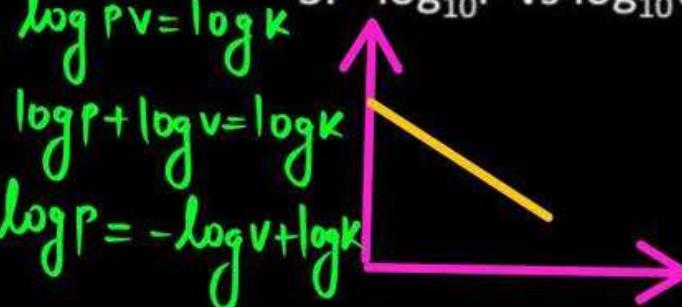
$$PV = K$$

$$\log PV = \log K$$

$$\log P + \log V = \log K$$

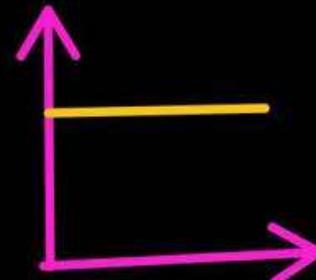
$$\log P = -\log V + \log K$$

3. $\log_{10} P$ vs $\log_{10} V$



$$PV = K$$

4. Pv vs p



Charle's Law



For each $^{\circ}\text{C}$ rise in temp, volume of a gas increases by $\frac{1}{273.15}$ of the original volume of gas at 0°C at const pressure.

OR

At const pressure for a fixed amount of a gas volume is directly proportional to the absolute temp (T in k)

$$V \propto T$$

$$V = kT$$

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

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

$$\begin{array}{ll} \text{state 1} & \text{state 2} \\ V_1, T_1 & V_2, T_2 \end{array}$$

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



Q.

A sample of a gas has a volume 0.2 L at 1 atm pressure and 0°C. Find volume at 273°C when pressure kept const?

$$P = \text{const}$$

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

$$\frac{0.2}{273} = \frac{V_2}{273}$$

$$V_2 = 0.4 \text{ L}$$



Q.

On a ship sailing in pacific ocean where temp is 23.4°C , a balloon is filled with 2L . what will be the volume of the balloon when the ship reaches Indian ocean, where temp is 26.1°C ?

$$\begin{array}{r} 273.0 \\ 23.4 \\ \hline 296.4 \end{array}$$

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

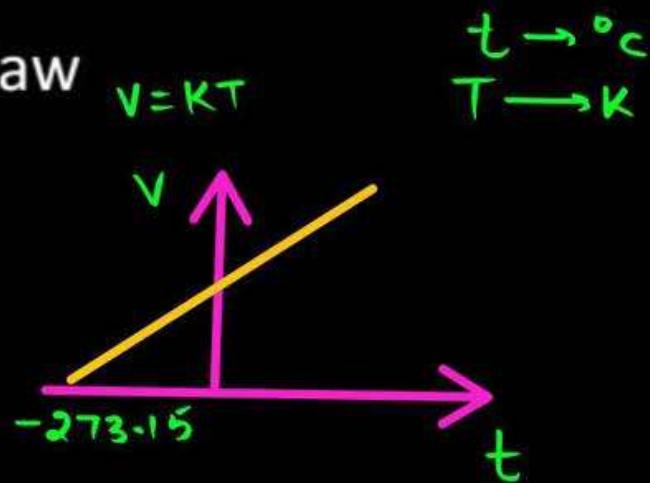
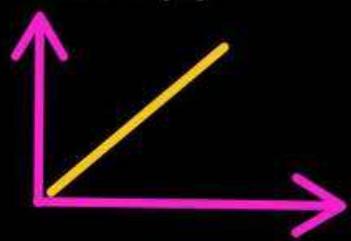
$$\frac{2}{296.4} = \frac{V_2}{299.1}$$

$$\begin{array}{r} 273.0 \\ 26.1 \\ \hline 299.1 \end{array}$$

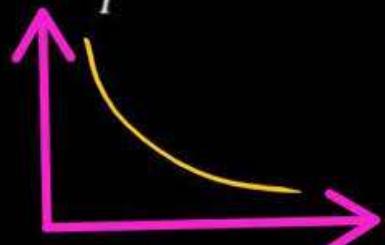
$$V_2 = L$$

Graphs Charles law

1. V vs T (k)



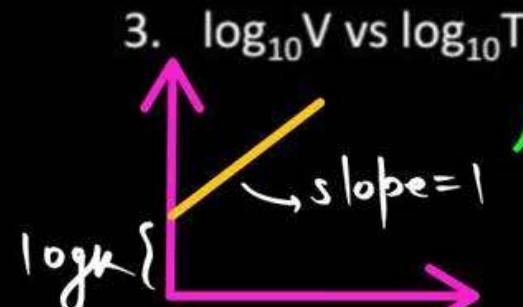
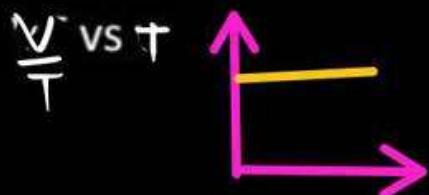
2. V vs $\frac{1}{T}$



$$V = kT$$

$$V \times \frac{1}{T} = k$$

5. $\frac{V}{T}$ vs T

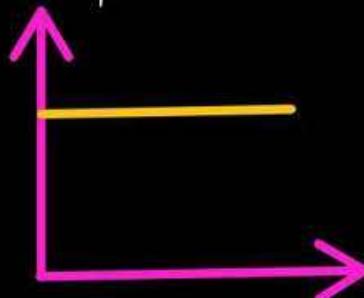


$$V = kT$$

$$\log V = \log kT$$

$$\log V = \log T + \log k$$

4. $\frac{V}{T}$ vs V



$$V = kT$$

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



>> GayLussac's Law



- ❖ At const volume pressure of fixed amount of a gas is directly proportional to absolute temp.

$$P \propto T$$

$$P = kT$$

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

state 1 state 2

$$P_1, T_1, P_2, T_2$$

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

Graphs

Same as charles
law



Q.

At const volume pressure of 2 mole of a gas is 76 mm of Hg at 27°C then find pressure (in atm) at 327°C for fixed amount of gas?

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

$$\frac{76}{300} = \frac{P_2}{\frac{600}{2}}$$

$$P_2 = 76 \times 2 \text{ mm of Hg}$$

$$P_2 = \frac{76 \times 2}{760} = 0.2 \text{ atm}$$

Avogadro's Law



- Equal volumes of all gases under the same cond of temp and pressure contain equal no of molecules.

$$V \propto n$$

$$V = kn$$

state 1 state 2

$$V_1, n_1$$

$$V_2, n_2$$

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

Graphs
Same as
Charles law

Q.

2 moles of a gas has volume 10 dm^3 at 27°C then find the no. of moles when volume is increased by 90 dm^3 at const P and T?



$$V_1 = 10 \quad V_2 = 10 + 90 = 100 \text{ dm}^3$$

$$n_1 = 2 \quad n_2 = ?$$

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

$$\frac{10}{2} = \frac{100}{n_2}$$

$$n_2 = 20$$

Ideal gas equation



A , B , C

$$V \propto n \quad P \propto \frac{1}{V} \quad V \propto T$$

$$PV \propto NT$$

$$PV = NRT$$

R = Univ gas const

$$= 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}} \quad (25/3)$$

$$= 0.0821 \frac{\text{L-atm}}{\text{mol}\cdot\text{K}} \left(\frac{1}{12}\right) \checkmark$$

$$= 1.98 \frac{\text{Cal}}{\text{mol}\cdot\text{K}} \quad (2)$$



Q.

Find volume (cm^3) occupied by 16gm oxygen at 300k and 8.31MPa

$$n = \frac{16}{32} = \frac{1}{2}$$

$$\begin{array}{ccc} PV = nRT & & \\ \downarrow & & \downarrow \\ \text{atm} & L & \frac{1}{12} \end{array}$$

$$\begin{array}{ccc} PV = nRT & & \\ Pa & \downarrow m^3 & \downarrow \frac{25}{3} \\ & & K \end{array}$$

$$8.31 \times 10^8 \times V = \frac{1}{2} \times 8.31 \times 300$$

$$V = \frac{3}{2} \times \frac{1}{10^4}$$

$$V = \frac{3 \times 10^{-4}}{2} \text{ m}^3$$

$$V = 1.5 \times 10^{-4} \text{ m}^3$$

$$V = 150 \text{ cc.}$$

Q.

2.8 gm of a gas at 1 atm and 273k occupies a volume of 2.24 L the gas can not

$$n = \frac{2.8}{M}$$



- (a) O₂
(c) N₂

$$PV = nRT$$

$$1 \times 2.24 = \frac{2.8}{M} \times \frac{1}{12} \times 273$$

- (b) CO
(d) C₂H₄

$$\left(\frac{273}{12} \right) = 22.7$$

≈
22.4

$$\frac{22.7}{10} = \frac{2.8}{M} \times 22.4$$

$$M = 28$$



Q.

5 gm each of the following gases at 87°C and 750 mm of Hg. Which of them will have the least volume?

- (a) HF
(c) HBr

- (b) HCl
(d) HI

$$PV = nRT$$

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

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

$$M \uparrow V \downarrow$$

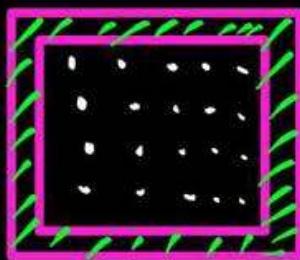
Types of containers



❖ Closed container :

Case 1

- Rigid closed container



$V = \text{fixed}$, $n = \text{const}$
 (const)

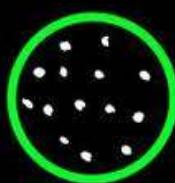
$P \propto T$ ($n, V = \text{const}$)

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

Case 2

- Movable closed container

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$



$n = \text{const}$

$PV = nRT$
 $n = \text{const}$

$$\frac{PV}{T} = \text{const}$$



spherical movable closed container

Q. An air bubble at the bottom of the lake has radius 1 cm at 3 atm & 300K find radius of air bubble when it reaches at surface at 340 K? ($p_{atm} = 1 \text{ atm}$)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_1 = 3 \text{ atm}, V_1 = \frac{4}{3} \pi (1)^3, T_1 = 300 \text{ K}$$

$$P_2 = 1 \text{ atm}, V_2 = \frac{4}{3} \pi r_2^3, T_2 = 340 \text{ K}$$

$$\frac{3 \times \frac{4}{3} \pi (1)^3}{300} = \frac{1 \times \frac{4}{3} \pi r_2^3}{340}$$

$$r_2 = (3.4)^{1/3} \text{ cm}$$

O

.....

.....

.....

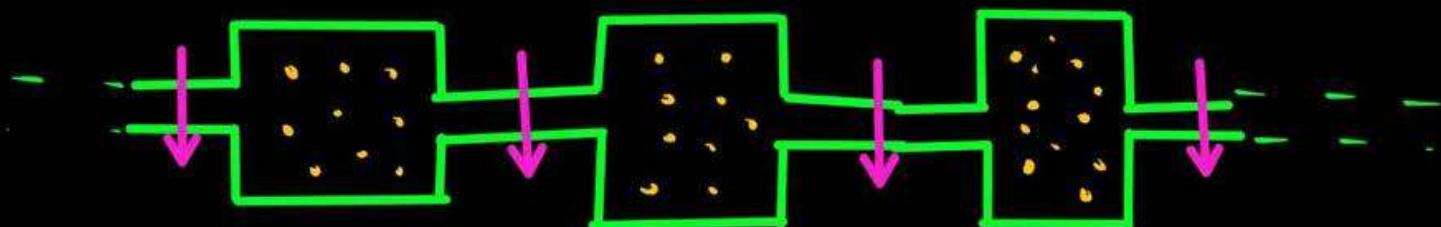
.....

.....

O

State 1

Connected containers



Q.

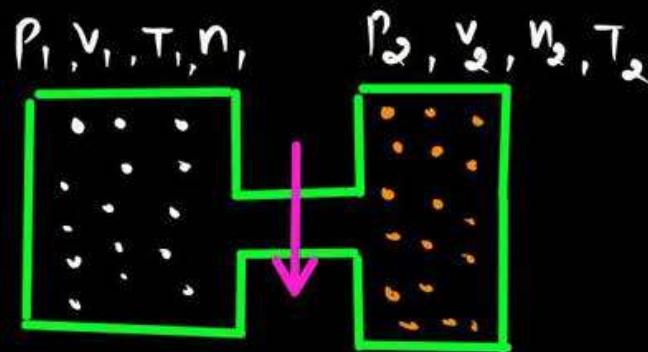
Find final pressure after removing partition at const temp?

$$(T_1 = T_2)$$



$$PV = nRT$$

$$(n = \frac{PV}{RT})$$



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

if $T = \text{const}$

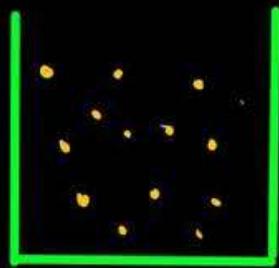
$$n_1 + n_2 = n_f \quad V_f = V_1 + V_2$$

$$\frac{P_1 V_1}{R T_1} + \frac{P_2 V_2}{R T_2} = \frac{P_f V_f}{R T_f}$$

$$P_1 V_1 + P_2 V_2 = P_f V_f$$

$$P_f = \frac{P_1 V_1 + P_2 V_2}{V_1 + V_2}$$

Open container :



$P = \text{same}$
 $V = \text{same}$

$$\frac{n}{T}$$

$$PV = nRT$$

 $= = =$

$$nT = \text{const}$$

$$n_1 T_1 = n_2 T_2$$



Q.

An open container is heated such that $\frac{3}{5}$ of air in it is expelled out. If initial temp was 27°C then find final temp?

$$n_1 = n \quad n_2 = n - \frac{3n}{5} = \frac{2n}{5}$$

$$T_1 = 300\text{K} \quad T_2 = ?$$

$$n_1 T_1 = n_2 T_2$$

$$1 \times 300 = \frac{2}{5} \times T_2$$

$$T_2 = 750\text{K}$$



Q.

An open vessel at 27°C is heated until two fifth of the air (assumed as an ideal gas) in it has escaped from the vessel. Assuming that the volume of the vessel remains constant, the temperature at which the vessel has been heated is

(2019 Main, 12 Jan II)

a. 750 K $n_1 = n$, $n_2 = n - \frac{2n}{5}$

c. 750°C $T_1 = 300\text{K}$ $\frac{T_2 = ?}{T_2 = ?} = \frac{3n}{5}$

b. 500 K

d. 500°C

Taaza Taaza

$$n_1 T_1 = n_2 T_2$$

$$n \times 300 = \frac{3n}{5} \times T_2$$

$$T_2 = 500\text{K}$$

Combined gas Law



For a fixed amount of a gas, if temp pressure and volume changes from T_1, P_1, V_1

to T_2, P_2, V_2

$$[n_1 = n_2]$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$



Q.

At 0°C and 1 atm pressure, a gas occupies 100 cc . If pressure is increased to one and a half time and temperature is increased by one-third of absolute temp, then find final volume (in cc)?

 $\frac{1}{3}$

$$1\frac{1}{2} = \frac{3}{2}$$

$$P_1 = 1 \text{ atm} \quad P_2 = \frac{3}{2} \text{ atm}$$

$$V_1 = 100 \text{ cc}, V_2 = ?$$

$$T_1 = 273 \text{ K}, T_2 = 273 + 273 \times \frac{1}{3}$$

$$\frac{273}{364} = \frac{91}{364}$$

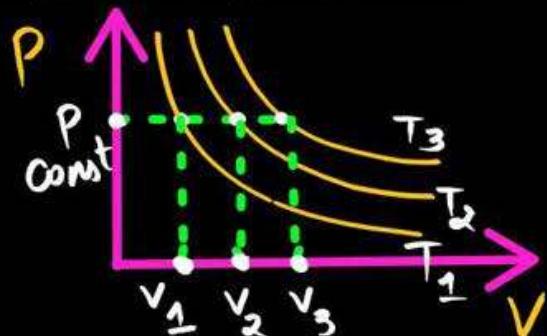
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{1 \times 100}{273} = \frac{\frac{3}{2} \times V_2}{364}$$

$$V_2 = \text{cc}$$



Q. Compare Temperatures ?



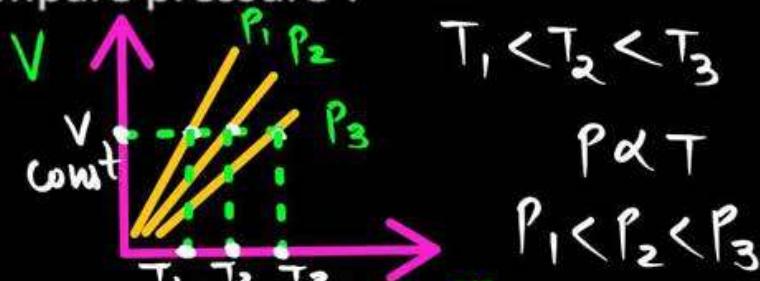
$$V_1 < V_2 < V_3$$

$$P = \text{const}$$

$$(V \propto T)$$

$$T_1 < T_2 < T_3$$

Compare pressure ?



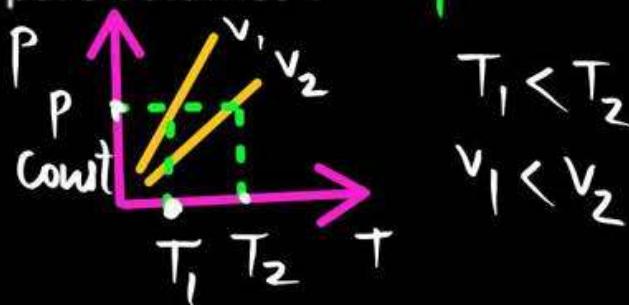
$$T_1 < T_2 < T_3$$

$$V = \text{const}$$

$$P \propto T$$

$$P_1 < P_2 < P_3$$

Compare volumes ?



$$T_1 < T_2$$

$$V_1 < V_2$$

$$V \propto T \text{ when } P = \text{const}$$

Dalton's Law of partial pressure



- For non reacting gaseous mixture the total pressure exerted is the sum of partial pressure (Individual pressure) of each gas

$$P_T = P_1 + P_2 + P_3 + \dots$$

P_1, P_2, P_3, \dots
Partial pressures

$$P_{\text{gas}} = \chi_{\text{gas}} P_T$$

P_{gas} = Partial pressure of gas

χ_{gas} = mole fraction of gas

P_T = Total pressure

$$P_1 V = n_1 RT$$

$$P_2 V = n_2 RT$$

$$P_3 V = n_3 RT$$

$$\vdots \quad \vdots \quad \mid$$

>>> DLPP is not valid in :

1. $\text{CO} + \text{O}_2$
2. $\text{NO} + \text{Cl}_2$
3. $\text{CO} + \text{Cl}_2$
4. $\text{HCl} + \text{NH}_3$
5. $\text{NH}_3 + \text{Cl}_2$ (excess)
6. $\text{SO}_2 + \text{Cl}_2$
7. $\text{NO} + \text{O}_2$
8. $\text{H}_2 + \text{Cl}_2$
9. $\text{H}_2 + \text{F}_2$





Q.

D.L.P.P is not valid for

- (a) H_2 & SO_2
- (c) H_2 & CO_2

- (b) H_2 & Cl_2
- (d) CO_2 & Cl_2

Q.

D.L.P.P is valid at room temp is?

- (a) $\text{HCl} + \text{NH}_3$
- (c) $\text{H}_2 + \text{He}$

- (b) $\text{SO}_2 + \text{Cl}_2$
- (d) $\text{CO} + \text{O}_2$



Q.

Find partial pressure of each gas when 6 gm of H_2 & 44 gm CO_2 are mixed in a container at 10 atm total press and 25°C?

$$w_{H_2} = 6 \text{ gm}$$

$$w_{CO_2} = 44$$

$$n_{H_2} = \frac{6}{2} = 3$$

$$n_{CO_2} = \frac{44}{44} = 1$$

$$\chi_{H_2} = \frac{3}{3+1} = \frac{3}{4}$$

$$P_{H_2} = \chi_{H_2} P_T$$

$$P_{CO_2} = P_T - P_{H_2}$$

$$= 10 - 7.5$$

$$\chi_{CO_2} = \frac{1}{4}$$

$$= \frac{3}{4} \times 10$$

$$P_{CO_2} = 2.5 \text{ atm}$$

$$P_{H_2} = 7.5 \text{ atm}$$



Q.

Find fraction of total pressure exerted by each gas when 16gm SO₂ is mixed with 56gm N₂ in a container at 27°C.

$$P_{\text{gas}} = \chi_{\text{gas}} P_T$$

fraction
of
Total
pressure

$$\left(\frac{P_{\text{gas}}}{P_T} \right) = \chi_{\text{gas}}$$

$$w_{\text{SO}_2} = 16 \text{ gm}$$

$$n_{\text{SO}_2} = \frac{16}{64}$$

$$= \frac{1}{4}$$

$$w_{\text{N}_2} = 56 \text{ gm}$$

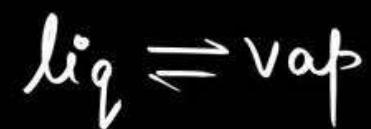
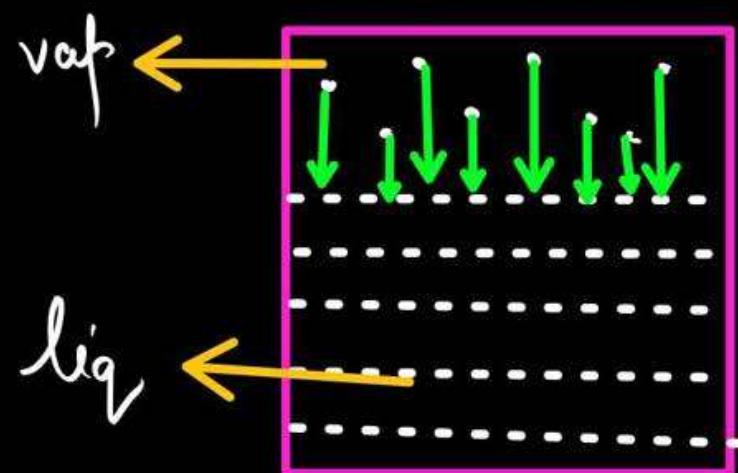
$$n_{\text{N}_2} = \frac{56}{28} = 2$$

$$\chi_{\text{SO}_2} = \frac{\frac{1}{4}}{\frac{1}{4} + 2} = \frac{\frac{1}{4}}{\frac{9}{4}} = \frac{1}{9}$$

$$\chi_{\text{N}_2} = \frac{8}{9}$$

Vapour pressure

- The pressure exerted by vapours over the surface of liq when liq and vap are in equilibrium.



Rate of evaporation

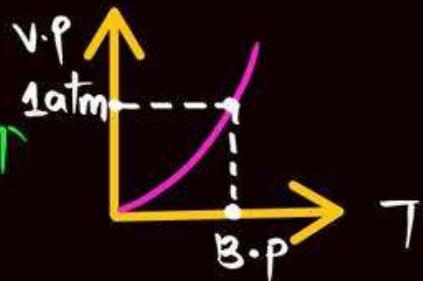
=
Rate of condensation

factors affecting vapour pressure

① Temp

$$T \uparrow, Vap \uparrow \quad V \cdot P \propto T$$

$$V \cdot P \propto T$$



② Intermolecular forces :-

$$V \cdot P \propto \frac{1}{I \cdot M \cdot F \text{ of } liq}$$

IMF \nearrow due to Hydrogen bonding
 $HF > HCl$
 $V \cdot P \quad HF < HCl$

$$P_{\text{moist gas}} = P_{\text{dry gas}} + \underbrace{v \cdot P \text{ of } H_2O}_{\text{aq. Tension}}$$



Q.

A mixture of He & Ne gas is collected over water at 28°C and 745 mm Hg. If the partial pressure of He is 368 mm Hg. Find partial pressure of Ne?
(V.P of H_2O at 28°C is 28.3 mm Hg)

$$P_{\text{moist gas}} = P_{\text{He}} + P_{\text{Ne}} + \text{aq Tension}$$

$$745 = 368 + P_{\text{Ne}} + 28.3$$

$$P_{\text{Ne}} = 348.7 \text{ mm of Hg}$$

Q.

O_2 gas is collected over water. The volume of O_2 collected at $24^\circ C$ and atmospheric pressure of 760 mm Hg is 128mL. Find w_{O_2} (pressure of H_2O vap at $24^\circ C$ is 22.4 mm Hg)



$$P_{\text{moist gas}} = P_{O_2} + \text{aq Tension} \quad PV = nRT$$

$$760 = P_{O_2} + 22.4$$

$$0.97 \times 128 \times \frac{1}{10} = n_{O_2} \times \frac{1}{2} \times 297$$

$$P_{O_2} = 737.6 \text{ mm of Hg}$$

$$n_{O_2} = ?$$

$$P_{O_2} = \frac{737.6}{760} \text{ atm}$$

$$w_{O_2} = n_{O_2} \times 32$$

$$= 0.97 \text{ atm}$$

>>> Graham's Law of diffusion / Effusion





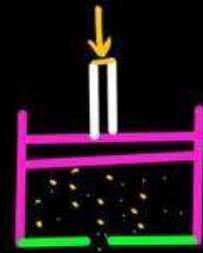
Diffusion



The spont. flow of gas molecules from higher concn to lower concn is called diffusion.

>>> Effusion

forced diffusion is called effusion



or

The spontaneous flow of gas molecules from higher conc'n to lower conc'n via small hole (or pin hole or orifice)



Law



The rate of diffusion or effusion is inversely proportional to the square root of the density of the gas at similar conditions.

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

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

$$d \propto m$$

$$\boxed{\gamma \propto \frac{1}{\sqrt{m}}}$$

M.W \uparrow $\gamma \downarrow$

$(P = \text{const})$
 $(T = \text{const})$



Compare rate of diffusion

Gas 1

γ_1

M_1

Gas 2

γ_2

M_2

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

$$\frac{\gamma_1}{\gamma_2} = \sqrt{\frac{M_2}{M_1}}$$



Rate

1. Volume flow rate

$$\gamma = \frac{V}{t}$$

Gas 1
 v_1, n_1, l_1, t_1

Gas 2
 v_2, n_2, l_2, t_2



$$\frac{v_1}{v_2} \times \frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$$

2. Moles flow rate

$$\gamma = \frac{n}{t}$$

$$\frac{n_1}{n_2} \times \frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$$

3. Length flow rate

$$\gamma = \frac{l}{t}$$

$$\frac{l_1}{l_2} \times \frac{t_2}{t_1} = \sqrt{\frac{M_2}{M_1}}$$



Q.

50 mL of gas A diffuse through a membrane in the same time as for the diffusion of 40mL of a gas B under identical condⁿ. If MW_A = 64 find M.W_B?

$$\begin{array}{lll} V_A = 50 & t_A = t & M_A = 64 \\ V_B = 40 & t_B = t & M_B = ? \end{array}$$

$$\frac{V_A}{V_B} \times \frac{t_B}{t_A} = \sqrt{\frac{M_B}{M_A}}$$

$$\frac{50}{40} \times 1 = \sqrt{\frac{M_B}{64}}$$

$$\frac{25}{16} = \frac{M_B}{64}$$

$$M_B = 100$$



Q.

The rate of diffusion of a gas having M.W just double of N_2 gas is 56 mL/sec find the rate of diffusion of N_2 gas?

$$M_x = 2 M_{N_2} \quad \gamma_x = 56 \text{ mL/sec}$$

$$\frac{\gamma_x}{\gamma_{N_2}} = \sqrt{\frac{M_{N_2}}{M_x}}$$

$$\frac{56}{\gamma_{N_2}} = \sqrt{\frac{28}{2 \times 28}}$$

$$\gamma_{N_2} = 56\sqrt{2} \text{ mL/sec}$$



Q.

The R.O.D of CH_4 at given temp is twice that of x find M.W of x?

$$\gamma_{\text{CH}_4} = 2 \gamma_x$$

$$\frac{\gamma_{\text{CH}_4}}{\gamma_x} = 2$$

$$M_x = 64$$

$$\sqrt{\frac{M_x}{M_{\text{CH}_4}}} = 2$$

$$\frac{M_x}{16} = 4$$



Q.

Four rubber tubes are respectively filled with H_2 , O_2 , N_2 , CO_2 . The tube which will be reinflated first is ?



$MW \downarrow \gamma \uparrow$



Q.

A football bladder contains 4 : 1 molar ratio ($n_{H_2} : n_{O_2}$) of H_2 and O_2 . Find the composition by weight ($H_2 : O_2$) of the mixture effusing out of punctured football ?

$$\left(\frac{\gamma_{H_2}}{\gamma_{O_2}} \right)_{\text{effused out}} = \left(\frac{P_{H_2}}{P_{O_2}} \right)_{\text{inside}} \sqrt{\frac{M_{O_2}}{M_{H_2}}}$$

$$\left(\frac{n_{H_2}}{n_{O_2}} \right)_{\text{effused}} = \left(\frac{n_{H_2}}{n_{O_2}} \right)_{\text{inside}} \sqrt{\frac{M_{O_2}}{M_{H_2}}}$$

$$\left(\frac{n_{H_2}}{n_{O_2}} \right)_{\text{effused out}} = \frac{4}{1} \sqrt{\frac{32}{2}}$$

" " "

$$= 4 \sqrt{16}$$

$$= 16$$

$$\left(\frac{\omega_{H_2}}{\omega_{O_2}} \right)_{\text{effused out}} \times 16 = 16$$

$$\left(\frac{\frac{\omega_{H_2}}{2}}{\frac{\omega_{O_2}}{32}} \right)_{\text{effused out}} = 16$$

$$\left(\frac{\omega_{H_2}}{\omega_{O_2}} \right)_{\text{effused}} = \frac{1}{1}$$

If P is variable

$$\gamma \propto \frac{1}{\sqrt{M}} ; \gamma \propto P$$

$$\gamma \propto \frac{P}{\sqrt{M}}$$

$$\frac{\gamma_1}{\gamma_2} = \frac{P_1}{P_2} \sqrt{\frac{M_2}{M_1}}$$

Q.

A bottle of dry NH_3 and a bottle of dry HCl connected through a long tube are opened simultaneously at both ends. The white fumes of NH_4Cl first formed will be :

- (a) at center of the tube
- (b) near HCl end
- (c) near NH_3 end
- (d) throughout the length of tube

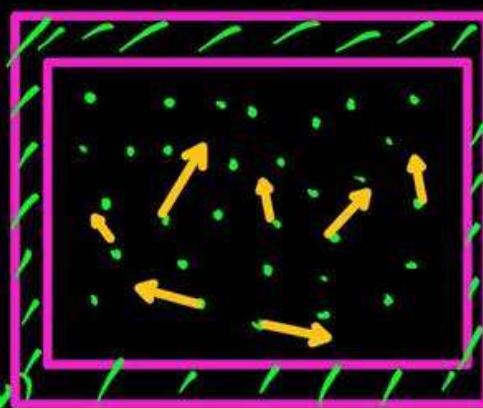


Kinetic theory of gases



Postulates :

1. There is no force of attracⁿ b/w gas molecules.
2. Volume of gas molecule is negligible (point mass)
3. The motion of gas molecules is straight line and random (chaotic motions)
4. Collision b/w gas molecules and wall of the container is perfectly elastic.
5. the avg. KE is directly proportional to the absolute temp. (T in K)



$$\text{Avg } k \cdot E \propto T$$

kinetic gas equation

$$P = \frac{1}{3} m N v_{rms}^2$$

pressure (Pa) ($\frac{N}{m^2}$)

Volume (m^3)

mass of molecule (Kg)

No. of molecules

Root mean square velocity (m/s)



❖ Relation b/w avg. KE and absolute temp (T)

for n moles $\text{Avg KE} = \frac{3}{2} n R T$

for 1 mol $\text{Avg KE} = \frac{3}{2} R T$

for 1 molecule $\text{Avg KE} = \frac{3}{2} \frac{R T}{N_A}$

$$\text{Avg KE} = \frac{3}{2} K_B T$$

$$P V = \frac{1}{3} m N v_{rms}^2$$

$$P V = \frac{2}{3} \times \left(\frac{1}{2} m N v_{rms}^2 \right)$$

$$\frac{3 n R T}{2} = \text{Avg KE}$$

$$\boxed{\frac{R}{N_A} = K_B}$$

$$K_B = 1.380 \times 10^{-23}$$



Q.

In a container of capacity 1 L there are 10^{25} molecules each of mass 10^{-22} kg if root mean square velocity is 10^5 cm/s find pressure of the gas in pa ?
 10^3 m/s

$$PV = \frac{1}{3} m N V_{rms}^2$$

$$1 \text{ m}^3 = 1000 \text{ L}$$

$$P \times 10^{-3} = \frac{1}{3} \times 10^{-22} \times 10^{25} \times (10^3)^2 \quad 1 \text{ L} = 10^{-3} \text{ m}^3$$

$$P = \frac{1}{3} \times \frac{10^3}{10^{-3}} \times 10^6$$

$$P = \frac{1}{3} \times 10^{12} \text{ Pa}$$



Q.

Consider three 1L flask A, B and C filled with gases NO, NO₂ & N₂O respect each at 1 atm, 273K. In which flask do the molecules have the highest avg K.E ?.

- (a) Flask C
- (b) All are the same
- (c) Flask A
- (d) N. O. T



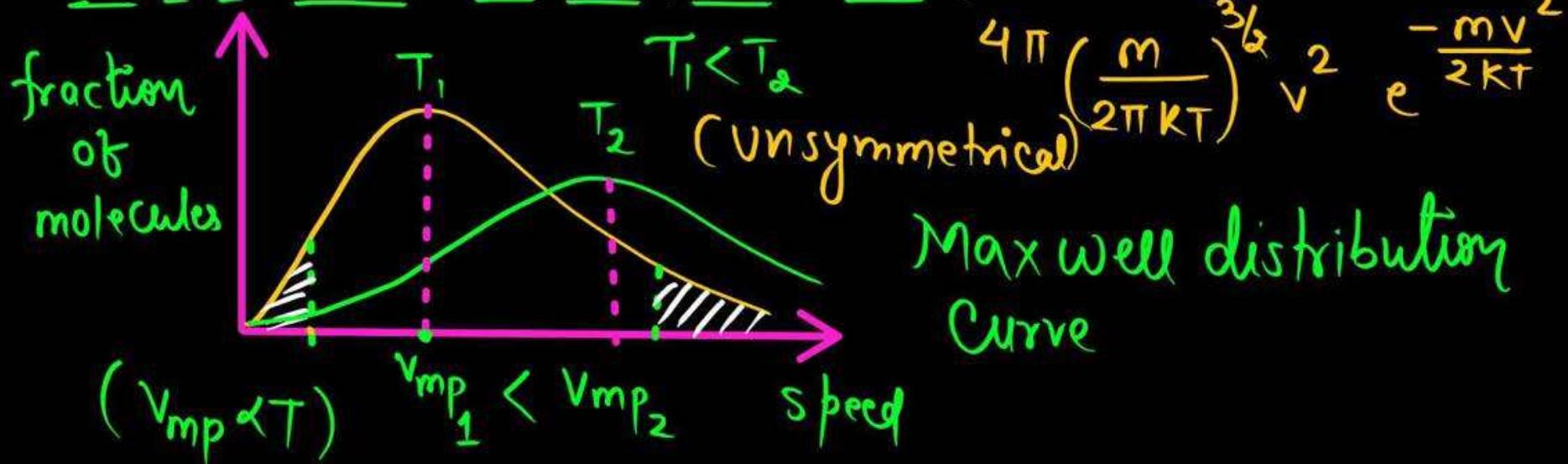
Q.

Incorrect for K.T.G ?

- (a) Gas particles are considered as point mass
- (b) The molecules are in random motion
- (c) When molecules collide, they lose energy
- (d) When the gas heated, the molecules move faster

❖ The distribution of velocity can be calculated by probability and it may be concluded as

1. Small fraction of molecules have very low & very high velocities.
2. Curve become flat on increasing temp.
3. Most of the molecules have most probable velocity.



$$f'(v) = 0$$

K = Boltzmann
const

T = Temp(T)

m = mass(kg)

$$R = 8.314 \text{ or } \frac{25}{3}$$

T = Temp(K)

M = M.w (kg)

$$V_{mp} = \sqrt{\frac{2kT}{m}}$$

$$V_{mp} = \sqrt{\frac{2RT}{M}}$$

$$\frac{K}{m} = \frac{R}{M}$$

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

Avg velocity

$$V_{avg} = \frac{n_1 c_1 + n_2 c_2 + n_3 c_3 + \dots}{n_1 + n_2 + n_3 + \dots}$$

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

Rms velocity

$$V_{rms} = \sqrt{\frac{n_1 c_1^2 + n_2 c_2^2 + n_3 c_3^2 + \dots}{n_1 + n_2 + n_3 + \dots}}$$

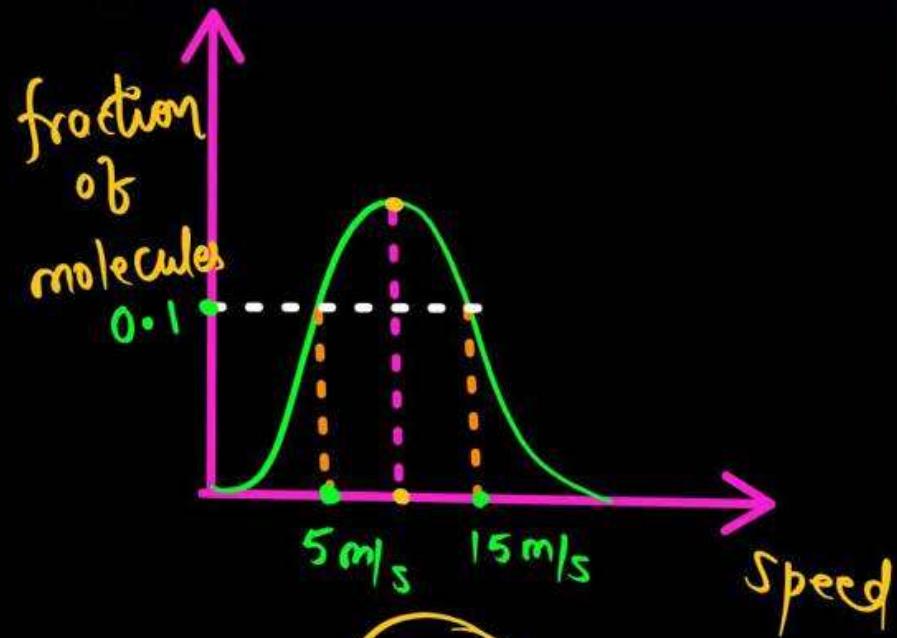
$$V_{rms} = \sqrt{\frac{3RT}{M}} \\ = \sqrt{\frac{3kT}{m}}$$

$$R > A > M$$

$$\sqrt{3} > \sqrt{\frac{8}{\pi}} > \sqrt{2}$$

$$V_{rms} : V_{avg} : V_{mp} = \sqrt{3} : \sqrt{\frac{8}{\pi}} : \sqrt{2}$$

MI* If Maxwell – Boltzmann curve is symmetrical then



$$V_{rms} > V_{avg} = V_{mp}$$

$$\begin{aligned} V_{avg} &= \frac{0.1 \times 5 + 0.1 \times 15}{0.1 + 0.1} \\ &= \frac{0.5 + 1.5}{0.2} \\ &= \frac{2}{0.2} \\ &= 10 \text{ m/s} \end{aligned}$$

$$V_{mp} = \left(\frac{5+15}{2} \right)$$

$$V_{mp} = 10 \text{ m/s}$$



$$\begin{aligned}V_{rms} &= \sqrt{\frac{0.1 \times 5^2 + 0.1 \times 15^2}{0.1 + 0.1}} \\&= \sqrt{\frac{2.5 + 22.5}{0.2}} \\&= \sqrt{\frac{25}{0.2}} \\&= \sqrt{125}\end{aligned}$$



Q.

Four particles have speed 2, 3, 4 & 5 cm/s respectively find Vrms ?

$$\begin{aligned}V_{rms} &= \sqrt{\frac{1 \times 2^2 + 1 \times 3^2 + 1 \times 4^2 + 1 \times 5^2}{1+1+1+1}} \\&= \sqrt{\frac{4+9+16+25}{4}} \text{ cm/s} \\&= \sqrt{13.5} \text{ cm/s}\end{aligned}$$



Q.

The most probable speed of 8 gm H₂ is 200m/s find avg K.E of H₂ gas?

$$V_{MP} = \sqrt{\frac{2RT}{M}}$$

$$KE = \frac{3}{2} nRT$$

$$(200)^2 = \frac{2 \times RT}{8 \times 10^{-3}}$$

$$\begin{aligned} &= \frac{3}{2} \times \left(\frac{8}{2}\right) \times 40 \\ &= 240 \end{aligned}$$

$$\begin{aligned} (RT) &= 4 \times 10^4 \times 10^{-3} \\ &= 40 \end{aligned}$$



Q.

The density of gas filled electric lamp is 0.75 kg/m^3 . After the lamp has been switched on, the pressure in it increases from $4 \times 10^4 \text{ Pa}$ to $9 \times 10^4 \text{ Pa}$ find the increase in V_{rms}

$$V_{\text{rms}} = \sqrt{\frac{3RT}{M}} \quad d = \frac{PM}{RT}$$

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

$$\Delta V_{\text{rms}} = \sqrt{\frac{3 \Delta P}{d}} = \sqrt{\frac{3(5 \times 10^4)}{0.75}} = \sqrt{\frac{15 \times 10^6}{75}} = \sqrt{10^6} \text{ m/s}$$



Q.

If V_{rms} of gas is $30\sqrt{R}$ m/s at 27°C then find molar mass of gas ?

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$30\sqrt{R} = \sqrt{\frac{3RT}{M}}$$

$$900 R = \frac{3R \times 300}{M}$$

$$M = 1 \text{ kg}$$



Q.

Calculate V_{rms} of O_3 kept in a closed container at $20^\circ C$ and $\underbrace{82 \text{ cm Hg}}$ pressure?

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$= \sqrt{\frac{3 \times 25 \times 293}{48 \times 10^{-3}}} \text{ m/s}$$



Q.

At what temp the V_{mp} of O_2 molecules have the same value of V_{rms} speed of O_2 molecules at 300K?

$$V_{mp} = V_{rms}$$

$$\sqrt{\frac{2RT}{M}} = \sqrt{\frac{3R \times 300}{M}}$$

$$\frac{2RT}{M} = \frac{900R}{M}$$

$$T = 450K$$

Mean free path, Collision freq and mean free time



1. K.T.G is valid ✓
2. Only one molecule is moving ✓
3. Mean free path (λ)

$$\lambda = v_{avg} \times \text{time}$$

$$PV = nRT$$

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

σ = Collision diameter $\frac{N}{V} = \frac{P N_A}{R T}$

N^* = Number density $= \frac{N}{V}$
 (No. of molecules per unit volume)

$$N^* = \frac{P N_A}{R T} = \frac{P}{K T}$$

$$\lambda = \frac{1}{\sqrt{2} \pi \sigma^2 N^*}$$

$$\lambda = \frac{K T}{\sqrt{2} \pi \sigma^2 P}$$

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

4. Mean free time

$$\tau = \frac{1}{z} = \frac{1}{\sqrt{2} \pi \sigma^2 v_{avg} N^*}$$

5. Collision freq (z)

$$z = \sqrt{2} \pi \sigma^2 v_{avg} N^*$$



Q.

If the mean free path is λ at 1 atm then find its value at 5 atm at const temp?

$$\lambda \propto \frac{1}{P} \quad T = \text{const} \quad \lambda \propto \frac{1}{P}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{P_2}{P_1}$$

$$\frac{\lambda}{\lambda_2} = \frac{5}{1}$$

$$\boxed{\lambda_2 = \frac{\lambda}{5}}$$



Q.

Calculate the ratio mean free path of the molecules of two gases having molecular diameter 1 \AA and 2 \AA res. At same P & T.

$$\lambda = \frac{1}{\sqrt{2} \pi \sigma^2 N^*}$$

$$\lambda \propto \frac{1}{\sigma^2}$$

$$\lambda = \frac{kT}{\sqrt{2} \pi \sigma^2 P}$$

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{\sigma_2}{\sigma_1} \right)^2$$

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

$$= \frac{4}{1}$$



Real gas

❖ Two postulates of K.T.G do not hold good

1. There is no force of attracⁿ b/w gas molecules
2. Molecular volume is neglegible

① Compressibility factor (z)

$$z = \frac{PV_{\text{obs}}}{nRT}$$

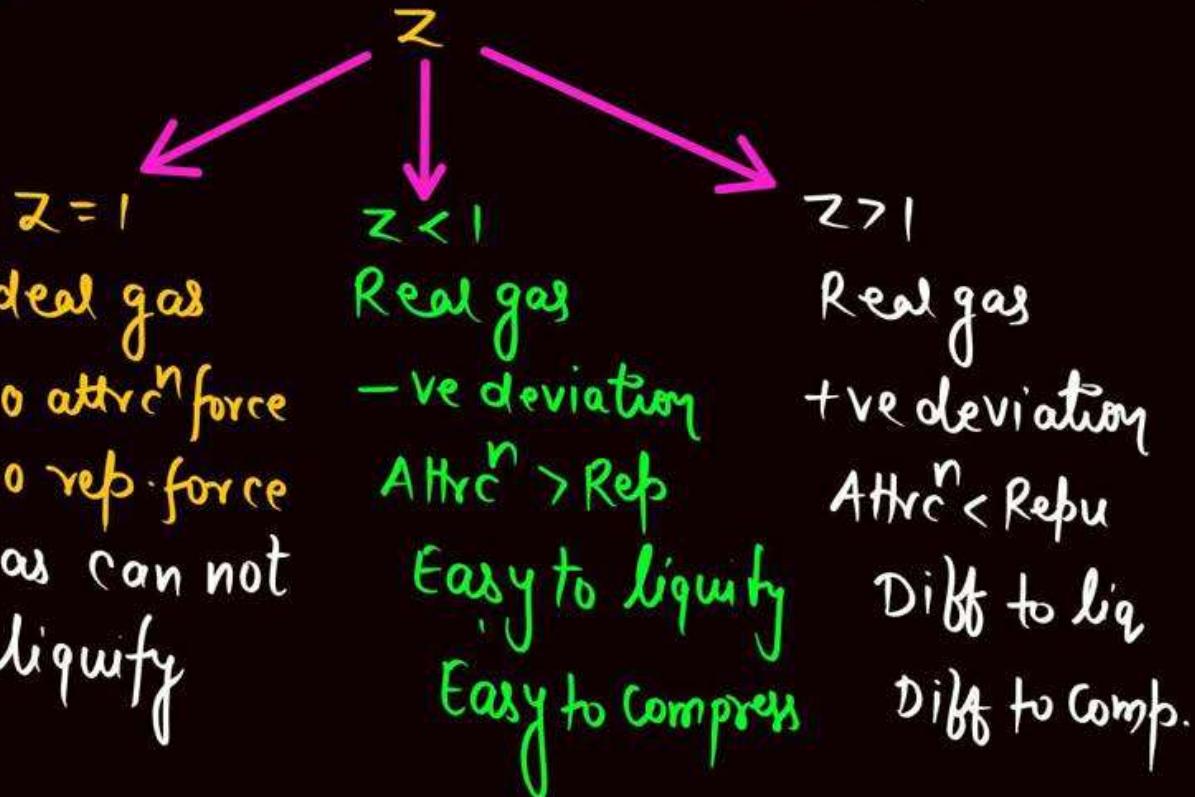
$$z = \frac{V_{\text{obs}}}{\frac{nRT}{P}}$$

$$z = \frac{V_{\text{obs}}}{V_{\text{ideal}}}$$

$$z = \frac{V_{\text{real}}}{V_{\text{ideal}}}$$

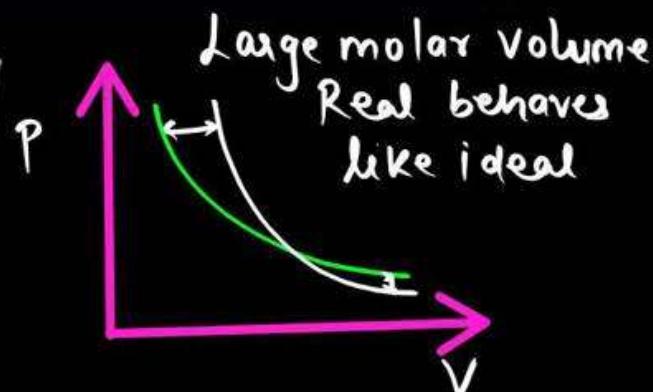
$\boxed{z = \frac{V_{\text{real}}}{V_{\text{ideal}}}}$

$$z \neq 1$$

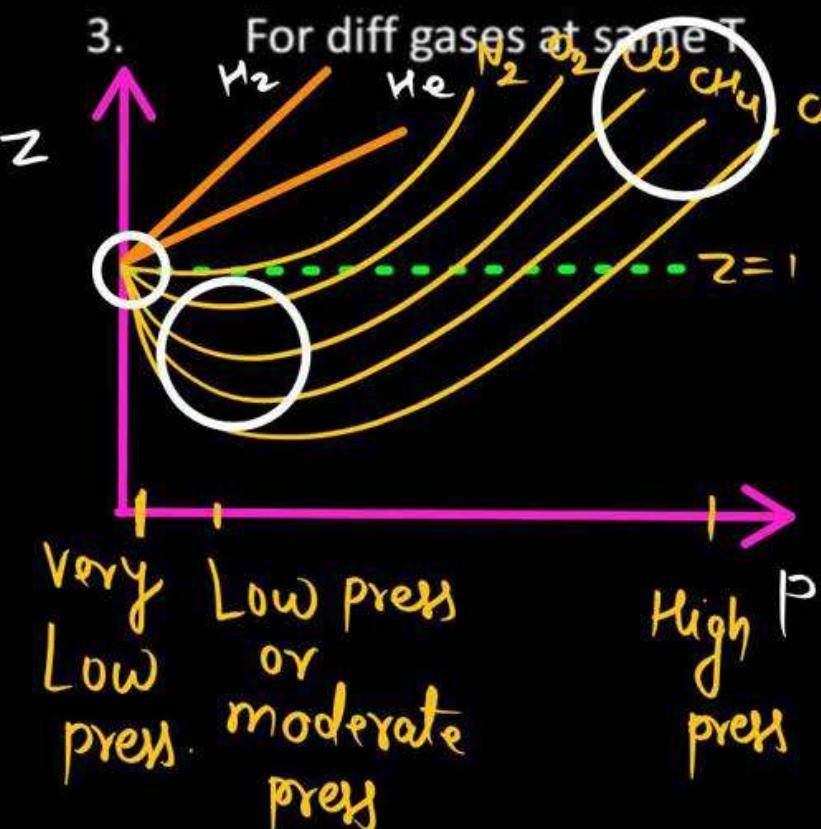
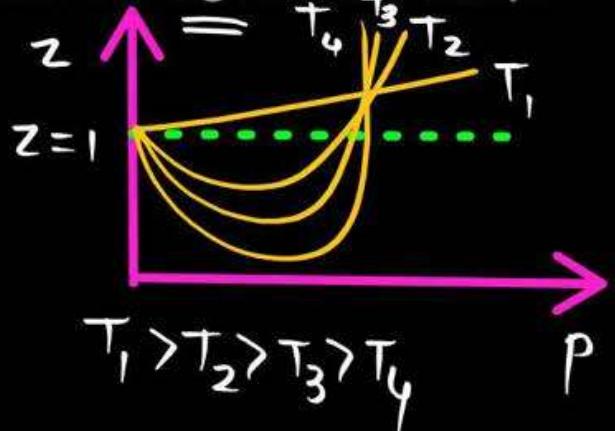


Graphical analysis

1. P Vs V



2. Z Vs P for a gas at diff temp



Case ① At very Low pressure

$\gamma = 1$ (All gases)

Case ② At Low pressure

$\gamma < 1$ (Except H₂ & He)

Case ③ At high pressure

$\gamma > 1$ (All gases)

Case ④ for H₂ and He

①

$\gamma = 1$

At very
low pressure

②

$\gamma > 1$

At Low(moderate)
& High pressure



Vander Waal Equation

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

\downarrow \downarrow

pressure correction term Volume correction term

$$\left(+ \frac{n^2 a}{V^2}\right) \quad (-nb)$$

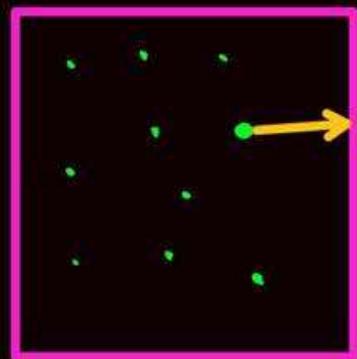
a, b = Vander waal const

$a, b \rightarrow$ depends
on
Nature
of the gas

Independent of
the temp.

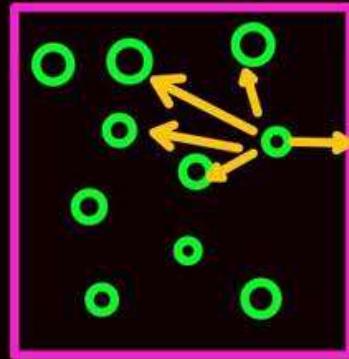
- ❖ a – measure of intermolecular attrⁿ forces & connected with liquefaction
- ❖ b – Excluded volume or Co-volume

① Pressure correction term



ideal

$$P_i$$



Real

$$P_r$$

$$P_i^{\circ} = P_r + \frac{n^2 a}{V^2}$$

$$PCT \propto \frac{n}{V} \times \frac{n}{V}$$

$$PCT \propto \frac{n^2}{V^2}$$

$$PCT = a \frac{n^2}{V^2}$$

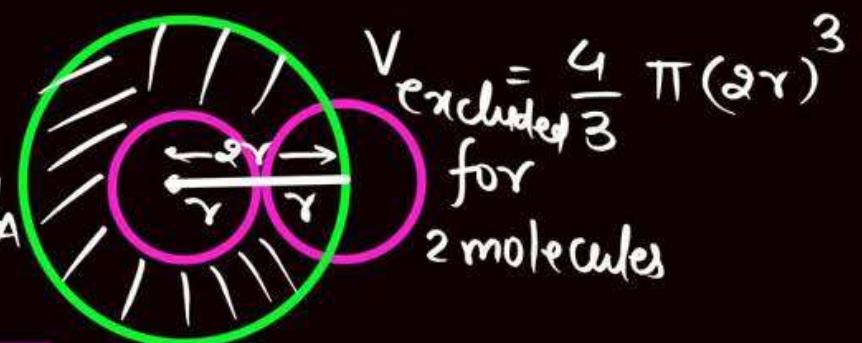
② V.C.T



$$V_r - nb = V_i$$

V_{excluded} for 1 molecule = $\frac{2}{3} \pi (8r^3)$ Bimolecular collision

V_{excluded} for N_A molecules = $\frac{16}{3} \pi r^3 \times N_A$ (1 mol)



$$\cancel{b} = 4 V N_A = 4 V_m$$

$$P_i V_i = n R T$$

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = n R T$$



Case 1

- ❖ At very Low pressure ($Z=1$)

$a = \text{neglected}$, $b = \text{neglected}$

$$PV = nRT$$

$$Z = 1$$



Case 2

❖ At Low pressure or moderate ($z < 1$)

$b = \text{neglected}$

$$\left(P + \frac{n^2 a}{V^2} \right) V = nRT$$

$$\left(PV + \frac{n^2 a}{V} \right) = nRT$$

for 1 mol

$$PV_m + \frac{a}{V_m} = RT$$

$$\frac{PV_m}{RT} + \frac{a}{RTV_m} = 1$$

$$z = 1 - \frac{a}{RTV_m}$$

$$z < 1$$



Case 3

❖ At high pressure ($z > 1$)

$a = \text{neglected}$

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

$$P(V - nb) = nRT$$

for 1mol

$$P(V_m - b) = RT$$

$$PV_m - Pb = RT$$

$$\frac{PV_m}{RT} - \frac{Pb}{RT} = 1$$

$$z = 1 + \frac{Pb}{RT}$$

$$z > 1$$



Case 4

❖ For H_2 & H_e

$$Z=1$$

$$Z > 1$$

$$Z = 1 + \frac{pb}{RT}$$

OMG

At very Low \rightarrow Real
pressure = Ideal



1. At Low pressure and High temp. Real=ideal
2. At high press and Low temp \rightarrow Maximum deviation



$$(RT)^2 = 4ap$$

Q.

At Low pressure, If $RT = 2\sqrt{ap}$ then find the volume occupied by a real gas?

$$V_m = \frac{RT \pm \sqrt{(RT)^2 - 4ap}}{2P} \quad z < 1 \quad b = \text{neglected}$$

(a) $\frac{2RT}{P}$

$$V_m = \frac{RT}{2P}$$

(b)

$$\frac{2P}{RT}$$

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

(d)

$$\frac{2RT}{P}$$

$$\left(PV_m + \frac{a}{V_m} \right) = RT$$

$$PV_m^2 + a = RTV_m$$

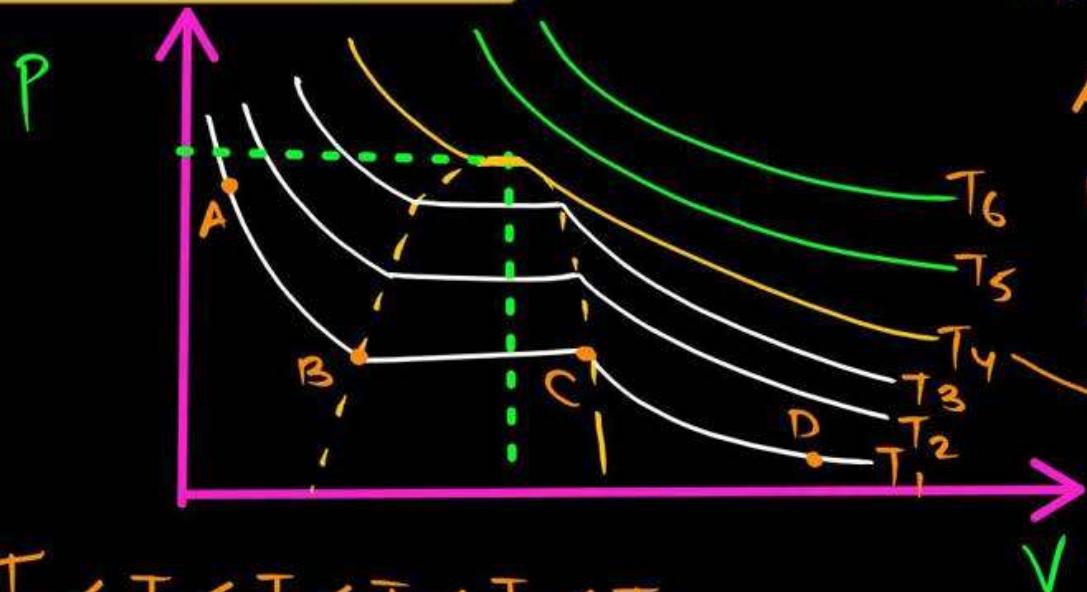
$$PV_m^2 - RTV_m + a = 0$$

(c) $\frac{RT}{2P}$

Liquefaction of gases

Andrew

CO_2 isotherm.



$AB \rightarrow \text{liq}$

$T_6 \quad BC \rightarrow \text{liq} \rightleftharpoons \text{vap}$

$T_5 \quad CD \rightarrow \text{gas}$

$T_4 \quad T_3 \quad T_2 \quad T_1 \rightarrow T_C$

$$T_1 < T_2 < T_3 < T_4 < T_5 < T_6$$



1. Critical temp (T_c) : - The temp above which gas can not be liquefy

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

2. Critical pressure (P_c) : - The pressure at T_c is called P_c

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

3. Critical volume (V_c) : - The volume of 1 mol of the gas at P_c, T_c is called V_c

$$V_c = 3b$$

OMG



$\frac{dp}{dv} = 0$ and $\frac{d^2p}{dv^2} = 0$ at critical point

Compressibility factor at C.P (Z_c) :

$$Z_c = \frac{P_c V_c}{n R T_c}$$

$$= \frac{\frac{9}{27 b^2} \times 3b}{n R \left(\frac{89}{27 R b} \right)}$$

$$Z_c = \frac{3}{8} < 1$$



>>> Condⁿ for liquifaction



$a \uparrow$ liquefaction \uparrow

$b \downarrow$ "

$$\text{liquefaction} \propto \frac{a}{b}$$

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

$$T_c \propto \frac{a}{b}$$

$$\text{Liq} \propto T_c$$

Liq & Tc



- ❖ He < H₂ < N₂ < O₂ < CO₂ < NH₃ < H₂O ✓

$$\text{H}_2 < \text{N}_2 < \text{O}_2 < \text{CO} < \text{NH}_3 < \text{H}_2\text{O}$$

Boyle's Temp



The Temp when Real gas behaves like ideal

$$T_B = \frac{a}{Rb}$$

Q.

b will be larger if $\frac{T_c}{P_c}$ is?

$$\frac{\frac{8a}{27Rb}}{a} \quad \frac{8b}{R}$$

~~$\frac{8a}{27Rb}$~~
~~a~~
 ~~$\frac{8b}{R}$~~

$$\frac{T_c}{P_c} \propto b$$

unit of a and b

- (a) Small
- (b) Large
- (c) Equal to 1
- (d) less than 1

$$\textcircled{a} \quad \frac{(P + \frac{n^2 a}{V^2})(V - nb)}{mol^2}$$

$$\textcircled{b} \quad L \text{ mol}^{-1}$$





Q.

However great the pressure, a gas cannot be liquified above its :-

- (a) Boyle Temp
- (b) Critical temp ✓
- (c) Both
- (d) None



Q.

Compare ease of liquefaction





Q.

b of He is 24 mL/mol find molecular diameter of He?

$$b = 4 N_A v$$

$$24 \times 10^{-3} = 4 \times 6.023 \times 10^{23} \times \frac{4}{3} \pi r^3$$

$$r = ?$$

$$d = 2r$$



Q.

For gas deviation from ideal behavior is maximum at

$T \downarrow$ $P \uparrow$

P

T

- | | | |
|--------------|-------|---|
| (a) | 1 atm | 0°C <input checked="" type="checkbox"/> |
| (b) | 2 atm | 100°C <input checked="" type="checkbox"/> |
| (c) | 1 atm | -13°C |
| (d) <u>✓</u> | 2 atm | -13°C |



» Inversion Temp

- ❖ The temp at which gas shows Neither heating nor cooling

» Case 1

- ❖ $T > T_i$, on Expansion gas will show Heating

» Case 2

- ❖ $T = T_i$, on Expansion gas neither show heating no cooling

» Case 3

- ❖ $T < T_c$, on Expansion gas will show cooling

Compare T_i , T_B & T_c



$$T_i = \frac{2a}{Rb} \quad T_B = \frac{a}{Rb} \quad T_c = \frac{8a}{27Rb}$$

$$T_i > T_B > T_c$$

Q.

Points I, II and III in the following plot respectively correspond to (v_{mp} : most probable velocity) (2019 Main, 10 April II)

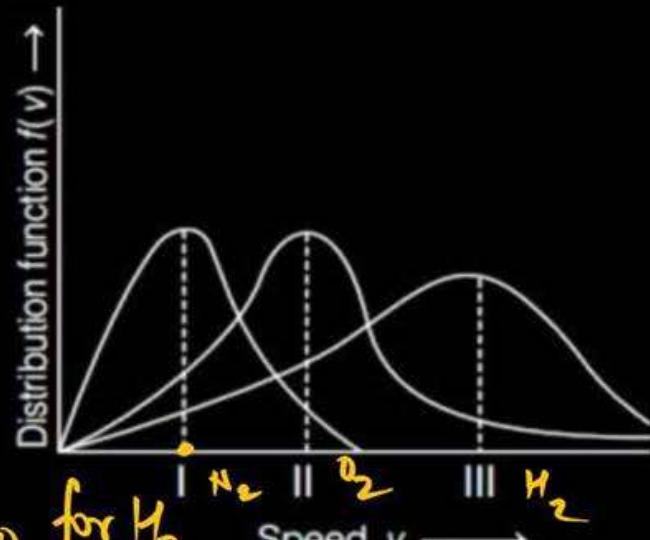
- a. v_{mp} of H₂(300 K); v_{mp} of N₂(300 K); v_{mp} of O₂(400 K) X
- b. v_{mp} of O₂(400 K); v_{mp} of N₂(300 K); v_{mp} of H₂(300 K)
- c. v_{mp} of N₂(300 K); v_{mp} of O₂(400 K); v_{mp} of H₂(300 K) X
- d. v_{mp} of N₂(300 K); v_{mp} of H₂(300 K); v_{mp} of O₂(400 K) X

$$V_{mp} = \sqrt{\frac{2RT}{M}}$$

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

$$\sqrt{\frac{300}{2}} = \sqrt{150} \text{ for H}_2$$

$$\sqrt{\frac{300}{28}} = \sqrt{\frac{300}{28}} \text{ for N}_2 \quad \sqrt{\frac{400}{32}} \text{ for O}_2$$



Q.

Consider the following table.

Gas	$a(\text{k Pa dm}^6\text{mol}^{-1})$	$b(\text{dm}^3\text{mol}^{-1})$
A	642.32	0.05196
B	155.21	0.04136
C	431.91	0.05196
D	155.21	0.4382

$$a(A) > a(C)$$

$$a \uparrow \text{liq} \uparrow$$

$$b(D) > b(B)$$

$$\downarrow \\ \text{liq} \uparrow$$

easy
compress

a and b are van der Waals' constants. The correct statement about the gases is

(2019 Main, 10 April I)



gas C will occupy lesser volume than gas A; gas B will be lesser compressible than gas D



gas C will occupy more volume than gas A; gas B will be more compressible than gas D



gas C will occupy more volume than gas A; gas B will be lesser compressible than gas D



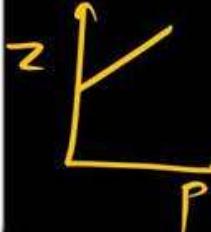
gas C will occupy more volume than gas A; gas B will be lesser compressible than gas D



Q.

At a given temperature T , gases Ne, Ar, Xe and Kr are found to deviate from ideal gas behaviour. Their equation of state is given as, $p = \frac{RT}{V-b}$ at T . $z = 1 + \frac{pb}{RT}$ slope = $\frac{b}{RT}$

Here, b is the van der Waals' constant. Which gas will exhibit steepest increase in the plot of Z (compression factor) vs p ? (2019 Main, 9 April II)



- a. Xe
- b. Ar
- c. Kr
- d. Ne

a. Ar

c. Kr

Size ↑ $b \uparrow$ Slope ↑

Q.

Consider the van der Waals' constants, a and b , for the following gases.

Gas	Ar	Ne	Kr	Xe
$a/(\text{atm dm}^6 \text{ mol}^{-2})$	1.3	0.2	5.1	4.1
$b/(10^{-2} \text{ dm}^3 \text{ mol}^{-1})$	3.2	1.7	1.0	5.0

Which gas is expected to have the highest critical temperature ?

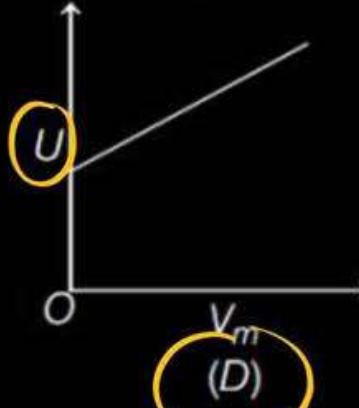
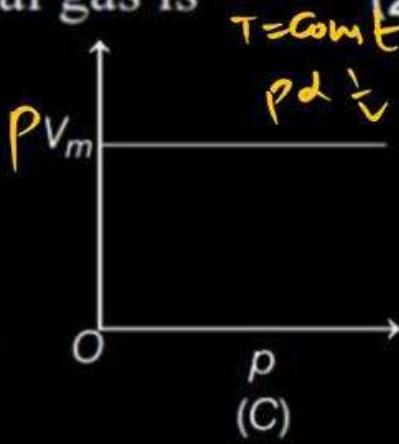
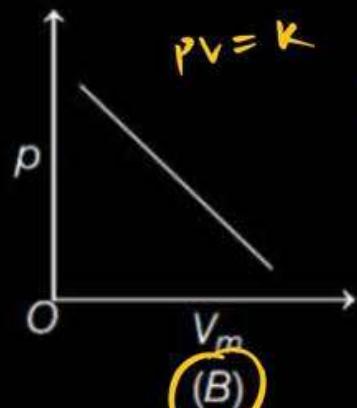
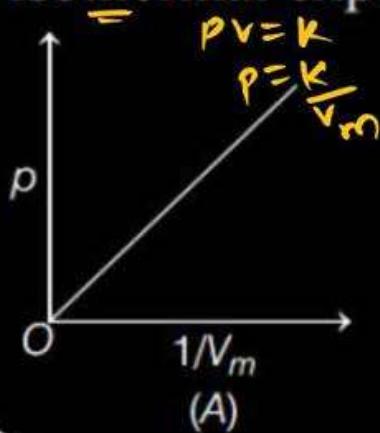
(2019 Main, 9 April I)

- a. Kr
 c. Ar

b. Xe $T_c \propto \frac{a}{b}$ $a \uparrow b \downarrow$
 d. Ne

Q.

The combination of plots which does not represent isothermal expansion of an ideal gas is (2019 Main, 12 Jan II)



- a. (A) and (C)
- c. (B) and (D)

- b. (B) and (C)
- d. (A) and (D)



$T = \text{const}$ $\Delta U = 0$

$T = \text{const}$ $PV = \text{const}$

$P \propto V$ Rectangular
 my

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



Q.

The volume of gas A is twice than that of gas B. The compressibility factor of gas A is thrice than that of gas B at same temperature. The pressures of the gases for equal number of moles are

(2019 Main, 12 Jan I)

a. $p_A = 2p_B$

$$\frac{V_A}{V_B} = 2$$

c. $p_A = 3p_B$

$$\frac{Z_A}{Z_B} = 3$$

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

$$T = \text{const}$$

$$Z \propto PV$$

b. $\cancel{2p_A = 3p_B}$

d. $3p_A = 2p_B$

$$2P_A = 3P_B$$

$$\frac{Z_A}{Z_B} = \frac{P_A V_A}{P_B V_B}$$

$$3 = \frac{P_A}{P_B} \times 2$$



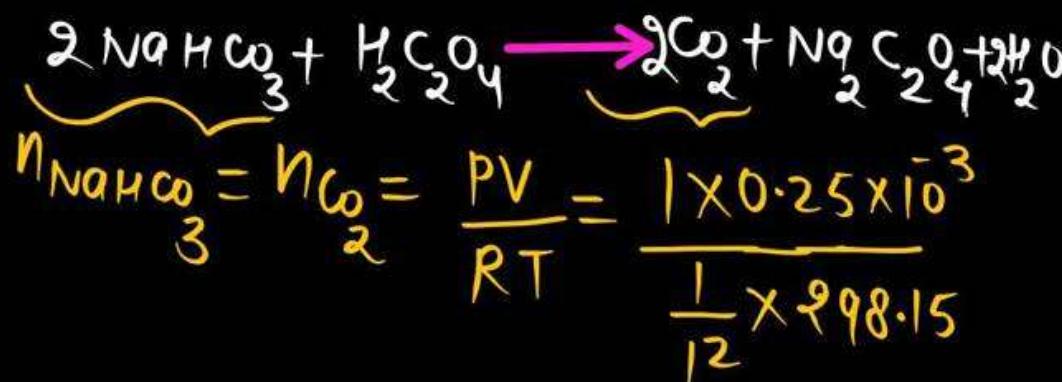
Q.

A 10 mg effervescent tablet containing sodium bicarbonate and oxalic acid releases 0.25 mL of CO_2 at $T = 298.15 \text{ K}$ and $p = 1 \text{ bar}$. If molar volume of CO_2 is 25.0 L under such condition, what is the percentage of sodium bicarbonate in each tablet?

[Molar mass of $\text{NaHCO}_3 = 84 \text{ g mol}^{-1}$] (2019 Main, 11 Jan I)

- a. 8.4
- b. 0.84
- c. 16.8
- d. 33.6

$$\% \text{ purity} = \frac{\omega_{\text{NaHCO}_3}}{\omega_{\text{sample}}} \times 100$$

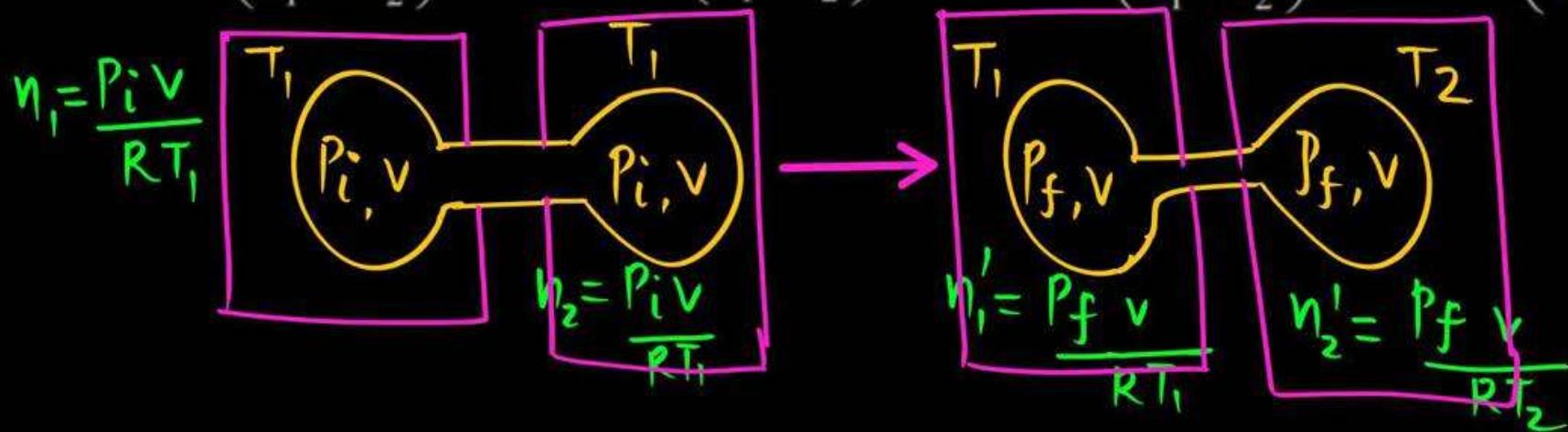


Q.

Two closed bulbs of equal volume (V) containing an ideal gas initially at pressure p_i and temperature T_1 are connected through a narrow tube of negligible volume as shown in the figure below. The temperature of one of the bulbs is then raised to T_2 . The final pressure p_f is

(2016 Main)

- a. $2p_i \left(\frac{T_1}{T_1 + T_2} \right)$ b. $2p_i \left(\frac{T_2}{T_1 + T_2} \right)$ c. $2p_i \left(\frac{T_1 T_2}{T_1 + T_2} \right)$ d. $p_i \left(\frac{T_1 T_2}{T_1 + T_2} \right)$



$$n_1 + n_2 = n'_1 + n'_2$$

$$\frac{P_i V}{R T_1} + \frac{P_i V}{R T_2} = \frac{P_f V}{R T_1} + \frac{P_f V}{R T_2}$$

$$\frac{\alpha P_i V}{R T_1} = \frac{P_f V}{R} \left[\frac{1}{T_1} + \frac{1}{T_2} \right]$$

$$\frac{\alpha P_i V}{T_1} = \frac{P_f V (T_1 + T_2)}{T_1 T_2}$$

$$P_f = \frac{\alpha P_i T_2}{(T_1 + T_2)}$$

Q.

If Z is a compressibility factor, van der Waals' equation at low pressure can be written as Z < 1

(2014 Main)



- a. $Z = 1 + \frac{RT}{pb}$ b. $Z = 1 - \frac{a}{VRT}$ c. $Z = 1 - \frac{pb}{RT}$ d. $Z = 1 + \frac{pb}{RT}$

Q.

For gaseous state, if most probable speed is denoted by C^* , average speed by \bar{C} and root square speed by C , then for a large number of molecules, the ratios of these speeds are

(2013 Main)

- a. $C^* : \bar{C} : C = 1.225 : 1.128 : 1$
- b. $C^* : \bar{C} : C = 1.128 : 1.225 : 1$
- c. $C^* : \bar{C} : C = 1 : 1.128 : 1.225$
- d. $C^* : \bar{C} : C = 1 : 1.225 : 1.128$

$$V_{mp} : V_{avg} : V_{rms}$$

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

$$1 : \sqrt{\frac{8}{2\pi}} : \sqrt{\frac{3}{2}}$$

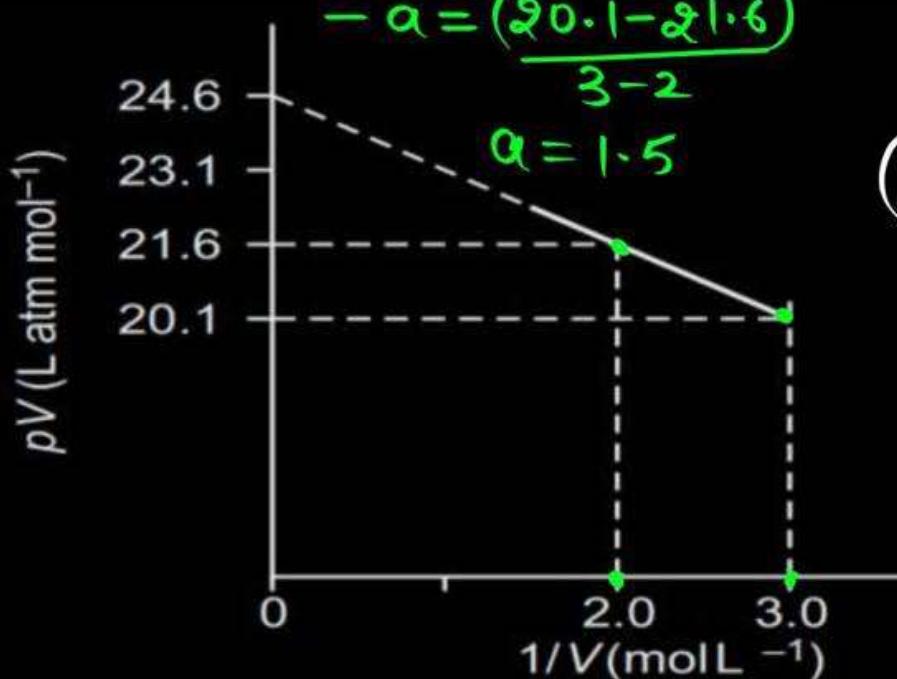
Q.

For one mole of a van der Waals' gas when $b = 0$ and $T = 300\text{ K}$, the pV vs $1/V$ plot is shown below. The value of the van der Waals' constant a (atm L mol^{-2})

(2012)



- a. 1.0
- b. 4.5
- c. 1.5
- d. 3.0



$$-\alpha = \frac{(20.1 - 21.6)}{3-2}$$

$$\alpha = 1.5$$

$$(P + \frac{n^2 a}{V^2})(V - nb) = nRT$$

$$(PV + \frac{a}{V}) = RT$$

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

$$PV \propto \frac{1}{V} \quad \text{So } \lim_{V \rightarrow 0} = -a$$

Q.

The term that corrects for the attractive forces present in a real gas in the van der Waals' equation is

(2009)

a. nb

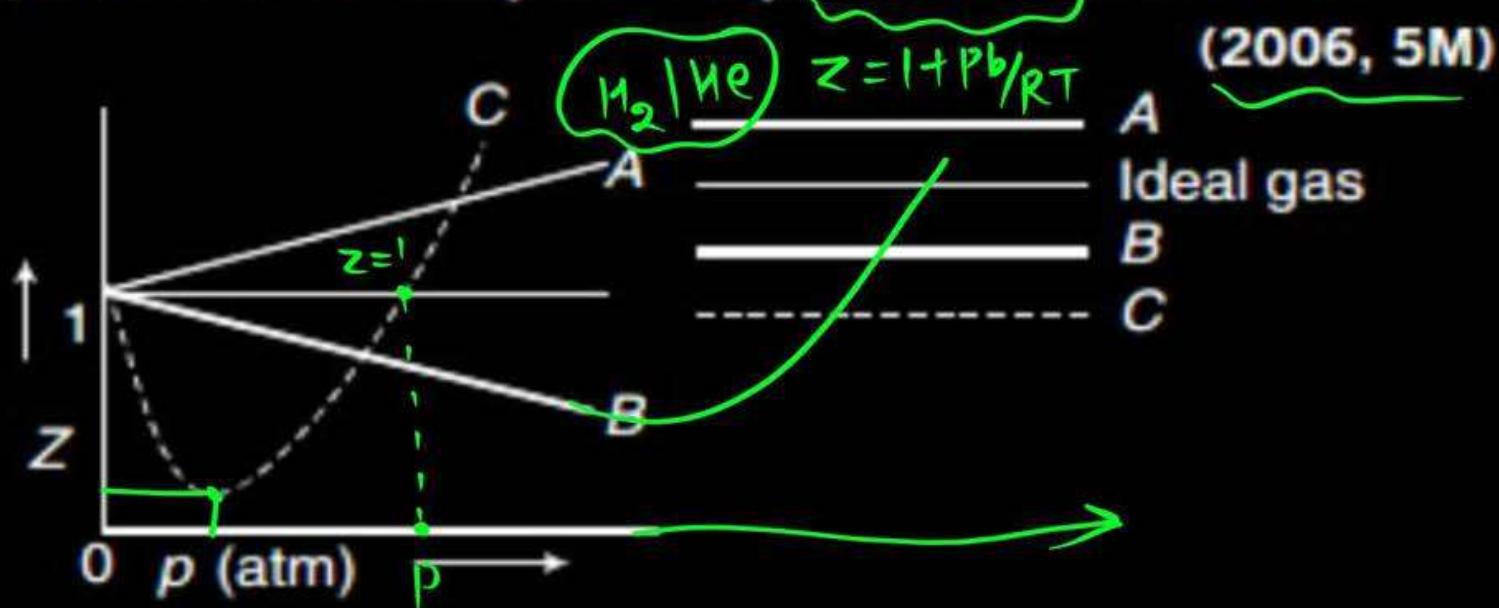
c. $-(n^2a/V^2)$

b. n^2a/V^2

d. $-nb$



Q. The given graph represent the variations of Z (compressibility factor (Z) = $\frac{PV}{nRT}$) versus p , for three real gases A , B and C . Identify the only incorrect statement.



Cont. next page



- (a) For the gas A , $a = 0$ and its dependence on p is linear at all pressure
- (b) For the gas B , $b = 0$ and its dependence on p is linear at all pressure
- (c) For the gas C , which is typical real gas for which neither a nor $b = 0$. By knowing the minima and the point of intersection, with $Z = 1$, a and b can be calculated
- (d) At high pressure, the slope is positive for all real gases

Q.

If helium and methane are allowed to diffuse out of the container under the similar conditions of temperature and pressure, then the ratio of rate of diffusion of helium to methane is (2005)

 a. 2.0 c. 0.5 b. 1.0 d. 4.0

$$\frac{\gamma_{He}}{\gamma_{CH_4}} = \sqrt{\frac{M_{CH_4}}{M_{He}}}$$

$$= \sqrt{\frac{16}{4}} = 2$$

Q.

For a monatomic gas kinetic energy = E . The relation with rms velocity is
(2004, 1M)

a. $u = \left(\frac{2E}{m} \right)^{1/2}$

c. $u = \left(\frac{E}{2m} \right)^{1/2}$

b. $u = \left(\frac{3E}{2m} \right)^{1/2}$

d. $u = \left(\frac{E}{3m} \right)^{1/2}$

$$\frac{1}{2}mv_{rms}^2 = E$$

$$v_{rms} = \sqrt{\frac{2E}{m}}$$



Q.

Positive deviation from ideal behaviour takes place because
of ——————
(2003, 1M)

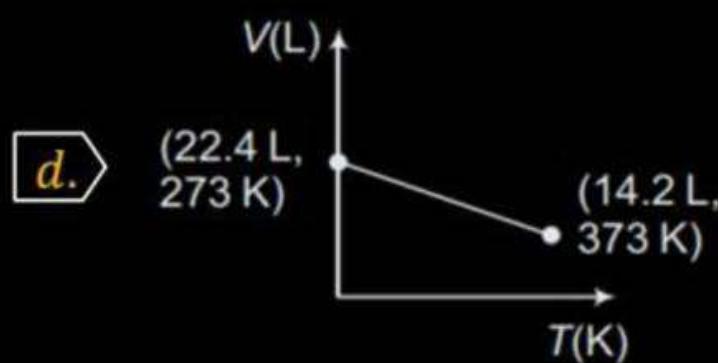
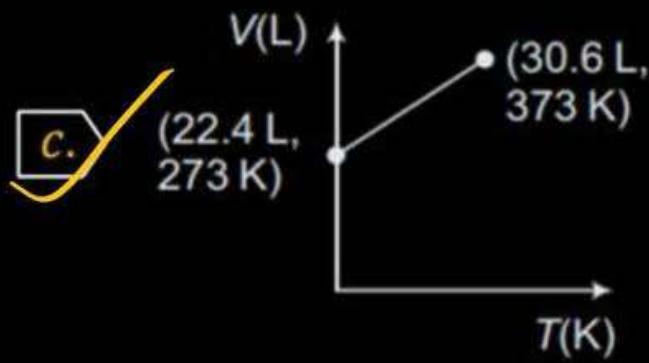
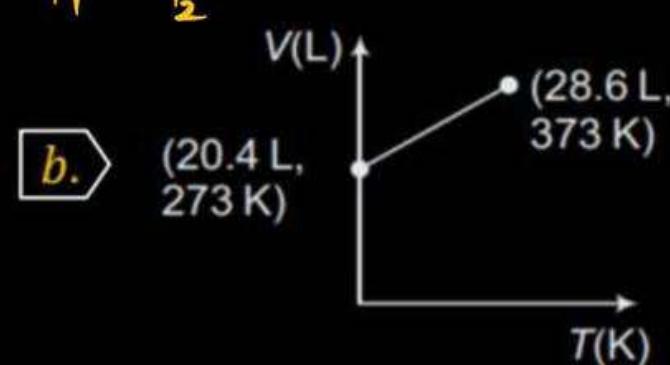
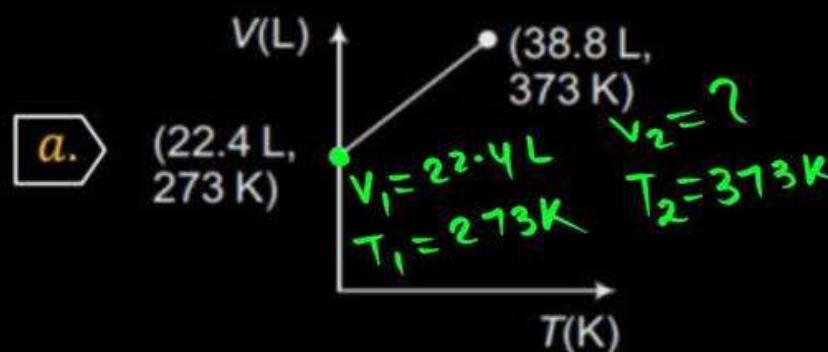


- a. molecular interaction between atom and $pV/nRT > 1$
- b. molecular interaction between atom and $pV / nRT < 1$
- c. finite size of atoms and $pV/nRT > 1$
- d. finite size of atoms and $pV/nRT < 1$

$$\gamma > 1 \quad (\text{Rep} > \text{Att})$$
$$\frac{PV}{nRT} > 1$$

Q.

Which of the following volume (V) temperature (T) plots represents the behaviour of one mole of an ideal gas at the atmospheric pressure? $P = \text{const}$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (2002, 3M)



$$\frac{22.4}{273} = \frac{V_2}{373}$$

$$V_2 = 30.6 \text{ L}$$

Q.

The root mean square velocity of an ideal gas at constant pressure varies with density (d) as (2001, S, 1M)



a. d^2

b. d

c. \sqrt{d}

d. $1/\sqrt{d}$

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

Q.

The compressibility of a gas is less than unity at STP.

Therefore,

(2000, 1M)



a. $V_m > 22.4 \text{ L}$

b. $V_m < 22.4 \text{ L}$

$Z < 1$

c. $V_m = 22.4 \text{ L}$

d. $V_m = 44.8 \text{ L}$

$$\frac{PV}{nRT} < 1$$

$$\frac{PV_m}{RT} < 1$$

$$V_m < \frac{RT}{P}$$

$$V_m < 22.4$$

Q.

The rms velocity of hydrogen is $\sqrt{7}$ times the rms velocity of nitrogen. If T is the temperature of the gas (2000, 1M)



a. $T(H_2) = T(N_2)$

b. $T(H_2) > T(N_2)$

c. $T(H_2) < T(N_2)$

d. $T(H_2) = \sqrt{7} T(N_2)$

$$\frac{V_{H_2}}{\alpha} = \sqrt{7} V_{N_2}$$

$$\sqrt{\frac{3RT_{H_2}}{2 \times 10^3}} = \sqrt{7} \sqrt{\frac{3RT_{N_2}}{28 \times 10^3}}$$

$$\frac{\cancel{3RT_{H_2}}}{\cancel{2 \times 10^3}} = \cancel{7} \times \frac{\cancel{3RT_{N_2}}}{\cancel{28 \times 10^3}}$$

$$\frac{T_{N_2}}{T_{H_2}} = \frac{4}{2}$$

Q.

A gas will approach ideal behaviour at

(1999, 2M)



- a. low temperature and low pressure
- b. low temperature and high pressure
- c. high temperature and low pressure
- d. high temperature and high pressure

Q.

According to Graham's law, at a given temperature the ratio of the rates of diffusion $\frac{r_A}{r_B}$ of gases A and B is given by

(where, p and M are pressures and molecular weights of gases A and B respectively) (1998, 2M)

a.
$$\left(\frac{p_A}{p_B}\right) \left(\frac{M_A}{M_B}\right)^{\frac{1}{2}}$$

b.
$$\left(\frac{M_A}{M_B}\right) \left(\frac{p_A}{p_B}\right)^{\frac{1}{2}}$$

c.
$$\left(\frac{p_A}{p_B}\right) \left(\frac{M_B}{M_A}\right)^{\frac{1}{2}}$$

d.
$$\left(\frac{M_A}{M_B}\right) \left(\frac{p_B}{p_A}\right)^{\frac{1}{2}}$$

Q.

The compressibility factor for an ideal gas is (1997, 1M)



a. 1.5

b. 1.0

c. 2.0

d. ∞



Q.

The ratio between the root mean square speed of H₂ at 50 K and that of O₂ at 800 K is (1996, 1M)

- a. 4 b. 2 c. 1 d. $\frac{1}{4}$

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{T_{H_2} \times M_{O_2}}{T_{O_2} \times M_{H_2}}} = \sqrt{\frac{50 \times 32}{800 \times 2}} = 1$$



Q.

Equal weights of ethane and hydrogen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by hydrogen is (1993, 1M)

- a. 1 : 2 b. 1 : 1 c. 1 : 16 d. 15 : 16

$$\frac{P_{H_2}}{P_T} = \chi_{H_2}$$

$$n_1 = \frac{\omega}{30} \quad n_2 = \frac{\omega}{2}$$

$$\begin{aligned}\chi_{H_2} &= \frac{\frac{\omega}{2}}{\frac{\omega}{2} + \frac{\omega}{30}} = \frac{1}{1 + \frac{1}{15}} \\ &= \frac{15}{16}\end{aligned}$$

Q.

At constant volume, for a fixed number of moles of a gas the pressure of the gas increases with rise of temperature due to

$$P \propto T \quad (1992, 1M)$$

- a. increase in average molecular speed $T \propto \sqrt{\frac{8kT}{\pi}}$ n fix v fixed
- b. increase rate of collisions amongst molecules
- c. increase in molecular attraction X
- d. decrease in mean free path X

Q.

According to kinetic theory of gases, for a diatomic molecule
(1991, 1M)



- a. the pressure exerted by the gas is proportional to mean velocity of the molecule
- b. the pressure exerted by the gas is proportional to the root mean velocity of the molecule
- c. the root mean square velocity of the molecule is inversely proportional to the temperature
- d. the mean translational kinetic energy of the molecule is proportional to the absolute temperature



Q.

The rate of diffusion of methane at a given temperature is twice that of a gas X . The molecular weight of X is

(1990, 1M)

a. 64.0

b. 32.0

c. 4.0

d. 8.0

$$\gamma_{\text{CH}_4} = 2 \gamma_X$$

$$\sqrt{\frac{M_X}{16}} = 2$$

$$\frac{\gamma_{\text{CH}_4}}{\gamma_X} = 2$$

$$M_X = 16 \times 4$$

$$M_X = 64$$



Q. The density of neon will be highest at

(1990, 1M)

- a. STP 1 atm, 0°C ✓ b. 0°C, 2 atm
- c. 273°C, 1 atm ✗ d. 273°C, 2 atm

$$PV = nRT$$

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

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

$$PM = d RT$$

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

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

$$P \uparrow T \downarrow \frac{P}{T} \uparrow d \uparrow$$



Q.

The value of van der Waals' constant a for the gases O_2 , N_2 , NH_3 and CH_4 are 1.360, 1.390, 4.170 and $2.253 L^2 \text{ atm mol}^{-2}$ respectively. The gas which can most easily be liquefied is

- a. O_2
- b. N_2
- c. NH_3
- d. CH_4

Q.

A bottle of dry ammonia and a bottle of dry hydrogen chloride connected through a long tube are opened simultaneously at both ends the white ammonium chloride ring first formed will be

(1988, 1M)

- a. at the centre of the tube
- b. near the hydrogen chloride bottle
- c. near the ammonia bottle
- d. throughout the length of the tube



Q.

In van der Waals' equation of state for a non-ideal gas, the term that accounts for intermolecular forces is (1988, 1M)

- a. $(V - b)$
- b. RT
- c. $\left(p + \frac{a}{V^2} \right)$
- d. $(RT)^{-1}$



Q.

The average velocity of an ideal gas molecule at 27°C is 0.3 m/s. The average velocity at 927°C will be (1986, 1M)

- a. 0.6 m/s b. 0.3 m/s c. 0.9 m/s d. 3.0 m/s

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

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

$$V_2 = 0.6 \text{ m/s}$$

$$\frac{0.3}{V_2} = \sqrt{\frac{300}{1200}}$$

Q.

Rate of diffusion of a gas is

(1985, 1M)



- a. directly proportional to its density
- b. directly proportional to its molecular weight
- c. directly proportional to the square root of its molecular weight
- d. inversely proportional to the square root of its molecular weight



Q.

Equal weights of methane and hydrogen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by hydrogen is (1984, 1M)

a. $\frac{1}{2}$

b. $\frac{8}{9}$

$$n_1 = \frac{\omega}{16} \quad ; \quad n_2 = \frac{\omega}{2}$$

c. $\frac{1}{9}$

d. $\frac{16}{17}$

$$\chi_H = \frac{\frac{\omega}{2}}{\frac{\omega}{2} + \frac{\omega}{16}} = \frac{1}{1 + \frac{1}{8}} = \frac{8}{9}$$

$$\frac{P_{H_2}}{P_T} = \chi_{H_2}$$

Q.

When an ideal gas undergoes unrestrained expansion, no cooling occurs because the molecules

(1984, 1M)



- a. are above the inversion temperature
- b. exert no attractive forces on each other
- c. do work equal to loss in kinetic energy
- d. collide without loss of energy

Q.

Helium atom is two times heavier than a hydrogen molecule.

At 298 K, the average kinetic energy of a helium atom is

(1982, 1M)



- a. two times that of a hydrogen molecule
- b. same as that of a hydrogen molecule
- c. four times that of a hydrogen molecule
- d. half that of a hydrogen molecule



Q.

The temperature at which a real gas obeys the ideal gas laws over a wide range of pressure is

(1981, 1M)

- a. critical temperature
- b. Boyle temperature
- c. inversion temperature
- d. reduced temperature

Q.

The ratio of root mean square velocity to average velocity of a gas molecule at a particular temperature is (1981, 1M)

a. 1.085 : 1

c. 2 : 1.086

b. 1 : 1.086

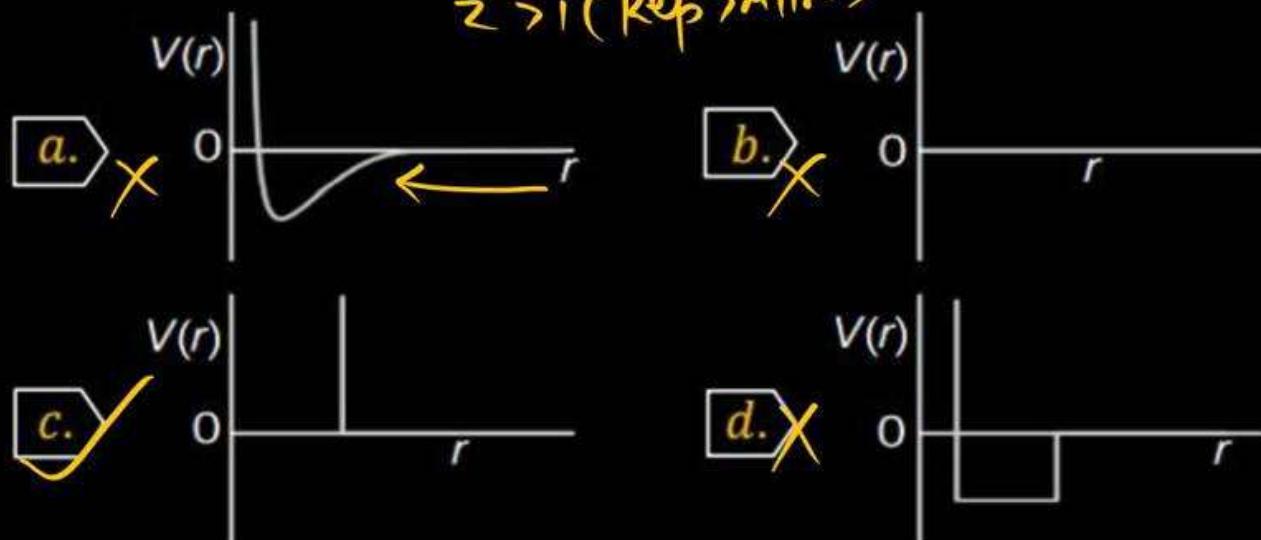
d. 1.086 : 2

$$\frac{V_{rms}}{V_{avg}} = \frac{\sqrt{3}}{\sqrt{8/\pi}} = \sqrt{\frac{3\pi}{8}}$$

Q.

One mole of a monoatomic real gas satisfies the equation $p(V - b) = RT$ where, b is a constant. The relationship of interatomic potential $V(r)$ and interatomic distance r for gas is given by $\frac{V(r)}{RT} = 1 + \frac{pb}{RT}$ (2015 Adv.)

$$\frac{V(r)}{RT} > 1 \quad (\text{Rep} > \text{Attr})$$



Q*

According to kinetic theory of gases

(2011)



- a. collisions are always elastic
- b. heavier molecules transfer more momentum to the wall of the container
- c. only a small number of molecules have very high velocity
- d. between collisions, the molecules move in straight lines with constant velocities

Q.*

A gas described by van der Waals' equation

(2008, 4M)



- a. behaves similar to an ideal gas in the limit of large molar volumes
- b. behaves similar to an ideal gas in the limit of large pressures
- c. is characterised by van der Waals' coefficients that are dependent on the identity of the gas but are independent of the temperature
- d. has the pressure that is lower than the pressure exerted by the same gas behaving ideally

Q.*

If a gas is expanded at constant temperature

(1986, 1M)



$$V \uparrow \quad P \downarrow \quad (T = \text{const})$$

- a. the pressure decreases
- b. the kinetic energy of the molecules remains the same
- c. the kinetic energy of the molecules decreases
- d. the number of molecules of the gas increases



$$Q. \frac{n'_A}{n'_B} = \frac{n_A}{n_B}$$

$$\frac{V'_A}{V'_B} = \frac{n_A}{n_B}$$

$$\frac{1+x}{3-x} = \frac{5}{4}$$

$$4+4x = 15 - 5x$$

$$9x = 11$$

$$x = \frac{11}{9}$$

$$\frac{n'_A}{n'_B} = \frac{n_A}{n_B}$$

$$V'_A = 1+x$$

$$= 1 + \frac{11}{9}$$

$$= \frac{20}{9}$$

A closed tank has two compartments A and B , both filled with oxygen (assumed to be ideal gas). The partition separating the two compartments is fixed and is a perfect heat insulator (Fig. 1). If the old partition is replaced by a new partition which can slide and conduct heat but does not allow the gas to leak across (Fig. 2), the volume (in m^3) of the compartment A after the system attains equilibrium is _____.



Fig. 1

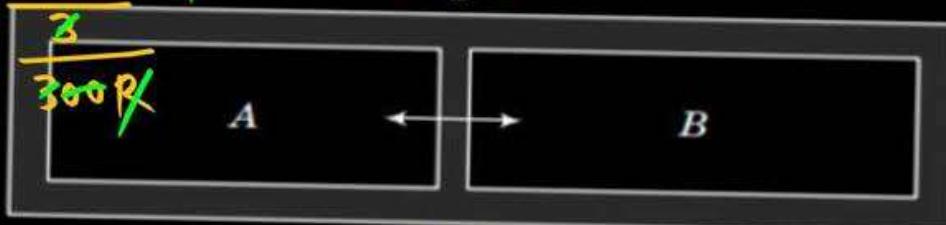


Fig. 2

At eq^m

$$P_A = P_B$$

$$T_A = T_B$$

(2018 Adv)

Q.

Passage

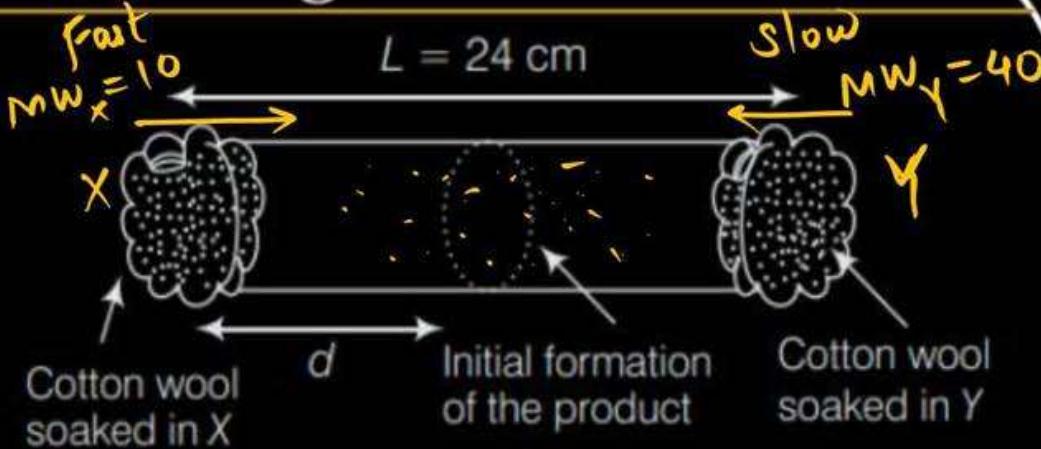
X and Y are two volatile liquids with molar weights of 10 g mol^{-1} and 40 g mol^{-1} respectively.

Two cotton plugs, one soaked in X and

the other soaked in Y , are simultaneously placed at the ends of a tube of length $L = 24 \text{ cm}$, as shown in the figure.

The tube is filled with an inert gas at 1 atm pressure and a temperature of 300 K . Vapours of X and Y react to form a product which is first observed at a distance $d \text{ cm}$ from the plug soaked in X . Take X and Y to have equal molecular diameters and assume ideal behaviour for the inert gas and the two vapours.

(2014 Adv.)



Q.

The exp value of d is found to be smaller than the estimate obtained using graham's law
This is due to



- a. larger mean free path for X as compared of that of Y
- b. larger mean free path for Y as compared to that of X
- c. increased collision frequency of Y with the inert gas as compared to that of X with the inert gas
- d. increased collision frequency of X with the inert gas as compared to that of Y with the inert gas



Q.

The value of d in cm (shown in the figure), as estimated from Graham's law, is

a. 8 b. 12 c. 16

d. 20

$$d = 16 \text{ cm}$$

$$\begin{array}{l} 1 \rightarrow x \\ 2 \rightarrow y \end{array}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\frac{d}{24-d} = \sqrt{4}$$

$$\frac{d}{24-d} = \sqrt{\frac{40}{10}}$$

$$\frac{d}{24-d} = 2$$

$$d = 48 - 2d$$

$$3d = 48$$



Match the Columns

Q.

Match the gases under specified conditions listed in Column I with their properties/laws in Column II.

Column I (Real Gas)	Column II
A. Hydrogen gas ($p = 200 \text{ atm}$, $T = 273 \text{ K}$) $\gamma > 1$ (P, S)	p. compressibility factor $\neq 1$
B. Hydrogen gas ($p \sim 0$, $T = 273 \text{ K}$) $\gamma = 1$ (R)	q. attractive forces are dominant
C. CO_2 ($p = 1 \text{ atm}$, $T = 273 \text{ K}$) (P, Q)	r. $pV = nRT$
D. Real gas with very large molar volume (R)	s. $p(V - nb) = nRT$ $\gamma = 1 + \frac{Pb}{RT}$

(2007, 6M)

True / False



Q.

A mixture of ideal gases is cooled up to liquid helium temperature (4.22 K) to form an ideal solution. (1996, 1M)

False



Integer Answer Type Questions

Q.

The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases x times. The value of x is ...

(2016 Adv.)

$$D \cdot C \propto \lambda V_{avg}$$

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

$$V_{avg} \propto \sqrt{T}$$

$$D \cdot C \propto \frac{T \times \sqrt{T}}{P}$$

$$D \cdot C \propto \frac{(T)^{3/2}}{P}$$

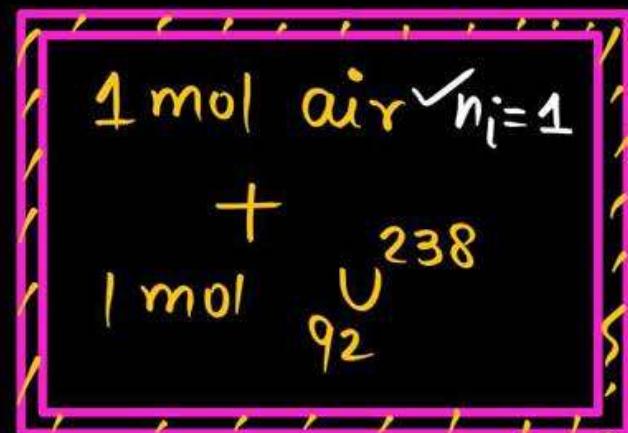
$$\frac{(4)^{3/2}}{2}$$

$$\frac{2^3}{2} = 4$$

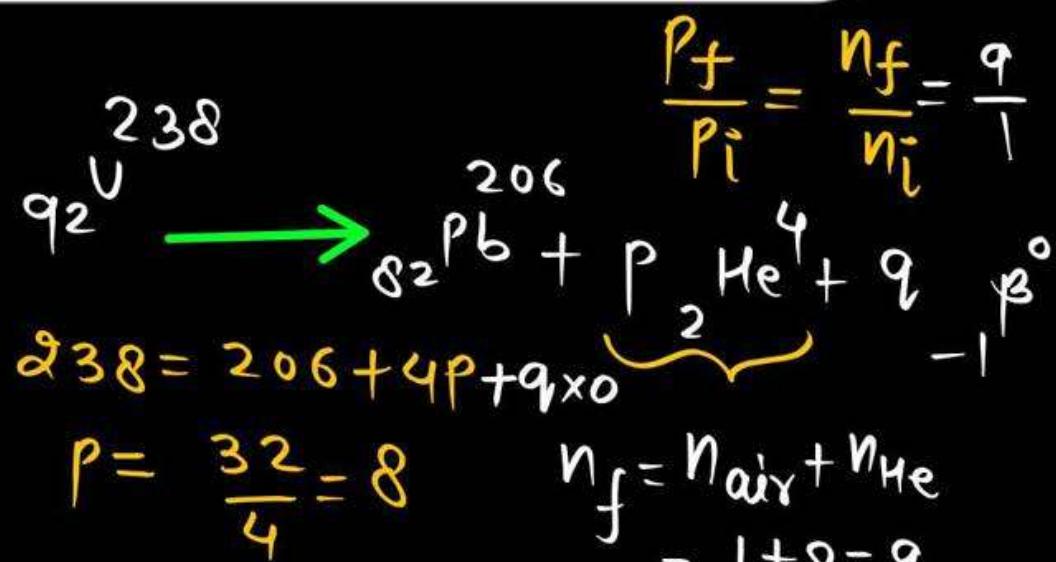
Q.

A closed vessel with rigid walls contains 1 mole of $^{238}_{92}\text{U}$ and 1 mole of air at 298 K. Considering complete decay of $^{238}_{92}\text{U}$ to $^{206}_{82}\text{Pb}$, the ratio of the final pressure to the initial pressure of the system at 298 K is

(2015 Adv.)

 $(P \propto n)$ 

298 K
V fixed





Q.

To an evacuated vessel with movable piston under external pressure of 1 atm, 0.1 mole of He and 1.0 mole of an unknown compound (vapour pressure 0.68 atm at 0°C) are introduced. Considering the ideal gas behaviour, the total volume (in litre) of the gases at 0°C is close to (2011)

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

$$(1 - 0.68)V = 0.1 \times \frac{1}{12} \times 273$$

$$0.32 \times V = 0.1 \times 22.4$$

$$V = \frac{2.24}{0.32} = 7$$