Physical Chemistry (8 hours) 12 marks

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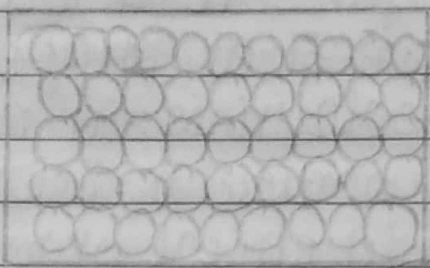
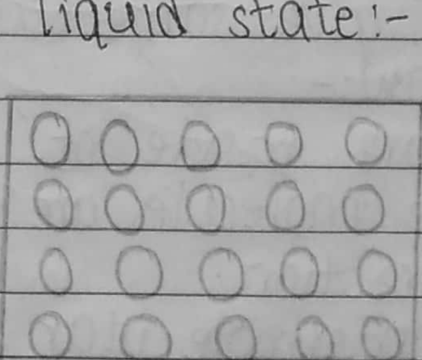
State of Matter

Matter: Any thing that has mass is called matter. Matter are further classified into solid state, liquid state & gas state.

Solid state: The matter whose molecules are very tightly packed & has fixed shape & size. There is very small intermolecular space between these. They have high density & strong intermolecular force. Structure of solid state:-

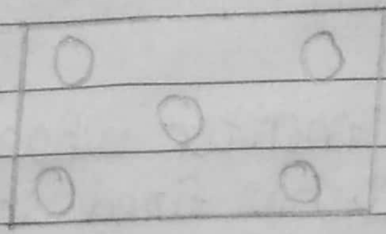


Liquid state: The state of matter in which molecules can flow (mobile) is called liquid state. There is intermolecular distance greater than solid but less than gas. They do not have fixed shape & size. They accquire the volume of vessels. Structure of liquid state:-



Gases state: The state of matter in which molecules can blow (mobile) in all possible directions called gases state. There is large intermolecufar distance between the molecules greater than solid & liquid.

Structure of gas:-



Characterized of gases

1) All the gaseous molecules expand from high pressure to lower pressure & accquire volume of vessel

2) They don't have fixed shape, size, volume. Most of gases are colourless in nature but (Cl_2, F_2, Br_2, I_2 has their particular colour.

3) The physical & chemical properties depend upon temperature & pressure.

4) Gaseous molecules are compressible in nature & some gases are combustible in nature.

Kinetic molecular theory of gases (4 marks)

To study physical properties of these gaseous molecules K.E give some basic postulates which are given below:-

1) All the gases are made of small particles called molecules. These molecules are moving randomly to all possible direction.

2) There is large intermolecular distance between these gaseous molecules.

3) The collision between these gaseous molecules is perfectly elastic. (It means that there no loss of energy)

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4) The average kinetic energy of these gaseous molecules is directly proportional to absolute temperature.
5) The pressure applied by these gaseous molecules on the wall of container due to continous bombarment.
6) There is no effect of gravity on these gases molecules.

All the gaseous molecules have almost same physical properties. To study about their physical properties following Genralization is made.

* Boyle's law (5 marks)

In 1662 AD, Robert Boyle's study about relationship between volume of given mass of gas & pressure at constant temperature.

According to Boyle's law "volume of given mass of gas is inversely proportional to pressure of given gas at constant temperature."

Mathmatically, $V \propto \frac{1}{P}$ at constant temperature.

For gas A

Let P_1 & V_1 is pressure & volume of gas A.

According to Boyle's law,

$V_1 \propto \frac{1}{P_1}$

$V_1 = \frac{k}{P_1}$

$P_1V_1 = k$ — (i)

For gas B.

Let P_2 & V_2 is pressure & volume of gas B.

According to Boyle's law

$V_2 \propto \frac{1}{P_2}$

$V_2 = \frac{k}{P_2}$

$P_2V_2 = k$ — (ii)

Combining eq^n (i) & (ii),

$P_1V_1 = P_2V_2$

$\therefore \frac{P_1}{P_2} = \frac{V_2}{V_1}$

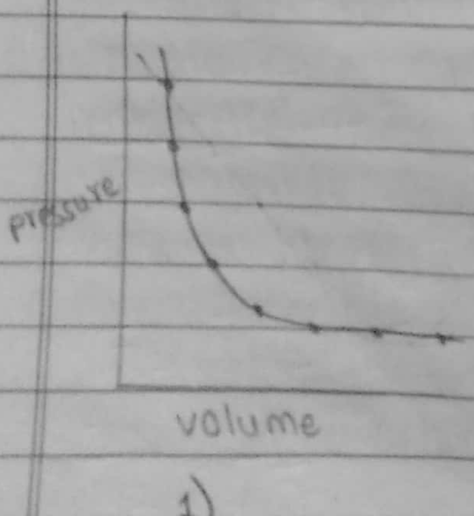
Graphical Representation of Boyle's law

1) volume vs pressure graph

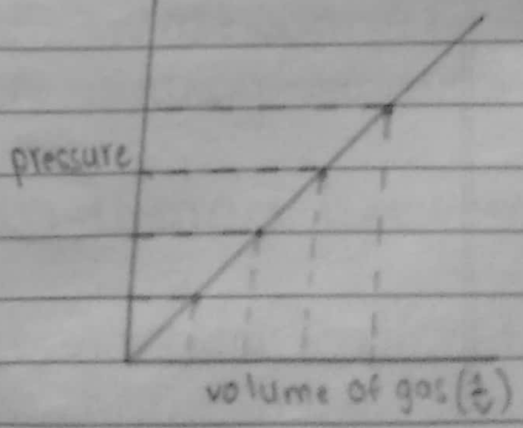
When volume of certain mass of gas is plotted against pressure hyperbolic curve is obtain.

2) pressure vs $\frac{1}{V}$ graph

When pressure of given gas is plotted against $(\frac{1}{V})$ a linear straight line is obtained.



1)



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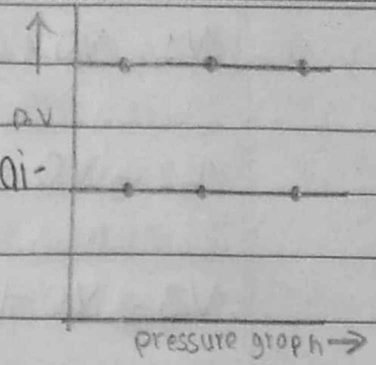
3) Pressure x volume vs pressure graph

When pressure volume product (Pv) is plotted against pressure then a straight line is obtained parallel to axis.



Significance of Boyle's law

1) Boyle's law prove mathmatically, that gases are compressible in nature.
2) It gives relationship between volume of given mass & gas & pressure at constant temperature.
3) It also give relationship between pressure of gas with density of given mass of gas.

$\frac{m}{D} \propto \frac{1}{P}$

$\frac{m}{D} = \frac{K}{P}$

$P \times m = K \times D$

$\therefore P = \frac{K}{m} \times D$

$\therefore P \propto D$

2) Charle's law

Alexander Charle's 1787 AD give relationship between volume of certain mass of gas with temperature at constant pressure.

According to charle's law "At constant pressure, volume of given mass of gas increases or decreases by $\frac{1}{273}$ of volume at 0°C for each rise or fall in temperature."

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$$V_1 = V_0 + \frac{1}{273} \times V_0$$

$$V_2 = V_0 + \frac{2}{273} \times V_0$$

$$V_3 = V_0 + \frac{3}{273} \times V_0$$

$$V_t = V_0 + \frac{t}{273} \times V_0$$

$$= V_0 \left[1 + \frac{t}{273} \right]$$

$$V_t = V_0 \left[\frac{273 + t}{273} \right]$$

Or,

"Volume of given mass of gas is kelvin directly proportional to temperature at constant pressure.

i.e. $V \propto T$

$V = kT$ [at constant]

For gas A

If V_1 & T_1 are volume & temperature of gas A.

According to charle's law

$V_1 \propto T_1$ at constant pressure

$V_1 = kT_1$

$$\frac{V_1}{T_1} = k \quad \text{--- (i)}$$

For gas B

If V_2 & T_2 are volume & temperature of gas B,

According to charle's law

$V_2 \propto T_2$ at constant pressure

$V_2 = kT_2$

$$\frac{V_2}{T_2} = k \quad \text{--- (ii)}$$

comparing eq^n (i) & (ii)

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

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

This is required combine gas equation of charele's law.

One litre of gas at 0°C is heated to 100°C keeping pressure constant. What is new volume at 100°C?

Given,

Volume (V_1) = 1 litre
Temperature (T_1) = 0 + 273
= 273 K

Volume (V_2) = ?
Temperature (T_2) = 100 + 273
= 373 K

From Charle's law,

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

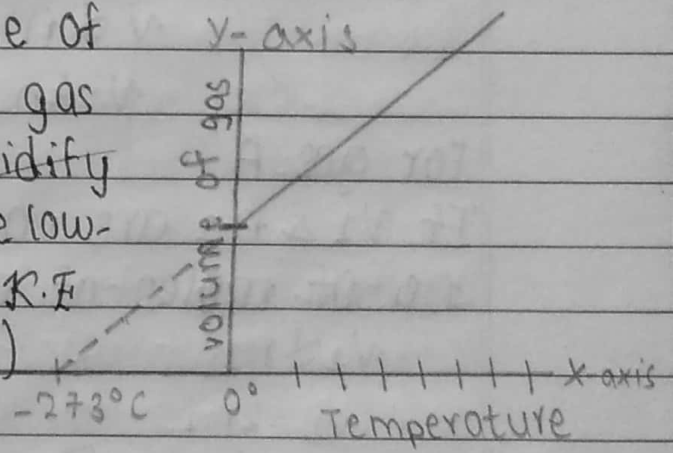
$$\frac{1}{273} = \frac{V_2}{373}$$

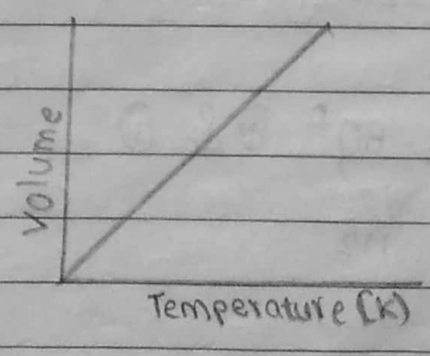
$$V_2 = \frac{1}{273} \times 373$$

$$V_2 = 1.36 \text{ litre}$$

Graphical representation of Charle's law

At temperature 0°C volume of gas is not zero on cooling gas below 0°C it start to liquidify & finally get solidify. The lowest temperature at which K.E of gas become zero (ceased) called absolute temperature (-273°C).





Signification of charle's law
1) It gives concept about relationship between volume of given mass of gas with temperature.
2) It also gives concept about the temperature at which gas become liquid & solid.
3) Charle's law is applied in hot air ballon - Higher the temperature of gas higher volume of gas.

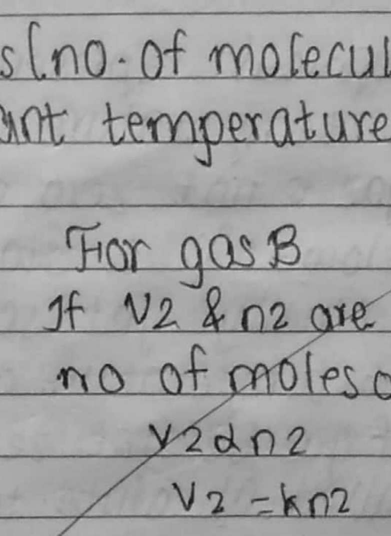
3) Avogadro's law
This law gives relationship between volume of different gas & no. of molecules at constant temperature & pressure.
"Equal volume of different gas contain equal no. of molecules at constant temperature & pressure"

$n \rightarrow$ no. of moles (no. of molecules)
$V \propto n$ at constant temperature & pressure
$V = kn$

For gas A
If V_1 & n_1 are volume & no of moles of gas A
$V_1 \propto n_1$
$V_1 = kn_1$
$\frac{V_1}{n_1} = k$ — (i)

For gas B
If V_2 & n_2 are volume & no of moles of gas B
$V_2 \propto n_2$
$V_2 = kn_2$
$\frac{V_2}{n_2} = k$ — (ii)

combining eq^n (i) & (ii)
$\frac{V_1}{n_1} = \frac{V_2}{n_2}$



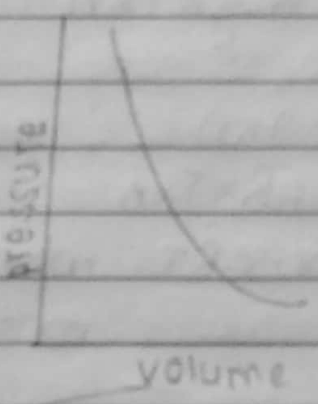
Graphical representation of Avogardo law.

1 mole of gas = 6.023×10^{23} molecules at NTP
(Avogadro number)
5 mole of gas = $5 \times (6.023 \times 10^{23})$ molecules
0.5 mole of gas = $0.5 \times 6.023 \times 10^{23}$ molecules

Ideal gas equation
The equation which gives relationship between Boyle's law, Charle's law & Avogadro's laws is called ideal gas equation. It is also called combined gas equation.

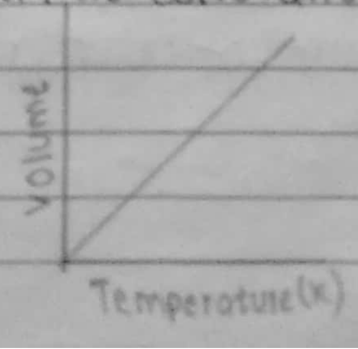
1) Boyle's law
According to Boyle's law "volume of given mass of gas is inversely proportional to pressure of given gas at constant temperature.

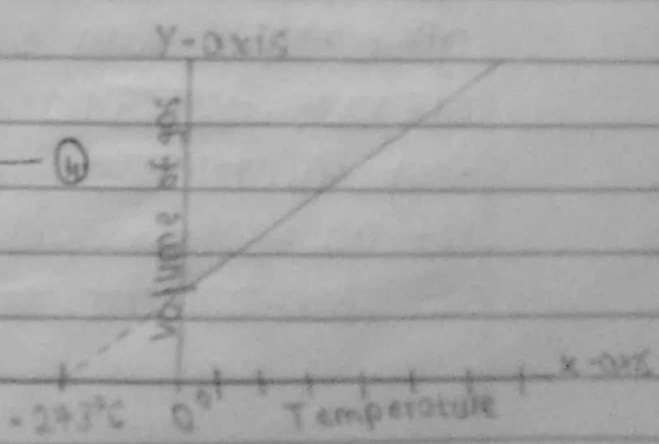
$V \propto \frac{1}{P}$ at constant temperature — ①



2) Charle's law
According to charle's law "At constant pressure, volume of given mass of gas increases or decreases by $\frac{1}{273}$ of volume at 0°C for each rise or fall in temperature."

$V \propto T$ at constant pressure — ④





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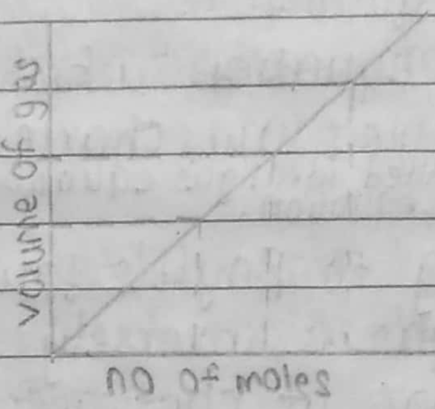
3) Avogadro law

According to Avogadro law, "Equal volume of different gas contain equal no of molecules at constant temperature & pressure."

$V \propto n$ at constant temperature & pressure — (iii)



combining eq^n (i), (ii) & (iii),

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

nR is constant

$PV \propto T \times n$

$PV = R \times T \times n$

$\therefore PV = nRT$ where n is no of moles, R is universal gas constant & T is temperature.

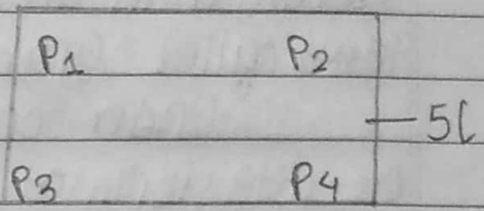
Dalton law of partial pressure (4 marks)

John Dalton in 1807 AD put forward the law to calculate the total pressure of gaseous mixture from the partial pressure of the constituent gases. This law is known as Dalton's law of partial pressure. According to this law "Temperature remaining constant, the total pressure exerted by mixture of gases is equal to the sum of partial pressure of component of gases".

If P_1, P_2, P_3 & P_4 are the partial pressure of gas 1, gas 2, gas 3 & gas 4 respectively.

$P_T = P_1 + P_2 + P_3 + P_4$ at constant temperature

From ideal gas eqⁿ



$P_T V = n_T RT$

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

$$\frac{n_T RT}{V} = \frac{n_1 RT}{V} + \frac{n_2 RT}{V} + \frac{n_3 RT}{V} + \frac{n_4 RT}{V}$$

$$\frac{RT}{V}(n_T) = \frac{RT}{V}(n_1 + n_2 + n_3 + n_4)$$

$n_T = n_1 + n_2 + n_3 + n_4$

Hence, Dalton law is also use to calculate total no of moles of gases mixture.

Application of Dalton's Law

i) It is used to calculate the partial pressure of different gas if total pressure is known at constant temperature.

$P_T = P_A + P_B + P_{unknown}$

$P_T - P_A - P_B = P_{unknown}$

ii) It is also used to relate no. of moles of gaseous mixture from pressure at constant temperature.

$n_T = n_1 + n_2 + n_3$

iii) It is also used to calculate pressure of dry gas from moisture of gas.

$P_{moisture} = P_{dry\ gas} + P_{water\ vapour}$

$P_{moisture} - P_{water\ vapour} = P_{dry\ gas}$

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5) Graham's law of Diffusion (4 marks)

Thomas Graham studied the rate of diffusion of different gases. He observed that lighter gas diffuse faster than denser gases. By his studied, he formulated law called "Graham's law of diffusion."

"Under constant temperature & pressure, the rate of diffusion of different gases are inversely proportional to square root of their densities."

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

where, $r \rightarrow$ rate of diffusion of gas
$d \rightarrow$ density of given gas.

gas A
If r_1 is rate of diffusion of gas A & d_1 is density of gas A.

$$r_1 \propto \frac{1}{\sqrt{d_1}}$$

$$r_1 = \frac{k}{\sqrt{d_1}} \quad \text{— (i)}$$

gas B
If r_2 is rate of diffusion of gas B & d_2 is density of gas B.

$$r_2 \propto \frac{1}{\sqrt{d_2}}$$

$$r_2 = \frac{k}{\sqrt{d_2}} \quad \text{— (ii)}$$

Dividing eq^n (ii) by eq^n (i)

$$\frac{r_2 = \frac{k}{\sqrt{d_2}}}{r_1 = \frac{k}{\sqrt{d_1}}}$$

or, $$\frac{r_2}{r_1} = \frac{\frac{1}{\sqrt{d_2}}}{\frac{1}{\sqrt{d_1}}}$$

$$\therefore \frac{r_2}{r_1} = \sqrt{\frac{d_1}{d_2}} \quad \text{— (iii)}$$

vapour density x 2 = molecular mass

$$d \times 2 = m$$

$$d_1 = \frac{m_1}{2} \qquad d_2 = \frac{m_2}{2}$$

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From eq^n (iii)

$$\frac{r_2}{r_1} = \sqrt{\frac{\frac{m_1}{2}}{\frac{m_2}{2}}}$$

$$\frac{r_2}{r_1} = \sqrt{\frac{m_1}{m_2}}$$

$r_2 \rightarrow$ rate of diffusion of gas B
$r_1 \rightarrow$ rate of diffusion of gas A
$m_1 \rightarrow$ molecular mass of gas A
$m_2 \rightarrow$ molecular mass of gas B

Again, rate of diffusion is defined as the volume of gas diffuse per unit time.

$$r = \frac{\text{volume of gas diffused}}{\text{time taken}} = \frac{v}{t}$$

If volume are equal then

$$r_1 = \frac{v}{t_1} \qquad r_2 = \frac{v}{t_2}$$

We have,

$$\frac{r_2}{r_1} = \sqrt{\frac{m_1}{m_2}}$$

$$\frac{\frac{v}{t_2}}{\frac{v}{t_1}} = \sqrt{\frac{m_1}{m_2}}$$

$$\frac{t_1}{t_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{d_2}{d_1}} \qquad \because \frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

Application of graham's law
i) To find density & molecular mass of unknown gas.
ii) To seperate the two gases having different density for their mixture.

Boyle's Law

Type - 1

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1) A gas occupies 100 cc at pressure of 340 mm of mercury. What will be volume at pressure of 1000 assuming that temperature to be constant.

Given,

Case I

$V_1 = 100$ cc

$P_1 = 340$ mmHg

Case II

$P_2 = 1000$ mmHg

$V_2 = ?$

Using Boyle's law,

$P_1V_1 = P_2V_2$

$(340 \text{ mmHg}) \times 100 \text{ cc} = (1000 \text{ mmHg}) \times V_2$

$\therefore V_2 = 34$ cc

Type-2

2) A vessel contain 250 ml of a gas at 650 mm Hg. The gas is compressed to 150 ml at constant temperature. Find out pressure of compressed gas.

Given,

Case I

Volume of gas $(V_1) = 250$ ml

Pressure of gas $(P_1) = 650$ mmHg

Case II

Volume of compressed gas $(V_2) = 150$ ml

Pressure of compressed gas $(P_2) = ?$

Using Boyle's law,

$P_1V_1 = P_2V_2$

$\frac{P_1V_1}{V_2} = P_2$

$\therefore P_2 = 250$ mm Hg

Type - 3

3) A gas occupies a certain volume under pressure of 10^3 torr. What pressure will be required to compressed gas to the volume to $\left(\frac{1}{3}\right)^{rd}$ at constant pressure.

Case I

Volume of gas(V_1) = V

Pressure of gas (P_1) = 10^3 torr

Case II

Volume of gas(V_2) = $\frac{1}{3}$ V

Pressure of gas (P_2) = ?

Using Boyle's law,

$P_1 V_1 = P_2 V_2$

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

$P_2 = \frac{10^3 \times \cancel{V}}{\frac{1}{3} \cancel{V}}$

$P_2 = 10^3 \times 3$

$\therefore P_2 = 3000$ torr

Charle's law

Type:1

A gas occupies 350 ml at 40°c. calculate temp at which volume of gas become 400 ml. Assume that pressure remain constant.

Given,

Case I

Temperature(T_1) = 40 + 273 = 313 K

Volume(V_1) = 350 ml

Case II

Temperature(T_2) = ?

Volume (V_2) = 400 ml

Applying charle's law,

$\frac{V1}{T1} = \frac{V2}{T2}$

$\frac{350}{313} = \frac{400}{T2}$

$\therefore T2 = 357.71$ K

Type-2

100 ml of nitrogen collected at 27°c & 650 mm pressure are cooled at to -65°c under a pressure of 710 mm. Find out volume occupied by the gas.

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Case I

Volume of N_2 gas (V_1) = 100 ml

Temperature (T_1) = 27+273
= 300 K

Pressure (P_1) = 650 mm

Case II

Volume of N_2 (V_2) = ?

Temperature (T_2) = −65+273
= 208

Pressure of N_2 (P_2) = 710 mm

combine gas eq^n,

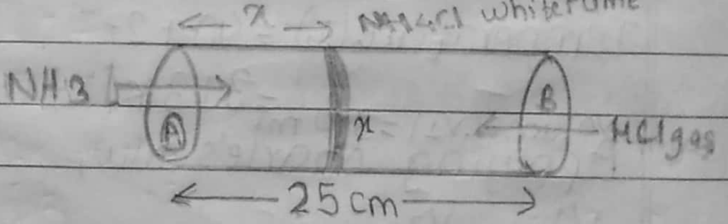
$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{650 \times 100}{300} = \frac{710 \times V_2}{208}$$

$\therefore V_2 = 63.47$ ml

Type: 3

A straight glass tube of length 25 cm has two inlets (A) & (B). NH_3 gas through the inlet B are allowed to enter the tube at same time. White fumes of NH_4Cl applears at point (m) inside the tube. Find distance of (m) & (A).



For NH_3,

$r_1 = \frac{\text{distance travel}(d_1)}{\text{time}}$

$= \frac{x}{t}$

Molecular mass (m_1) of NH_3
= 14+3
= 17 amu

For HCl

$r_2 = \frac{\text{distance travel by HCl}}{\text{time}}$

$= \frac{(25-x)}{t}$

Molecular mass of HCl (m_2) = 1+35.5
= 36.5 amu

By using graham's law of diffussion.

$$\frac{r_1}{r_2} = \sqrt{\frac{m_2}{m_1}}$$

$$\frac{\frac{x}{t}}{\frac{(25-x)}{t}} = \sqrt{\frac{36.5}{17}}$$

$$\frac{x}{25-x} = 1.46$$

$$x = 36.5 - 1.46x$$

$$2.46x = 36.5$$

$$\therefore x = 14.83 \text{ cm}$$

Type: 4 A saturated hydrocarbon (C_nH_{2n+2}) diffuse through porous membrane twice fast as SO_2 gas. Determine the molecular formula of hydrocarbon.

Soln:

Hydrocarbon (C_nH_{2n+2})
molecular mass = m_1
rate of diffusion ~~of~~ (C_nH_{2n+2}) = $2r$

Sulphurdioxide SO_2
molecular mass (m_2) = 64
rate of diffusion of SO_2 = r

By use of graham's law,

$$\frac{r_H}{r_{SO_2}} = \sqrt{\frac{m_2}{m_1}}$$

$$\frac{2\cancel{r}}{\cancel{r}} = \sqrt{\frac{64}{m_1}}$$

$$2 = \sqrt{\frac{64}{m_1}}$$

$$\therefore m_1 = 16$$

Now, $n \times C + (2n+2) \times H = 16$

$$n \times 12 + (2n+2) \times 1 = 16$$

$$12n + 2n + 2 = 16$$

$$14n = 14$$

$$\therefore n = 1$$

Now, C_nH_{2n+2}

$= C_1H_{2\times1+2} = CH_4$

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A saturated hydrocarbon (C_nH_{2n+2}) diffuse throu[gh] porous membrane thrice fast as CO_2 gas. Determ[ine] the molecular formula of hydrocarbon.

Saturated hydrocarbon (C_nH_{2n+1})
molecular mass $= m_1$
rate of diffusion (C_nH_{2n+2}) $= 3r$

Carbondioxide CO_2,
molecular mass $= 44$
rate of diffusion of $CO_2 = r$

By the use of graham's law,

$$\frac{r_H}{r_{CO_2}} = \sqrt{\frac{m_2}{m_1}}$$

$$\frac{3r}{r} = \sqrt{\frac{44}{m_1}}$$

$$9 = \frac{44}{m_1}$$

$$\therefore m_1 = 4.8$$

Now, $n \times C + (2n+2) \times H = 4.8$

$$n \times 12 + (2n+2) \times 1 = 4.8$$

$$12n + 2n + 2 = 4.8$$

$$14n = 4.8 - 2$$

$$\therefore n = 0.2$$

Now, $C_nH_{2n+2} = C_{0.2}H_{2\times 0.5+2}$

$$= C_{0.2}H_3$$

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1) What is ideal gas?

→ The gas which obey ideal gas equation at all temperature and pressure. It is hypothetical gas which is used to study the properties of the real gas.

Some properties of ideal gas

a) The distance between the molecules of the ideal gas is very far from each other.

b) The collision between the gases molecules ~~are~~ is perfectly elastic.

2) What is real gas?

→ The gas which does not obey the ideal gas equation at all temperature & pressure. It only obey at low pressure & high temperature.

Some properties of real gas are given below:-

a) The distance between the gaseous molecules are not very far from each other & the collision between the gases molecules is not perfectly elastic.

3) Why the rate of diffusion of the carbon dioxide is greater than the rate of diffusion of the sulphur dioxide.

→ The rate of diffusion of any gas is inversely proportional to the square root of molecular mass of gas.

$R_1 \propto \frac{1}{\sqrt{m}}$

The molecular mass of CO_2 gas is 44 while SO_2 gas

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is 64. Higher the molecular mass, lower the rate of diffusion.

4) What is diffusion of gases? Is it same or different from effusion. State Graham's law diffusion. Prove that $\frac{t_2}{t_1} = \sqrt{\frac{m_2}{m_1}}$. (1+1+2+2)

→ The process of spreading gases molecules (at all possible direction)~~s~~ from high pressure to low pressure at all possible direction is diffusion of gases.
It is different from effusion because effusion is the process of concentrating of gases molecules from low to high pressure.
The reverse process of diffusion is called effusion.
Graham's law diffusion states that "Under constant temperature & pressure, the rate of diffusion of different gases are inversely proportional to square root of their densities".

Prove that:- $\frac{t_2}{t_1} = \sqrt{\frac{m_2}{m_1}}$

soln:

Let r_1 is rate of diffusion of gas A & t_1 is time taken.

Let, r_2 is rate of diffusion of gas B & t_2 is time taken.

If volume are equal then,

$r_1 = \frac{V}{t_1}$ $\qquad$ $r_2 = \frac{V}{t_2}$

We have,

$$\frac{r_1}{r_2} = \sqrt{\frac{m_1}{m_2}}$$

$$\frac{\frac{\cancel{V}}{t_1}}{\frac{\cancel{V}}{t_2}} = \sqrt{\frac{m_1}{m_2}}$$

$$\therefore \frac{t_2}{t_1} = \sqrt{\frac{m_2}{m_1}}$$ //

5) A balloon can hold 1000 cc of air before brusting. The balloon can hold 975 cc of air at 5°C. Will it brust when it taken to a house at 25°C? Assume that pressure of gas in the balloon remain constant?

Case I
Volume of gas (V_1) = 975 cc
Temperature (T_1) = 5+273
= 278 K

Case II
Volume of gas (V_2) = ?
Temperature (T_2) = 25+273
= 298 K

According to charle's law,

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

$$\frac{975}{V_2} = \frac{278}{298}$$

$\therefore V_2 = 1045.12$ cc

But the capacity of balloon is 1000 cc. Hence, balloon will brust if it is taken to house at 25°C.

6) How long will it take 600 ml of H_2 gas to diffuse through a porous memberane if 300 ml of O_2 diffuse through it in 10 min under similar condition

Volume of H_2 gas (V_H) = 600 ml
~~Rate of diffusion (R_H) =~~
Time of H_2 gas (T_H) = ?

Volume of O_2 gas (V_O) = 300 ml
Time of O_2 gas (T_O) = 10 min

Now, $$\frac{r_H}{r_O} = \sqrt{\frac{m_O}{m_H}}$$

$$\frac{\frac{V_H}{t_H}}{\frac{V_O}{t_O}} = \sqrt{\frac{m_O}{m_H}}$$

$$\frac{V_H \times t_O}{t_H \times V_O} = \sqrt{\frac{m_O}{m_H}}$$

$$\frac{600 \times (10 \times 60)}{t_H \times 300} = \sqrt{\frac{32}{2}}$$

$\therefore t_H = 300$ sec $= 5$ min