IDEAL GAS

1. INTRODUCTION

Matter, as we know, broadly exist in three states - solid, liquid and gas.

There are always two opposite tendencies between particles of matter which determine the state of matter :

- Intermolecular forces.
- The molecular motion / random motion (energy of particles)

Intermolecular forces are the forces of attraction and repulsion between atoms or molecules. Attractive intermolecular forces are known as ***vander Waals forces***. These are dispersion forces, dipole-dipole forces & dipole induced forces. When two molecules are brought very close, they will exert repulsive forces. Magnitude of the repulsion rises very rapidly as the distance separating the molecules decreases. This is the reason that liquid & solids are hard to compress. In these states, molecules are already in close contact, therefore they resist further compression (in that case repulsive interaction will increase) Thermal energy is the energy of a body arising from motion of its atoms or molecules. It is directly proportional to the temperature of the substance. It is the measure of average kinetic energy of the particles of the matter and is thus responsible for movement of particles. This movement of particles is called ***thermal motion***. Intermolecular forces tend to keep the molecules together but thermal energy of the molecules tends to keep them apart. Three states of matter are the result of balance between intermolecular forces and the thermal energy of the molecules.

2. GENERAL CHARACTERISTICS OF SOLID, LIQUID & GAS

Each physical state of matter possesses characteristics properties of its own. For example,

❖ **Solids :**

All solids show the following characteristics :

(i) Solids are rigid and incompressible.

(ii) Solids have fixed shape and definite volume.

(iii) Solids have their melting and boiling points above room temperature.

(iv) Density of solid is high.

❖ **Liquids :**

All liquids show the following characteristics :

(i) Liquids are almost incompressible but less incompressible than solids.

(ii) Liquids have fixed volume but no fixed shape.

(iii) Liquids have their melting points below room temperature and boiling points above room temperature, under normal conditions.

(iv) Density of liquids is lower than that of solids but much higher than that of gases.

- **Gases :**

All gases show the following characteristics :

(i) Gases are highly compressible, i.e. gases can be compressed easily by applying pressure.

(ii) Gases have no fixed volume and shape. Gases fill the container of any size and shape completely.

(iii) Gases can diffuse into each other rapidly.

(iv) Gases have their melting and boiling points both below room temperature.

(v) Gases generally have low density.

3. MEASURABLE PROPERTIES OF GASES

The characteristics of gases are described fully in terms of four parameters or measurable properties :

(I) Amount of the gas (i.e., mass or number of moles).

(II) Volume (V) of the gas.

(III) Temperature (T)

(IV) Pressure (P)

I. Amount of the gas :

(i) The mass of a gas can be determined by weighing the container in which the gas is enclosed and again weighing the container after removing the gas. The difference between the two masses gives the mass of the gas.

Mass of gas (m) = Mass of filled container – mass of empty container

(ii) The mass of the gas is related to the number of moles of the gas as

Moles of gas (n) = Mass in grams / Molar mass = m/M

(iii) Mass is expressed in gram or kg.

II. Gas volume :

(i) Since gases occupy the entire space available to them, the measurement of volume of a gas only requires a measurement of the container confining the gas.

(ii) Volume is expressed in litres (L), millilitres (mL) or cubic centimeters (cm^3) or cubic meters (m^3).

(iii) $1\ L = 1000\ mL\ ;\ \ 1\ L = 1\ dm^3 = 10^{-3}\ m^3$

$1\ m^3 = 10^3\ dm^3 = 10^6\ cm^3 = 10^6\ mL = 10^3\ L$

$1\ mL$ or $1\ cc = 1\ cm^3$

III. Temperature :

(i) Gases expand on increasing the temperature.

(ii) Temperature is measured in degree centigrade (°C) or Celsius degree with the help of thermometers. Temperature is also measured in degree Fahrenheit (°F).

(iii) S.I. unit of temperature is kelvin (K) or absolute degree

$K = °C + 273$

(iv) Relation between °F and °C is

$°C/5 = (°F - 32) / 9$

IV. Pressure :

Force exerted by the gas per unit area of the walls of the container in all directions. Thus,

$$\textit{Pressure } (P) = \textit{Force}(F) / \textit{Area}(A)$$

❖ Atmospheric pressure :

The pressure exerted by atmosphere on earth's surface at sea level is called atmospheric pressure. Generally its unit is atm.

$$\begin{aligned}\textit{Pressure}(P) &= \textit{Force}(F) / \textit{Area}(A)\\ &= \textit{Mass}(m) \times \textit{Acceleration}(g) / \textit{Area}(a)\\ &= \textit{Volume} \times \textit{density} \times \textit{Acceleration}(g) / \textit{Area}(a)\\ &= \textit{Area } (a) \times \textit{height } (h) \times \textit{density } (\rho) \times \textit{Acceleration}(g) / \textit{Area}(a)\end{aligned}$$

$$\textit{Pressure}(P) = h\rho g$$

where h = Height of mercury column in the barometer.

ρ = Density of mercury.

g = Acceleration due to gravity.

Pressure does not depend on the cross section of tube, but only on the vertical height of the Hg. If area is doubled, volume also gets doubled and mass will also gets doubled. Now it will rest on twice area but pressure exerted remains same.

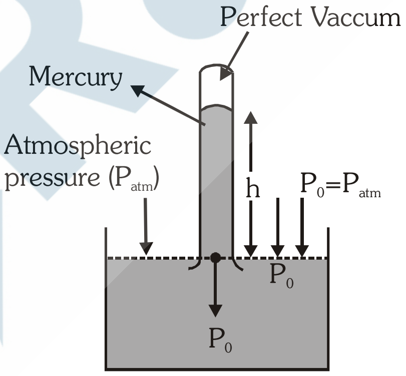
1 atm = 1.013 bar = 1.013×10^5 N/m^2 = 1.013×10^5 Pa

1 atm = 76 cm of Hg = 760 mm of Hg = 760 torr

◻ PRESSURE MEASURING DEVICES

Generally, the instruments used for the calculation of pressure of a gas are ***barometer*** and ***manometer***.

(i) Barometer : A barometer is an instrument that is used for the measurement of atmospheric pressure. The construction of the barometer is as follows -



A thin narrow calibrated capillary tube is filled up to the brim, with a liquid such as mercury, and is inverted into a trough filled with the same fluid. Now depending on the external atmospheric pressure, the level of the mercury inside the tube will adjust itself, the reading of which can be monitored. When the mercury column inside the capillary comes to rest, then the net forces on the column should be balanced.

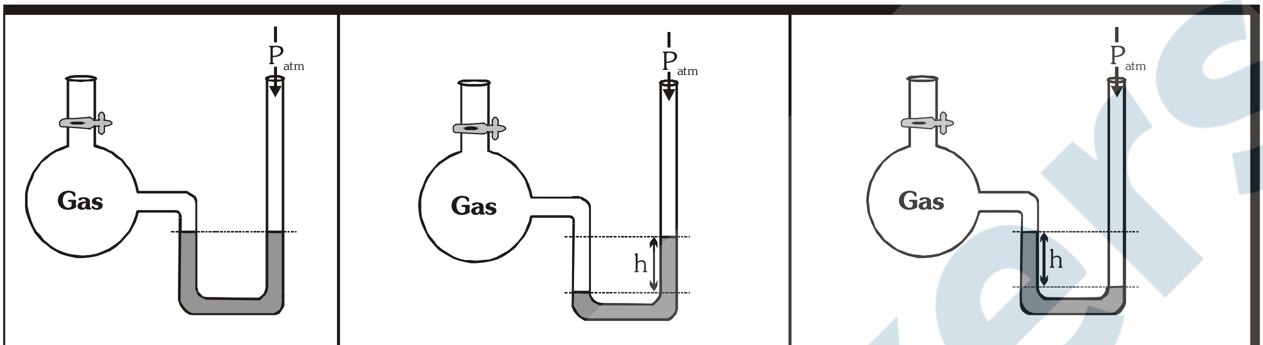
$\Rightarrow \quad P_0 \times A = \rho A \times gh$

$\Rightarrow \quad \boxed{P_0 = \rho gh} \quad$; where ρ is the density of the fluid.

(ii) Manometer :

(a) Open end manometer :

It consists of a U-shaped tube partially filled with mercury. One limb of the tube is shorter than the other. The shorter limb is connected to the vessel containing the gas whereas the longer limb is open as shown in fig. The mercury in the longer tube is subjected to the atmospheric pressure while mercury in the shorter tube is subjected to the pressure of the gas.



(i) Gas pressure = P_{atm} **(ii) Gas pressure =(P_{atm}+h) cm of Hg** **(iii) Gas pressure=(P_{atm}–h) cm of Hg**

Fig : Measurement of gas pressure

Where P_{atm} = 76 cm of Hg and h = Height in cm of Hg

There are three possibilities as described below :

(i) If the level of Hg in the two limbs is same, then gas pressure = atmospheric pressure (P_{atm}).

(ii) If the level of Hg in the longer limbs is higher, gas pressure

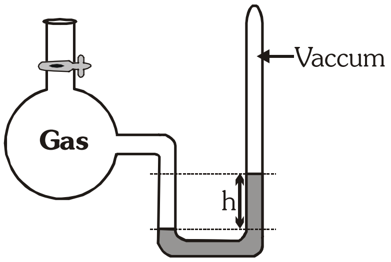
$$= P_{atm} + \text{(difference between the two levels)}$$
$$= P_{atm} + h.$$

(iii) If the level of Hg in the shorter limb is higher, then gas pressure

$$= P_{atm} - \text{(difference between the two levels)}$$
$$= P_{atm} - h.$$

(b) Closed end manometer :

This is generally used to measure low gas pressure. It also consists of U-tube with one limb shorter than the other and partially filled with mercury as shown in fig. The space above mercury on the closed end is completely evacuated. The shorter limb is connected to the vessel containing gas. The gas exerts pressure on the mercury in the shorter limb and forces its level down.



Closed end manometer

Gas pressure = [Difference in the Hg level in two limbs]

Ex.1 Why mercury is used in the barometer tube?

Sol. Mercury, a liquid with very high density, is normally used in the barometer because it does not stick to the surface of the glass tube. Mercury is also non-volatile at room temperature. Therefore, there are hardly any vapours of mercury above the liquid column and their pressure, if any , can be neglected. Due to high density of mercury, height of mercury column will be small and can be easily measured.

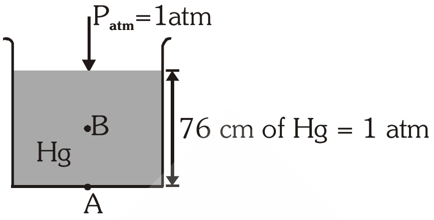
Ex.2 An open tank is filled with Hg upto a height of 76cm.

Find the pressure at the

(a) Bottom (A) of the tank

(b) Middle (B) of the tank.

(If atmospheric pressure is 1 atm)



Sol. **(a)** At bottom,

$$P_A = P_{atm} + P_{Hg}$$

$$= 1 + 1 = 2 \text{ atm}$$

(b) At middle,

$$P_B = P_{atm} + P_{Hg}$$

$$= 1 + \frac{1}{2} = 1.5 \text{ atm}$$

Ex.3 Find the height of water upto which water must be filled to create the same pressure at the bottom, as in above problem.

Given that $d_w = 1 \text{ gm/cm}^3$, $d_{Hg} = 13.6 \text{ gm/cm}^3$, $h_{Hg} = 76$ cm

Sol. $P_{water} = P_{Hg}$

$h_w d_w g = h_{Hg} d_{Hg} g$

$h_w d_w = h_{Hg} d_{Hg}$

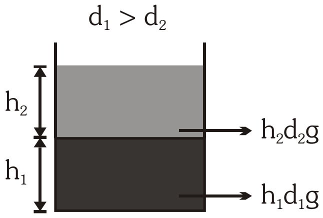
$h_w \times 1 \text{ g/cm}^3 = 76 \text{ cm} \times 13.6 \text{ g/cm}^3$

$h_w = 1033.6$ cm

Ex.4 What will be the pressure if two immiscible fluid is filled according to given diagram.

(a) Find the pressure at the bottom of tank.

(b) Find the pressure at the middle point of bottom layer.

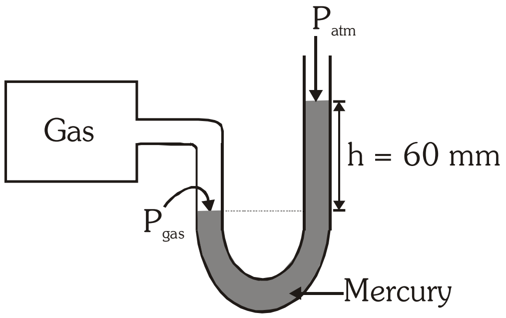


Sol. (a) $P_{atm} + h_2d_2g + h_1d_1g$;

(b) $P_{atm} + h_2d_2g + \frac{h_1}{2}d_1g$

Ex.5 Find the pressure of the gas inside a container if the open manometer attached to the container shows a difference of 60 mm.

Sol. **Case-I :** $P_{atm} < P_{gas}$

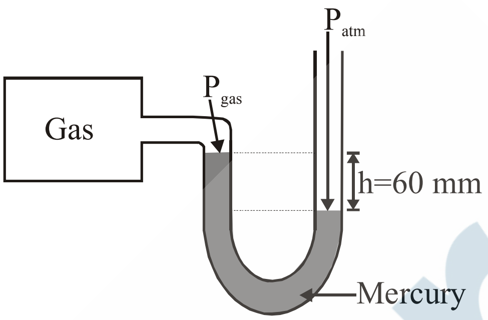


$P_{gas} = P_{atm} + 60$ mm

$= 760$ mm $+ 60$ mm

$= 820$ mm of Hg

Case-II : $P_{atm} > P_{gas}$



$P_{atm} = P_{gas} + 60$ mm

$760 \text{ mm} = P_{gas} + 60$

$P_{gas} = 700$ mm

4. GAS LAWS

The behaviour of the gases is governed by same general laws, which were discovered as a result of their experimental studies. These laws are relationships between measurable properties of gases. Some of these properties like pressure, volume, temperature and mass are very important because relationships between these variables describe state of the gas.

The first reliable measurement on properties of gases was made by Anglo-Irish scientist Robert Boyle in 1662. The law which he formulated is known as ***Boyle's Law***. Later on attempts to fly in air with the help of hot air balloons motivated Jaccques Charles and Joseph Lewis Gay Lussac to discover additional gas laws. Contribution from *Avogadro* and others provided lot of information about gaseous state.

4.1 Boyle's Law :

For a fixed amount of gas at constant temperature, the volume occupied by the gas is inversely proportional to the pressure applied on the gas or pressure of the gas.

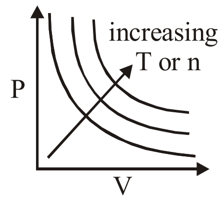
$$\Rightarrow \quad V \propto \frac{1}{P}$$

$$\Rightarrow \quad \text{Hence ,} \; PV = \text{const. (K)}$$

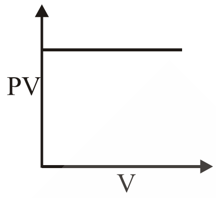
$$\Rightarrow \quad \boxed{P_1V_1 = P_2V_2}$$

❖ Graphical representation of Boyle's law :

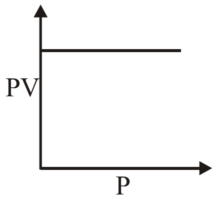
(i) P v/s V :



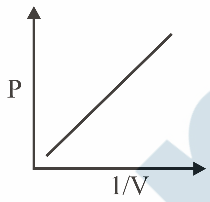
(ii) PV v/s V :



(iii) PV v/s P :



(iv) P v/s 1/V :



4.2. Charle’s Law :

For a fixed amount of gas at constant pressure, volume occupied by the gas is directly proportional to temperature of the gas on absolute scale of temperature.

⇒ $V \alpha T$

⇒ $V = KT$

$$\boxed{\frac{V}{T} = \text{constant (K)}}$$

T = Temperature on absolute scale, kelvin scale or ideal gas scale.

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

$$\boxed{V = V_0 + bt}$$

t = temperature on centigrade scale.

V_0 = volume of gas at 0°C.

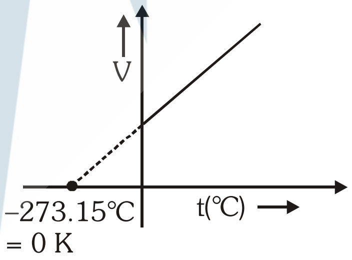
$$\boxed{V = b'T}$$

T = absolute temperature (K)

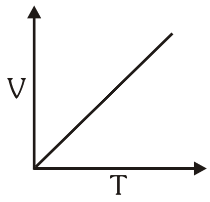
b, b' = constants

❖ Graphical representation of Charle’s Law :

(i) V v/s t (°C) :



(ii) V v/s T :



❖ **Important Points :**

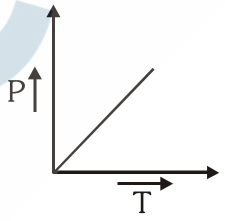
- Since volume is proportional to absolute temperature, the volume of a gas should be theoretically zero at absolute zero temperature.
- In fact, no substance exists as gas at a temperature near absolute zero, though the straight line plots can be inter polated to zero volume. Absolute zero can never be attained practically though it can be approached only.
- By considering –273.15°C as the lowest approachable limit, Kelvin developed temperature scale which is known as absolute scale.

4.3. Gay-lussac's law :

For a fixed amount of gas at constant volume, pressure of the gas is directly proportional to temperature of the gas on absolute scale of temperature.

$\Rightarrow \quad P \propto T$

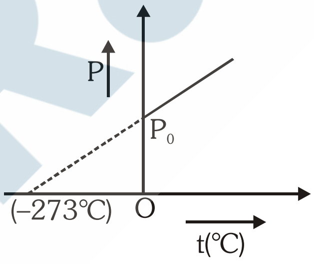
$$\frac{P}{T} = \text{constant (K)}$$



$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ Temperature on absolute scale, kelvin scale or ideal gas scale.

Note: Originally, the law was developed on the centigrade scale, where it was found that pressure is a linear function of temperature $\Rightarrow \boxed{P = P_0 + bt}$,

where 'b' is a constant and 'P_0' is pressure at zero degree centigrade.



But for kelvin scale : $\boxed{P = b''T}$ where T is in K.

4.4. Avogadro's law :

Equal volumes of all the gases under similar conditions of temperature and pressure contains equal number of molecules or moles of molecules (not atoms).

$V \propto N$ (Temperature and pressure constant)

$V \propto n$ (Temperature and pressure constant)

Where, N = number of molecules, n = number of moles of molecules

$$\boxed{\frac{V_1}{N_1} = \frac{V_2}{N_2} \text{ or } \frac{V_1}{n_1} = \frac{V_2}{n_2}}$$

Since volume of a gas is directly proportional to the number of moles; one mole of each gas at standard temperature and pressure (STP) will have same volume.

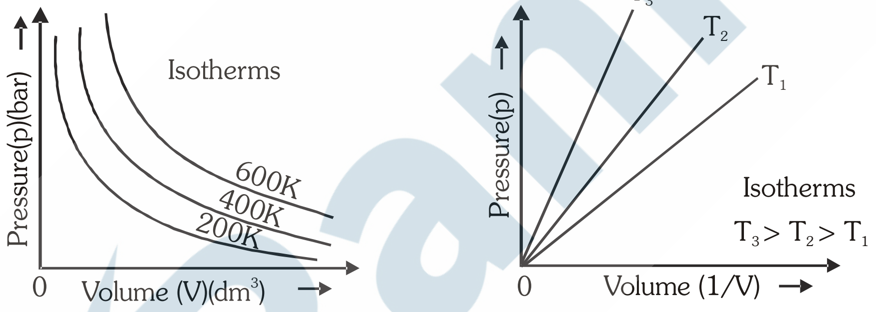
Standard temperature and pressure means 273.15 K (0°C) temperature and 1 bar (i.e., exactly 10^5 pascal) pressure. At STP, molar volume of an ideal gas or a combination of ideal gases is 22.71098 L mol^{-1}.

Molar volume in litres per mole of some gases at 273.15 K and 1 bar (STP).

Argon	22.37
Carbon dioxide	22.54
Dinitrogen	22.69
Dioxygen	22.69
Dihydrogen	22.72
Ideal gas	22.71

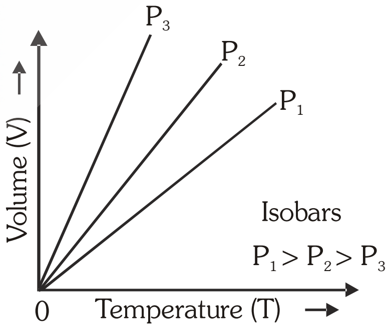
Ex.6 What is a pressure-volume isotherm ?

Sol. Graph between P & V at constant temperature is called ***PV-isotherm***.



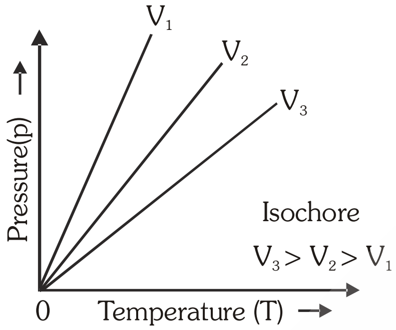
Ex.7 What is Isobar ?

Sol. Graph plotted at constant pressure is called isobar. Graph between V & T at constant pressure is called VT-isobar.



Ex.8 What is Isochore ?

Sol. Graph plotted at constant volume is called isochore. Graph between P & T at constant volume is called PT-isochore.



5. IDEAL GAS EQUATION

A single equation which is combination of Boyle's, Charle's & Avogadro's Law is known as ***Ideal gas equation***. Or we can say a single equation which describe the simultaneous effects of the change in temperature & pressure on volume of the given amount of the gas is called the ***Ideal gas equation.***

$$PV = nRT$$

According to Boyle's law, $V \propto \frac{1}{P}$ (at constant T and n)

According to Charle's law, $V \propto T$ (at constant P and n)

According to Avogadro's law, $V \propto n$ (at constant T and P)

According to the three laws, $V \propto \frac{nT}{P}$ or $PV \propto nT$

or $PV = nRT$ [Equation of state or combined gas law]

Where R is a constant called ***Universal gas constant***, which does not depend on variables (P, V, n, T) and nature of gas.

- Molar volume is the volume of 1 mole of gas.

Molar volume $(V_m) = \frac{\text{Volume}}{\text{mole}}$

$$PV_m = RT$$

Volume of 1 mole of an ideal gas under STP conditions (273.15 K and 1 bar pressure) is 22.7 L mol^{-1}.

- **Dimension of R :**

$$R = \frac{PV}{nT} = \frac{\text{Pressure} \times \text{Volume}}{\text{Mole} \times \text{Temperature}} = \frac{(\text{Force}/\text{Area}) \times (\text{Area} \times \text{Length})}{\text{Mole} \times \text{Temperature}(K)}$$

$$= \frac{\text{Force} \times \text{Length}}{\text{Mole} \times \text{Temperature}(K)} = \frac{\text{Work or energy}}{\text{Mole} \times \text{Temperature}(K)}$$

- **Physical significance of R :**

The dimensions of R are energy per mole per kelvin and hence it represents the amount of work (or energy) that can be obtained from one mole of a gas when its temperature is raised by 1 K isobarically.

- **Units of R :**

(i) In lit-atm $R = \frac{1\,\text{atm} \times 22.4\,\text{lit.}}{1\,\text{mol} \times 273\text{ K}}$ **= 0.0821 lit-atm mol^{-1}K^{-1}**

(ii) In C.G.S system $R = \frac{1 \times 76 \times 13.6 \times 980\ \text{dyne cm}^{-2} \times 22400\,\text{cm}^3}{1\,\text{mol} \times 273\text{ K}}$

= 8.314 × 10^7 erg mole^{-1} K^{-1}.

(iii) In M.K.S.system R **= 8.314 Joule mole^{-1} K^{-1}.** [10^7 erg = 1 joule]
(SI units)

(iv) In calories, $R = \frac{8.314 \times 10^7\ \text{erg mole}^{-1}\text{K}^{-1}}{4.184 \times 10^7\,\text{erg}}$

= 1.987 ≈ **2 calorie mol^{-1} K^{-1}.**

Ex.9 A sample of gas occupies 100 dm^3 at 1 bar pressure and at T °C. If the volume of the gas is reduced to 5 dm^3 at the same temperature, what additional pressure must be applied ?

Sol. From the given data :

$P_1 = 1$ bar $P_2 = ?$
$V_1 = 100\text{ dm}^3$ $V_2 = 5\text{ dm}^3$

Since the temperature is constant, Boyle's law can be applied

$$P_1V_1 = P_2V_2 = P_2 = \frac{P_1V_1}{V_2}$$

$$P_2 = \frac{(1\,\text{bar}) \times (100\,\text{dm}^3)}{(5\,\text{dm}^3)} = 20\,\text{bar}$$

∴ Additional pressure applied = 20 – 1 **= 19 bar**

Ex.10 A human adult breathes in approximately 0.50 dm^3 of air at 1.00 bar with each breath. If an air tank holds 100 dm^3 of air at 200 bar, how many breathes the tank will supply ?

Sol. From the given data :

Volume of air in the tank (V_1) = 100 dm^3

Pressure of air in the tank (P_1) = 200 bar

Pressure of air in each breath (P_2) = 1 bar

∴ Volume of air at 1 bar pressure (V_2) = ?

Since temperature is constant, Boyle's law is applicable

$$P_1V_1 = P_2V_2$$

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

$$V_2 = \frac{(200\,\text{bar}) \times (100\,\text{dm}^3)}{(1\,\text{bar})} = 20{,}000\,\text{dm}^3$$

Volume of air breathed in each breath = 0.50 dm^3

Total no. of breathes the tank will supply $= \frac{\text{total volume of air}}{\text{volume of air in each breath}} = \frac{20000}{0.50}$

= 40,000 breaths.

Ex.11 A certain amount of a gas at 27°C and 1 bar pressure occupies a volume of 25 m^3. If the pressure is kept constant and the temperature is raised to 77°C, what will be the volume of the gas ?

Sol. From the available data :

$V_1 = 25\ \text{m}^3$ $T_1 = 27 + 273 = 300$ K

$V_2 = ?$ $T_2 = 77 + 273 = 350$ K

Since the pressure of the gas is constant, Charles law is applicable

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

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

$$V_2 = \frac{(25\text{m}^3) \times (350\text{K})}{(300\text{K})} = \mathbf{29.17\ m^3}$$

Ex.12 A gas at a pressure of 5.0 bar is heated from 0°C to 546°C and simultaneously compressed to one third of its original volume. What will be the final pressure ?

Sol. From the available data :

$V_1 = V\ \text{dm}^3$ $V_2 = \frac{V}{3}\text{dm}^3$

$P_1 = 5$ bar $P_2 = ?$

$T_1 = 0 + 273 = 273$ K $T_2 = 546 + 273 = 819$ K

According to Gas equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ or $P_2 = \frac{P_1V_1T_2}{T_1V_2}$

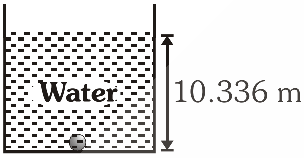
By substituting the values, $P_2 = \frac{(5\ \text{bar}) \times (V\,\text{dm}^3) \times (819\text{K})}{(273\text{K}) \times (V/3\ \text{dm}^3)}$ **= 45 bar**

Ex.13 The density of a gas is found to be 1.56 g dm^{-3} at 0.98 bar pressure and 65°C. Calculate the molar mass of the gas. **Use R = 0.083 dm^3 bar K^{-1} mol^{-1}**

Sol. We know that :

$$M = \frac{dRT}{P} = \frac{(1.56\,g\,dm^{-3}) \times (0.083\,dm^3\,bar\,K^{-1}\,mol^{-1}) \times 338K}{(0.98\,bar)} = \mathbf{44.66\ g\ mol^{-1}}$$

Ex.14 **(a)** Radius of a bubble at the bottom of the tank shown below was found to be 1 cm, then find the radius of the bubble at the surface of water considering the temperature at the surface & bottom being same.



(b) If absolute temperature at the surface is 4 times that at the bottom, then find radius of bubble at the surface.

Sol. **(a)** $\frac{P_bV_b}{n_bT_b} = \frac{P_sV_s}{n_sT_s}$

$$2 \times \frac{4}{3}\pi r_b^3 = 1 \times \frac{4}{3}\pi r_s^3$$

$$2 \times 1^3 = r_s^3$$

$$r_s = 2^{1/3}\,cm$$

(b) Given that $T_s = 4 \times T_b$

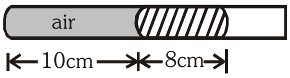
$$\frac{P_bV_b}{n_bT_b} = \frac{P_sV_s}{n_sT_s}$$

$$2 \times \frac{\frac{4}{3}\pi r_b^3}{T_b} = 1 \times \frac{\frac{4}{3}\pi r_s^3}{4 \times T_b}$$

$$r_s^3 = 8$$

$$\mathbf{r_s = 2\ cm}$$

Ex.15 A 10 cm length of air is trapped by a column of Hg, 8 cm long in capillary tube horizontally fixed as shown below at 1 atm pressure.



(fig. 1)

Calculate the length of air column when the tube is fixed at same temperature.

(a) Vertically with open end up

(b) Vertically with open end down

(c) At an angle of 45° from horizontal with open end up

Sol. **(a)** When the capillary tube is held vertically with open end up (fig.2),

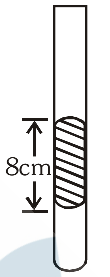
The pressure on the air column = atmospheric pressure + pressure of 8 cm Hg column

= 76 + 8 = 84 cm of Hg.

Let, at this condition the length of the air column = ℓ_2

and the length of air column when capillary is horizontally fixed = ℓ_1 = 10 cm and pressure on air column = 1atm.

Let the cross section area of the capillary = a cm^2



(fig. 2)

$$\therefore 76 \times 10 \times a = 84 \times \ell_2 \times a \quad \text{or} \quad \ell_2 = \frac{76 \times 10}{84} = \mathbf{9.04\ cm}$$

(b) When the capillary tube is held vertically with open end down (fig.3), the pressure on the air column

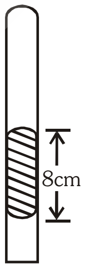
= atmospheric pressure – pressure of 8 cm Hg column

= 76 – 8 = 68 cm of Hg.

Let at this condition the length of air column = ℓ_3.

$$\therefore 68 \times \ell_3 \times a = 76 \times 10 \times a$$

$$\text{or } \ell_3 = \frac{76 \times 10}{68} = \mathbf{11.17\ cm}$$



(fig. 3)

(c) When the capillary is held at 45° with open end up, the weight of Hg is partially borne by the gas and partially by the Hg. The pressure on the gas due to Hg column

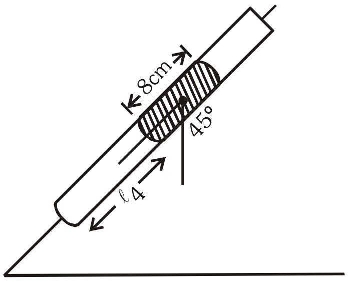
$$= 8 \times \sin 45° = 8 \times \frac{1}{\sqrt{2}} = \frac{8}{\sqrt{2}} \text{ cm of Hg}$$

$$\therefore \text{ total pressure on the gas} = \left(76 + \frac{8}{\sqrt{2}}\right) \text{cm of Hg.}$$

Let length of air column at this pressure = ℓ_4.

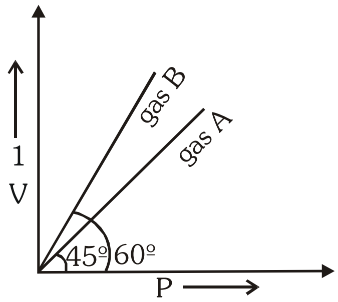
$$\therefore \ell_4 \times a \times \left(76 + \frac{8}{\sqrt{2}}\right) = 10 \times a \times 76$$

$$\therefore \ell_4 = \left(\frac{10 \times 76}{76 + 8/\sqrt{2}}\right) = \mathbf{9.3\ cm}$$



(fig. 4)

Ex.16 At constant temperature of 273 K, $\left(\frac{1}{V}\right)$ v/s P are plotted for two ideal gases A and B as shown.



Find out the number of moles of gas A and B.

Sol. $PV = nRT,\ P = \frac{1}{V}nRT \quad \Rightarrow \quad \frac{1}{V} = \frac{1}{nRT}P$

Comparing by equation : y = mx + C

C = 0

$$m = \frac{1}{nRT} \quad (\because m = \tan\theta)$$

$$\tan\theta = \frac{1}{nRT}$$

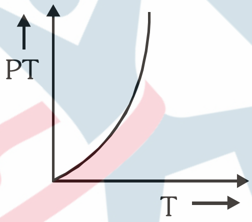
$$n_A = \frac{1}{RT\tan\theta} \quad \Rightarrow \quad n_A = \frac{1}{0.0821 \times 273 \times \tan 45^\circ} \quad \Rightarrow \quad n_A = \frac{1}{22.4}$$

$$n_B = \frac{1}{RT\tan 60^\circ} = \frac{1}{22.4\sqrt{3}}$$

Ex.17 (a) Plot the curve between PT vs T at const V & constant no. of moles.

(b) Find the number of moles of gas taken when the volume of the vessel is 82.1 ml and $\frac{d}{dT}[PT]$ at 300 K = 300 for the given curve.

Sol. (a)



(b) From graph, $P = KT \quad \Rightarrow \quad PT = KT^2$

$$\frac{d(PT)}{dT} = 2KT$$

$$300 = 2\,K \times 300$$

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

$$\frac{nR}{V} = \frac{1}{2} \Rightarrow \frac{n \times 0.0821}{0.0821} = \frac{1}{2} \quad \Rightarrow \quad n = \frac{1}{2}$$

Ex.18 A glass bulb of 2 L capacity is filled by helium gas at 10 atm pressure. Due to a leakage the gas leaks out. What is the volume of gas leaked if the final pressure in container is 1 atm.

Sol. $P_1 \times 2\ L = P_2 \times V$

$\Rightarrow$ $10 \times 2 = 1 \times V$

$\Rightarrow$ $20 = V$

$V = V' + 2\ L$

$20 = V' + 2\ L$

$V' =$ **18 L**

$\Rightarrow$ total volume of gas leaked

Ex.19 LPG is a mixture of n-butane & iso-butane. What is the volume of oxygen needed to burn 1 kg of LPG at 1 atm, 273 K ?

Sol. During the burning of LPG following reaction takes place -

$$C_4H_{10} + \frac{13}{2}O_2 \longrightarrow 4CO_2 + 5\ H_2O$$

Now, for complete combustion of 1 mole of LPG $\longrightarrow \frac{13}{2}$ moles of O_2 are required.

$\therefore$ for $\frac{1000}{58}$ moles of LPG $\longrightarrow \frac{13}{2} \times \frac{1000}{58}$ moles of O_2 are required.

Thus, the volume of oxygen needed to burn 1 kg of LPG at 1 atm & 273K would be

$$\text{Vol. of } O_2 = \text{Moles of } O_2 \times 22.4\ L = \frac{13}{2} \times \frac{1000}{58} \times 22.4 = \mathbf{2510\ L}$$

Ex.20 3.6 g of an ideal gas was injected into a bulb of internal volume of 8 L at pressure P atm and temp T K. The bulb was then placed in a thermostat maintained at (T + 15)K, 0.6 g of the gas was let off to keep the original pressure. Find P and T if mol weight of gas is 44.

Sol. Here, we are given with 2 conditions.

Initially :

Pressure , $P_1 = P$ atm

Volume, $V_1 = 8$ L

Moles, $n_1 = \frac{3.6}{44}$

Temperature $T_1 = T$ K

Finally $\Rightarrow$ At (T + 15)K 0.6 g of gas was let off to keep pressure constant.

$\therefore$ Pressure, $P_2 = P$ atm

Volume, $V_2 = 8$ L (const.)

Moles, $n_2 = \frac{3}{44}$

Temp, $T_2 = (T + 15)$ K

Now, applying -

$$\frac{P_1V_1}{n_1T_1}=\frac{P_2V_2}{n_2T_2}$$

$$\Rightarrow \quad \frac{P\times 8}{\frac{3.6}{44}\times T}=\frac{P\times 8}{\left(\frac{3}{44}\right)\times(T+15)}$$

T = 75 K

Now, putting the value of temp. in the following equation we get :

PV = nRT (putting initial condition)

$$P(8)=\frac{3.6}{44}(0.08)(75)$$

$\Rightarrow$ **P = 0.062 atm**

Ex.21 The best vacuum so far attained in laboratory is 10^{-10} mm of Hg. What is the number of molecules of gas remain per cm^3 at 20°C in this vacuum ?

Sol. Given conditions -

$$P = 10^{-10}\ \text{mmHg} = \frac{10^{-10}}{760}\text{atm}\ ;\ V = 1\ cm^3 = \frac{1}{1000}L\ ;\ T = 20°C = 293\ K$$

No. of molecules, N = ?

Now, applying

PV = nRT

$\therefore$ number of molecules per cm^3 , $N=\frac{N_A\times P\times V}{RT}$

$$\Rightarrow \quad N=\frac{6.023\times 10^{23}\ \times(10^{-10}/760)\times(1/1000)}{(0.0821)(293)}$$

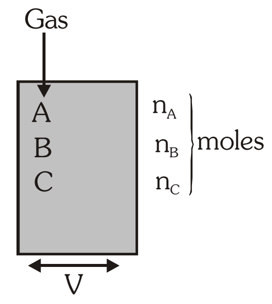
N = 3.29 × 10^6 molecules

6. DALTON'S LAW OF PARTIAL PRESSURES

6.1 Partial pressure :

In a mixture of non-reacting gases, partial pressure of any component gas is defined as the pressure exerted by the individual gas if whole of the volume of mixture had been occupied by this component only.

Partial pressure of component gases are -



$P_A=\frac{n_ART}{V}$ = partial pressure of A

$P_B=\frac{n_BRT}{V}$ = partial pressure of B

$P_C=\frac{n_CRT}{V}$ = partial pressure of C

6.2 Dalton’s Law :

Dalton's law of partial pressure states "at a given temperature, the total pressure exerted by two or more non-reacting gases occupying a definite volume is equal to the sum of the partial pressures of the component gases."

$$P_{Total} = p_1 + p_2 + p_3 + \ldots\ldots \text{ (At constant V and T)}$$

$$= \left(\frac{n_1}{V} + \frac{n_2}{V} + \frac{n_3}{V} + \ldots..\right)RT = (n_1 + n_2 + n_3 + \ldots\ldots)\frac{RT}{V} = \frac{nRT}{V}$$

Where $n = n_1 + n_2 + n_3 + \ldots\ldots$ = Total moles, V = Total volume

$$P_{Total} = \sum p_i = \frac{RT}{V}\sum n_i$$

- **Dalton's law of partial pressure is applicable only to non-reacting gases.**

If the two non-reacting gases A and B having n_A and n_B number of moles respectively are filled in a vessel of volume V at temperature T, then

$$\frac{p_A}{P} = \frac{n_A RT/V}{(n_A + n_B)RT/V} = \frac{n_A}{n_A + n_B} = x_A \text{ (mole fraction of A)}$$

$p_A = x_A \times P$, Similarly $p_B = x_B \times P$

Partial pressure of a component = Mole fraction × total pressure.

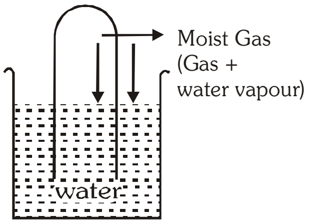
6.3

It has been observed that gases are generally collected over water and therefore are moist.

$$\mathbf{P_{dry\ gas} = P_{moist\ gas} - P_{water\ vapour}}$$

or Pressure of dry gas = Pressure of moist gas – aqueous tension

The pressure exerted by water vapour is constant when it is in equilibrium with liquid water at a particular temperature. It is called vapour pressure of water or ***aqueous tension***, which varies with the temperature and becomes 760 mm at 100°C.



6.4

$$\text{Relative Humidity (RH)} = \frac{\text{Partial pressure of water in air}}{\text{Vapour pressure of water (aq.tension)}}$$

7. AMAGAT'S LAW OF PARTIAL VOLUME

7.1 Partial Volume :

Partial volume of any component is defined as the volume occupied by that particular component when it is kept at same total pressure and temperature as of the mixture.

7.2 Amagat's law :

According to this law at constant temperature and pressure, the total volume of mixture of non-reacting gases is equal to the sum of partial volumes of each component present in mixture.

$$V_T = V_1 + V_2 + V_3 + \ldots\ldots.$$

Let us consider three non-reacting gases A, B and C are present in a container which have no. of moles n_A, n_B and n_C respectively. For each gas partial volume is

$$V_A = n_A\left(\frac{RT}{P}\right) = \text{partial volume of A}$$

$$V_B = n_B\left(\frac{RT}{P}\right) = \text{partial volume of B}$$

$$V_C = n_C\left(\frac{RT}{P}\right) = \text{partial volume of C}$$

- **Total volume** :

$$V_T = V_A + V_B + V_C = (n_A + n_B + n_C)\left(\frac{RT}{P}\right) = n_T\left(\frac{RT}{P}\right)$$

$$\frac{V_A}{V_T} = \frac{n_A}{n_T} = x_A \quad \text{(Mole fraction of gas A)}$$

$$\frac{V_B}{V_T} = \frac{n_B}{n_T} = x_B \quad \text{(Mole fraction of gas B)}$$

$$\frac{V_C}{V_T} = \frac{n_C}{n_T} = x_C \quad \text{(Mole fraction of gas C)}$$

∴ ***Partial volume of a gas = Mole fraction × Total volume***

Ex.22 (a) Find the total pressure and partial pressure of each component if a container of volume 8.21 lit. contains 2 moles of A and 3 mole of B at 300K.

(b) What will be the final pressure and partial pressure of each component if 5 moles of C is also added to the container at same temperature.

Sol. (a) $P_A = \frac{n_A RT}{V} = \frac{2 \times 0.821 \times 300}{8.21} = 6\,\text{atm}$

$P_B = \frac{n_B RT}{V} = \frac{3 \times 0.821 \times 300}{8.21} = 9\,\text{atm}$

Total pressure $P_T = P_A + P_B = 6 + 9 = 15$ atm

(b) $P_C = \frac{n_C RT}{V} = \frac{5 \times 0.821 \times 300}{8.21} = 15\,\text{atm}$

Note: If we add or remove a non reacting gas partial pressure of other gases remains unchanged.

$P_T = P_A + P_B + P_C = 6 + 9 + 15 = 30$ atm

Ex.23 If 2 lit. of gas A at 1.5 atm and 3 lit. of gas B at 2 atm are mixed in a 5 lit. container then find the final pressure, considering all are at same temperature.

Sol.
$$n_A = \frac{P_A V_A}{RT} = \frac{2 \times 1.5}{RT} = \frac{3}{RT}$$

$$n_B = \frac{P_B V_B}{RT} = \frac{3 \times 2}{RT} = \frac{6}{RT}$$

$$\because \quad n_T = n_A + n_B$$

$$\frac{P_T V_T}{RT} = \frac{3}{RT} + \frac{6}{RT}$$

$$P_T \times 5 = 3 + 6$$

$$P_T = 1.8 \text{ atm}$$

Ex.24 One mole of N_2 and 3 moles of H_2 are taken in a container of capacity 8.21 lit. at 300 K to produce NH_3. Find the partial pressures of N_2 and H_2 if partial pressure of NH_3 after sufficient time was found to be 3 atm.

Sol.

	N_2 +	$3H_2$	$\longrightarrow 2NH_3$
mole at t = 0	1	3	
mole at $t = t_{eq}$	1–x	3–3x	2x

Given that

$$P_{NH_3} = 3$$

$$\frac{n_{NH_3} RT}{V} = 3$$

$$\frac{2x \times 0.0821 \times 300}{8.21} = 3$$

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

$$n_{N_2} = 1 - x = \frac{1}{2}$$

$$n_{H_2} = 3 - 3x = \frac{3}{2}$$

$$n_{NH_3} = 2x = 1$$

$$P_{N_2} = \frac{n_{N_2} RT}{V} = \frac{1}{2} \times \frac{0.0821 \times 300}{8.21} = 1.5 \text{atm}$$

$$P_{H_2} = \frac{n_{H_2} RT}{V} = \frac{3}{2} \times \frac{0.0821 \times 300}{8.21} = 4.5 \text{atm}$$

Ex.25 2 moles of $NH_3(g)$ and 1 mole of $HCl(g)$ are taken in a container of capacity 8.21 lit at 300K to produce $NH_4Cl(s)$. Find the total pressure after the reaction.

Sol.

$$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$$

initial	2	1
after rxn	1	0

In this reaction HCl is L.R. so it will be completely consumed. We don't consider pressure due to solid.

$$\therefore \quad P_T = \frac{nRT}{V} = \frac{1 \times 0.821 \times 300}{8.21} = 3\,\text{atm}$$

Ex.26 A closed container containing O_2 and some liquid water was found to exert 740 mm pressure at 27°C.

(a) Then calculate the pressure exerted by O_2 if aqueous tension at 27°C is 20 mm.

(b) What will be the final pressure if volume is reduced to half.

(consider volume of liquid water negligible)

(c) What will be the final pressure if volume is doubled.

Sol. (a) $P_T = P_{\text{dry gas}} + P_{\text{aq. tension}}$

$$740 = P_{O_2} + 20$$

$$P_{O_2} = 740 - 20 = 720 \text{ mm}$$

(b) $(P_{O_2} V_{O_2})_{\text{initial}} = (P_{O_2} V_{O_2})_{\text{final}}$ (Boyle's law)

$$720 \times V = P_{O_2} \times \frac{V}{2}$$

$$P_{O_2} = 1440\,\text{mm}$$

$$P_T = P_T = P_{O_2} + P_{\text{aq.}}$$

$$= 1440 + 20 = 1460 \text{ mm}$$

(c) $(P_{O_2} V_{O_2})_{\text{initial}} = (P_{O_2} V_{O_2})_{\text{final}}$

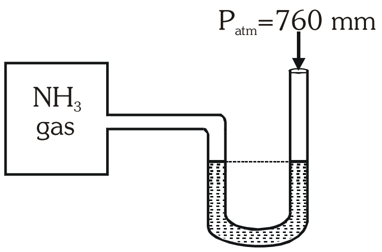
$$720 \times V = P_{O_2} \times 2V$$

$$P_{O_2} = 360 \text{ mm}$$

$$P_T = P_{O_2} + P_{\text{aq.}}$$

$$= 360 + 20 = \mathbf{380\ mm}$$

Ex.27 A manometer attached to a flask contains NH_3 gas have no difference in mercury level initially as shown in diagram. After the sparking into the flask, it have difference of 19 cm in mercury level in two columns. Calculate % dissociation of ammonia.



Sol. P_{NH_3} = 76 cm of Hg initially

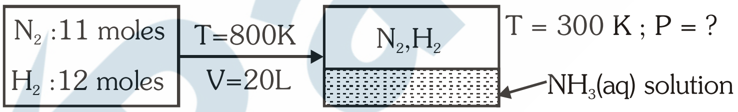
	$2NH_3 \longrightarrow$	N_2 +	$3H_2$
Before sparking	76		
After sparking	76 – 2x	x	3x

Total pressure after sparking = 76 + 2x
= 76 + 19 = 95

$$x = \frac{19}{2} = 9.75 \text{ cm of Hg}$$

$$\% \text{ dissociation} = \frac{2 \times 9.76}{76} \times 100 \Rightarrow 25\ \%$$

Ex.28 11 moles N_2 and 12 moles of H_2 mixture reacted in 20 litre vessel at 800 K. After equilibrium was reached, 6 mole of H_2 was present. 3.58 litre of liquid water is injected in equilibrium mixture and resultant gaseous mixture suddenly cooled to 300 K. What is the final pressure of gaseous mixture? Assume (i) all NH_3 dissolved in water (ii) no change in volume of liquid (iii) no reaction of N_2 and H_2 at 300 K (iv) Vapour pressure of water to be negligible :



Initial condition

Sol. The reaction will occur as follows -

	N_2	+ $3H_2$	$\longrightarrow$ $2NH_3$
initially at t = 0	11 moles	12 moles	0
$t = t_{eq.}$	9 moles	6 moles	4 moles

As 6 moles of H_2 are present at equilibrium it means that 6 moles of H_2 are reacted from the initial condition and along with that 2 moles of N_2 are also reacted to form 4 moles of NH_3.

Now, the final conditions will be -

Volume = (20 – 3.58) = 16.42 L [As 3.58 L of water is injected in vessel]

Total moles = 9 + 6 = 15 moles [All NH_3 dissolved in water]

Temperature = 300 K

Now applying, PV = nRT

$$P = \frac{(15) \times (0.0821) \times (300)}{(16.42)}$$

Total pressure, P_T = **22.5 atm**

Ex.29 What is the difference in the density of dry air at 1 atm and 25°C and moist air with 50% relative humidity under the same condition. The vapour pressure of water at 25°C is 23.7 Torr and dry air has 75.5% N_2 and 24.5% O_2.

Sol.

$$\text{M (dry air)} = \frac{M_1(O_2)X_1(\%\text{ of }O_2) + M_2(N_2)X_2(\%\text{ of }N_2)}{X_1 + X_2}$$

$$= \frac{32 \times 24.5 + 28 \times 75.5}{100} = 28.98 \text{ g mol}^{-1}$$

$$\text{d (dry air)} = \frac{\text{PM(air)}}{\text{RT}} = \frac{1 \times 28.98}{0.0821 \times 298} = 1.184 \text{ g L}^{-1}$$

$$= 1.184 \text{ kg m}^{-3} \left(\because 1\text{g L}^{-1} = \frac{10^{-3}\text{kg}}{10^{-3}\text{m}^3} = 1\text{kg m}^{-3} \right)$$

$$\text{Relative humidity (50\%)} = \frac{\text{partial pressure of } H_2O \text{ in air}}{\text{vapour pressure of } H_2O}$$

$$\therefore \quad P(H_2O) = 0.50 \times 23.7 \text{ Torr} = 11.85 \text{ torr} = \frac{11.85}{760} \text{ atm} = 0.0156 \text{ atm}$$

$$\%\text{ of } H_2O \text{ vapour in air} = \frac{0.0156 \times 100}{1} = 1.56\%$$

% of N_2 and O_2 in air = 98.44%

$$\text{M (wet air)} = \frac{28.98 \times 98.44(\text{air}) + 18 \times 1.56(\text{water vapour})}{100} = 28.81 \text{ g mol}^{-1}$$

$$\text{d (wet air)} = \frac{\text{PM(wet air)}}{\text{RT}} = \frac{1 \times 28.81}{0.0821 \times 298}$$

$$= 1.177 \text{ g L}^{-1} = 1.177 \text{ kg m}^{-3}$$

difference = 1.184 – 1.177 = 0.007 kg m^{-3}

Ex.30 A gaseous mixture at 760 mm in a cylinder has 65% N_2, 15% O_2 and 20 % CO_2 by volume. Calculate the partial pressure of each gas.

Sol. Partial pressure of gas = mole fraction of gas × total pressure = volume fraction of gas × total pressure

$$p_{N_2} = \frac{65}{100} \times 760 = 494 \text{ mm}$$

$$p_{O_2} = \frac{15}{100} \times 760 = 114 \text{ mm}$$

$$p_{CO_2} = \frac{20}{100} \times 760 = 152 \text{ mm}$$

8. PROBLEM RELATED WITH DIFFERENT TYPE OF CONTAINERS

I. Closed Container :

In this case gas can neither go outside nor it can come inside. So number of moles of gas is always constant.

Closed container can be of following types -

(a) **Closed rigid container** : In this case number of moles constant, volume constant.

At this condition :

Initial Final

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

Example : Gas cylinder

(b) **Closed non rigid container : (fitted with freely movable piston)**

In this kind of container inside pressure is always equal to outside pressure, i.e., atmospheric pressure so that n = constant , p = constant

Ex: Balloon, Water bubble

Initial Final

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

Ex.31 A balloon is inflated to $\frac{7}{8}$ of its maximum volume at 27°C then calculate the minimum temperature above which it will burst.

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

$$\frac{7V}{8 \times 300} = \frac{V}{T}$$

T = 342.8 K

Ex.32 A gas cylinder containing cooking gas can with stand a pressure of 18 atm. The pressure gauge of cylinder indicates 12 atm at 27°C. Due to sudden fire in building the temperature start rising at what temperature will the cylinder explode.

Sol. $\frac{P_1}{T_2} = \frac{P_2}{T_2}$

$$\frac{12}{300} = \frac{18}{T}$$

T = 450 K

II. Tyre tube type container :

In this case temperature is always constant. Initially on adding gas volume of tube will increase and pressure of tube will remain constant until it will gain maximum volume.

$\because\ V \propto n$

Initial Final

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

after attaining maximum volume on adding gas pressure reach to a maximum possible pressure. Hence at this condition volume constant or temperature constant.

V = constant T = constant

$P \propto n$

$$\frac{P_1}{n_1} = \frac{P_2}{n_2}$$

Ex.33 A tyre tube of maximum volume 8.21 lit. can withstand a pressure of 10 atm. Initially the tube is empty.

(i) Calculate the number of moles required to inflate completely the tube upto a pressure of 1 atm & 300 K temperature.

(ii) Calculate the minimum number of moles required to burst the tyre tube at 300 K.

Sol. **(i)** $PV = nRT$

$1 \times 8.21 = n_1 \times 0.0821 \times 300$

$$n_1 = \frac{1}{3}$$

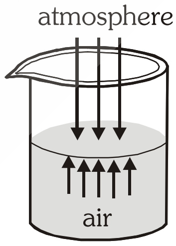
(ii) $PV = nRT$

$10 \times 8.21 = n_2 \times 0.0821 \times 300$

$$n_2 = \frac{10}{3}$$

III. Open rigid container :

When air is heated in an open vessel , pressure is always atmospheric pressure i.e., constant and volume is also constant.



At this condition

Initial Final

$n_1 T_1 = n_2 T_2$

n_1 = initial number of moles

n_2 = final number of moles

$$\mathbf{n_{initial} = n_{final} + n_{removed.}}$$

Ex.34 An open flask contains air at 27°C. Calculate the temperature at which it should be heated so that

(a) 1/3rd of air measured in the container at 27°C escape out.

(b) 1/3rd of air measured in the container at final temperature escape out.

Sol. **(a)** $\mathbf{n_{initial} - n_{final} = n_{expelled}}$

$$\frac{PV}{R\times300}-\frac{PV}{R\times T}=\frac{1}{3}\times\frac{PV}{R\times300}$$

$$\frac{1}{300}-\frac{1}{T}=\frac{1}{900}$$

$$\frac{1}{T}=\frac{1}{300}-\frac{1}{900}=\frac{3-1}{900}=\frac{2}{900}$$

⇒ T = 450 K = 177°C

(b) $\mathbf{n_{initial} - n_{final} = n_{expelled}}$

$$\frac{PV}{R\times300}-\frac{PV}{R\times T}=\frac{1}{3}\times\frac{PV}{R\times T}$$

$$\frac{1}{300}-\frac{1}{T}=\frac{1}{3\times T}$$

⇒ T = 400 K = 127°C

Ex.35 A bulb of unknown volume containing air is heated from 27°C to 227°C at constant pressure. The expelled air is measured at different temperature of determine volume of container. What will be volume of container if -

(a) 200 ml of air measured at 227°C was expelled.

(b) 200 ml of air measured at 27°C was expelled.

(c) 200 ml of air measured at 127°C was expelled.

Sol. **(a)** $\mathbf{n_{initial} - n_{final} = n_{expelled}}$

$$\frac{PV}{R\times300}-\frac{PV}{R\times500}=\frac{P\times200}{R\times500}$$

$$\frac{V}{3}-\frac{V}{5}=\frac{200}{5}$$

$$\frac{5V-3V}{15}=\frac{200}{5}$$

⇒ $2V=\frac{200\times15}{5}$ ⇒ V = 300 ml

(b) $$\frac{PV}{R\times300}-\frac{PV}{R\times500}=\frac{P\times200}{R\times300}$$

$$\frac{2V}{15}=\frac{200}{3}\Rightarrow V=\frac{100\times15}{2\times3}=500\text{ml}$$

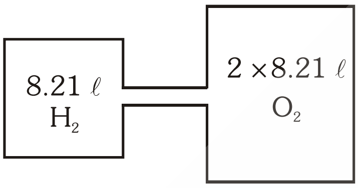
(c) $$\frac{PV}{R\times300}-\frac{PV}{R\times500}=\frac{P\times200}{R\times400}$$

$$\frac{2V}{15}=\frac{200}{4}\quad\Rightarrow\quad V=\frac{200\times15}{2\times4}=375\text{ml}$$

IV. Connected Container :

If containers are connected for substantial time then gases move from one container to another container till partial pressure of each component of mixtures becomes equal in all connected containers (irrespective whether containers have same or different temperature and volumes)

Ex.36 A container of 8.21 lit. capacity is filled with 1 mole of H_2 at 300 K and it is connected to another container of capacity 2 × 8.21 lit. containing 4 moles of O_2 at 300 K, then find the final pressure & partial pressure of each gas.



Sol. $P_fV_f = n_fRT$

$P_f(3 \times 8.21) = 5 \times 0.0821 \times 300$

$P_f = 5$ atm

$$P_{H_2} = x_{H_2}P_f = \frac{1}{1+4} \times 5 = 1\,\text{atm}$$

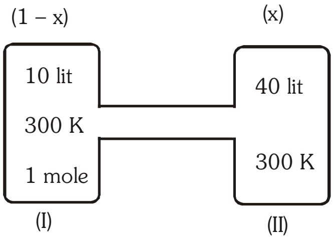
$$P_{O_2} = x_{O_2}P_f = \frac{4}{1+4} \times 5 = 4\,\text{atm}$$

Ex.37 A 10 litre container consist of 1 mole of gas at 300 K. It is connected to another container having volume 40 litre and is initially at 300 K. The nozzle connecting two containers is opened for a long time and once the movement of gas stopped, the larger container was heated to a temperature of 600 K. Calculate

(a) Moles and pressure of gas in both the containers before heating.

(b) Moles and pressure in two containers after heating.

(Assume that initially the larger container is completely evacuated.)



Sol. **(a)** Before heating :

$P_I = P_{II}$

$$\frac{(1-x)R \times 300}{10} = \frac{x \times R \times 300}{40}$$

x = 0.8 moles

$n_I = 1 - x = 0.2$ mole

$n_{II} = x = 0.8$ mole

$$\text{Pressure} = \frac{x \times R \times T}{V} = \frac{0.8 \times R \times 300}{40} = 0.492\ \text{atm}$$

(b) After heating :

$$\frac{(1-x_1)R \times 300}{10} = \frac{x_1 \times R \times 600}{40}$$

$x_1 = 0.67$ moles, Given $T_1 = 600$ K

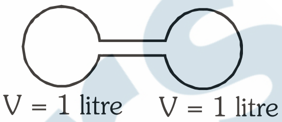
$$\text{Pressure} = \frac{x_1 \times R \times T_1}{V} = \frac{0.67 \times .0821 \times 600}{40} = 0.821\ \text{atm}$$

Ex.38 One litre flask contains air, water vapour and a small amount of liquid water at a pressure of 200 mmHg. If this is connected to another one litre evacuated flask, what will be the final pressure of the gas mixture at equilibrium? Assume that temperature to be 50ºC. Aqueous tension at 50°C = 93 mmHg.

Sol. The aqueous tension remains same in both the flask. Also flask are at same temperature

$\therefore \quad P_1V_1 = P_2V_2$

where $P_1 = 200 - 93 = 107$ mm



$V_1 = 1$ litre

$V_2 = 2$ litre

$\therefore \quad 107 \times 1 = P \times 2$

$P = 53.5$ mm

Since aqueous tension is also present in flask, equivalent to 93 mm.

$\therefore$ pressure of gaseous mixture = 93 + 53.5 = 146.5 mmHg.

9. GRAHAM'S LAW OF DIFFUSION & EFFUSION

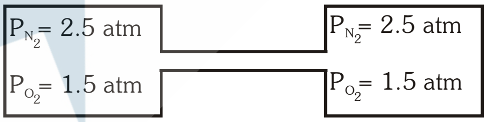
9.1 Diffusion :

The ***diffusion*** is the process of gradual mixing of molecules of one gas with molecules of another gas due to their molecular motion (kinetic energy). The diffusion always proceeds from a region of high concentration to a region of lower concentration (or high partial pressure to low partial pressure). For example, when a bottle of perfume is opened at one end of the room, the person sitting at the other end of the room can smell the perfume because of the diffusion process of perfume molecules.

Note : Initially

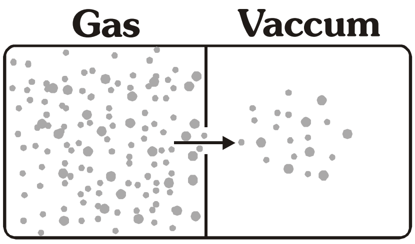
When stop cock is removed flow will be from both sides, N_2 will try to equalise its partial pressure in both the vessels, and so will O_2.

Finally



9.2 Effusion :

The effusion is the process of forcing a gas through a pin hole or small orifice from one compartment to another empty (vacuum) compartment.



9.3 Graham's Law :

Under similar condition of pressure (partial pressure) and temperature, the rate of diffusion of different gases is inversely proportional to square root of their density.

$\Rightarrow$ rate of diffusion, $\boxed{r \propto \frac{1}{\sqrt{d}}}$

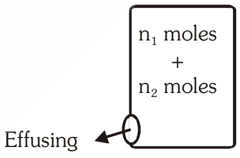
$$\Rightarrow \quad \frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} = \frac{\sqrt{M_2}}{\sqrt{M_1}} = \frac{\sqrt{V.D_2}}{\sqrt{V.D_1}}$$

where, d = density of gas
V.D = vapour density
M = molar mass of gas

- **Under conditions of same temperature but different pressure, we have -**

$$\boxed{r \propto \frac{P}{\sqrt{M}}}$$

$$\boxed{\frac{r_1}{r_2} = \frac{P_1}{P_2}\sqrt{\frac{M_2}{M_1}}}$$



If both gases are present in the same container at same temperature.

$P \propto n$

$$\Rightarrow \quad \frac{r_1}{r_2} = \frac{n_1}{n_2}\sqrt{\frac{M_2}{M_1}}$$

Rate of diffusion/effusion can be expressed as -

$$r = \frac{\text{volume diffused}}{\text{time taken}} \text{ or } \frac{\text{moles diffused}}{\text{time taken}} \text{ or } \frac{\text{pressure dropped}}{\text{time taken}}$$

$$\text{or } \frac{\text{distance travelled in horizontal tube of uniform cross} - \text{section}}{\text{time taken}}$$

Ex.39 32 ml of He effuses through a fine orifice in 1 minute. Then what volume of CH_4 will diffuse in 1 minute under the similar condition.

Sol. $\because \quad r \propto \frac{1}{\sqrt{M}}$

$$r = \frac{\text{volume diffused}}{\text{time}}$$

$\because$ time is same so

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

$$\frac{V_{CH_4}}{32} = \sqrt{\frac{4}{16}}$$

$$V_{CH_4} = \frac{1}{2} \times 32 = 16\,\text{mL}$$

Ex.40 20 dm^3 of Ne diffuse through a porous partition in 60 seconds. What volume of SO_3 will diffuse under similar conditions in 30 sec. (Atomic wt. of Ne = 20, S = 32)

Sol.
$$\frac{r_{N_e}}{r_{SO_3}} = \sqrt{\frac{M_{SO_3}}{M_{Ne}}} \Rightarrow \frac{V_{Ne}/t_{Ne}}{V_{SO_3}/t_{SO_3}} = \sqrt{\frac{M_{SO_3}}{M_{Ne}}}$$

$$\Rightarrow \quad V_{SO_3} = \frac{V_{Ne} \times t_{SO_3}}{t_{Ne}} \times \sqrt{\frac{M_{Ne}}{M_{SO_3}}} = \frac{20 \times 30}{60} \times \sqrt{\frac{20}{80}} = \frac{10}{2} = 5\ dm^3$$

Ex.41 A gaseous mixture of O_2 and X containing 20% (mole %) of X, diffused through a small hole in 234 seconds while pure O_2 takes 224 seconds to diffuse through the same hole. Molecular weight of X is :

Sol.
$$\frac{t_{mix}}{t_{O_2}} = \sqrt{\frac{M_{mix}}{M_{O_2}}}$$

$$\frac{234}{224} = \sqrt{\frac{M_{mix}}{32}}$$

$$\therefore \qquad M_{mix} = 34.921.$$

As the mixture contains 20% (mole %) of X, the molar ratio of O_2 and X may be represented as 0.8n : 0.2n, n being the total no. of moles.

$$\therefore \qquad M_{mix} = \frac{32 \times 0.8n + M_x \times 0.2n}{n} = 34.921$$

$$\therefore \qquad M_x \text{ (mol. wt. of X)} = 46.6$$

Ex.42 A mixture of H_2 and O_2 in 2 : 1 mole ratio is allowed to diffuse through a orifice. Calculate the composition of gases coming out initially.

Sol.
$$\frac{r_1}{r_2} = \frac{n_1}{n_2}\sqrt{\frac{M_2}{M_1}}$$

where n_1 and n_2 are the moles of gases taken.

$$\frac{n'_1}{n'_2} = \frac{n_1}{n_2}\sqrt{\frac{M_2}{M_1}}$$

where n_1' and n_2' are the moles of gases diffused.

$$\frac{n'_1}{n'_2} = \frac{2}{1}\sqrt{\frac{32}{2}} = \frac{8}{1}$$

Ex.43 One mole of nitrogen gas at 0.8 atm takes 38 s to diffuse through a pinhole, whereas one mole of an unknown compound of xenon with fluorine at 1.6 atm takes 57 s to diffuse through the same hole. Determine the molecular formula of the compound.

Sol. or $\frac{r_2}{r_1} = \frac{p_2}{p_1}\left(\frac{M_1}{M_2}\right)^{1/2} \Rightarrow \frac{t_1}{t_2} = \left(\frac{p_2}{p_1}\right)\left(\frac{M_1}{M_2}\right)^{1/2}$

or $M_2 = \left(\frac{p_2 t_2}{p_1 t_1}\right)^2 M_1$

$$M_2 = \left(\frac{1.6}{0.8} \times \frac{57}{38}\right)^2 \times 28 = 252 \text{ g mol}^{-1}$$

Let the molecular formula of the unknown compound be XeF_n.

$M_{xe} + nM_F = 252$ or $131 + 19n = 252$

$$n = \frac{252 - 131}{19} = 6.36 \simeq 6$$

Hence, the molecular formula of the gas is XeF_6.

Ex.44 At 1200°C, mixture of Cl_2 and Cl atoms (both in gaseous state) effuses 1.16 times as fast as krypton effuses under identical conditions. Calculate the fraction of chlorine molecules dissociated into atoms. M (Kr) = 83.8 g mol^{-1}.

Sol. $Cl_2 \rightleftharpoons 2Cl$

$$\frac{r(Cl_2 \text{ and } Cl \text{ mix})}{r(Kr)} = 1.16 \sqrt{\frac{M(Kr)}{M_{av}(Cl_2 + Cl)}} = \sqrt{\frac{83.8}{M_{av}}}$$

$\therefore$ $M_{av} = \frac{83.8}{(1.16)^2} = 62.28 \text{ g mol}^{-1}$

	$Cl_2 \rightleftharpoons$	$2Cl$
Initial mole	1	0
After dissociation	$(1 - x)$	$2x$

(x = degree of dissociation)

Total moles after dissociation = $1 - x + 2x = (1 + x)$

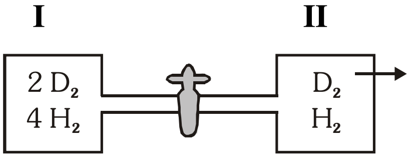
$\therefore$ $\frac{(1-x)M(Cl_2) + 2x\,M(Cl)}{(1+x)} = 62.28 \Rightarrow \frac{(1-x) \times 71 + 2x \times 35.5}{1+x} = 62.28$

x = 0.14

$\therefore$ % dissociation = 14%

Ex.45 A mixture containing 2 moles of D_2 and 4 moles of H_2 is taken inside a container which is connected to another empty container through a nozzle. The nozzle is opened for certain time and then closed. The second bulb was found to contain 4 gm D_2. Then find % by moles of the lighter gases in second container.

Sol.



$w_{D_2} = 4$ gm

$n_{D_2} = \frac{4}{4} = 1$

lighter gas = H_2

$$\frac{r_{H_2}}{r_{D_2}} = \frac{n_{H_2}}{n_{D_2}}\sqrt{\frac{M_{D_2}}{M_{H_2}}} = \frac{n'_{H_2}/t}{n'_{D_2}/t}$$

$$(\%\text{ mole of }H_2)_{II} = \left(\frac{n'_{H_2}}{n'_{H_2}+n'_{D_2}}\right)\times 100$$

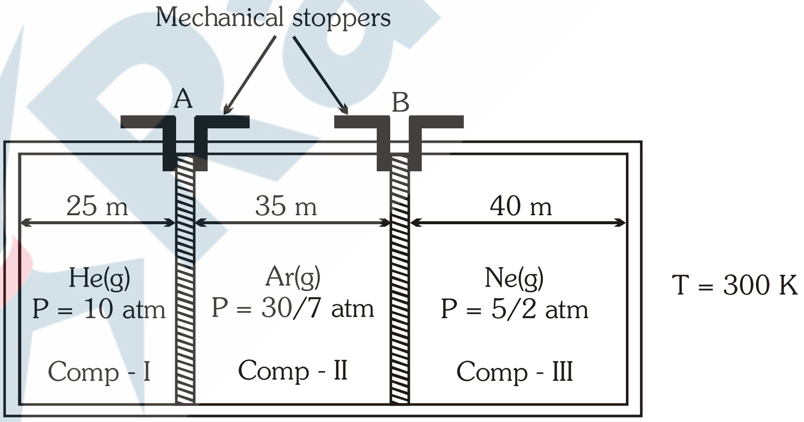
$$\therefore \quad \frac{n_{H_2}}{n_{D_2}}\sqrt{\frac{M_{D_2}}{M_{H_2}}} = \frac{n'_{H_2}}{n'_{D_2}} \quad \Rightarrow \quad \frac{4}{2}\sqrt{\frac{4}{2}} = \frac{n'_{H_2}}{1}$$

$$\Rightarrow \quad n'_{H_2} = 2\sqrt{2} \quad \Rightarrow \quad n'_{D_2} = 1$$

$$(\%\text{ mole of }H_2)_{II} = \frac{(2\sqrt{2})}{(2\sqrt{2}+1)}\times 100 = \frac{2\times 1.44}{[(2\times 1.44)+1]}\times 100 = \frac{(2.8)}{(2.8+1)}\times 100 = \frac{(2.8)}{(2.8+1)}\times 100$$

= 73.87%

Ex.46 The figure shows **initial conditions** of a uniform cylinder with frictionless pistons A and B held in shown position by mechanical stoppers.



If the mechanical stoppers holding piston A and B as shown in figure are removed.

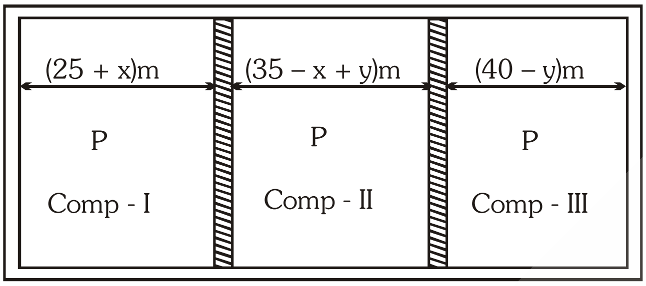
[Assume that temperature remains constant.]

(a) Pressure developed in each compartment in final state.

(b) What will be the final position of piston A (with respect to far left end of container)

(c) What will be the final position of piston B (with respect to far left end of container)

Sol. Piston will move whenever partial pressure will not equalize in each compartment.



(a) $n_T = n_1 + n_2 + n_3$

$P_fV_f = P_1V_1 + P_2V_2 + P_3V_3$

$P_f\ell_fA = P_1\ell_1A + P_2\ell_2A + P_3\ell_3A$

$$P(25 + 35 + 40) = 10 \times 25 + \frac{30}{7} \times 35 + \frac{5}{2} \times 40$$

$P = 5$ atm

(b) For comp I

$P_fV_f = P_1V_1$

$P_f\ell_fA = P_1\ell_1A$

$(25 + x)\ 5 = 10 \times 25$

$x = 25$ m

Final position of piston A (with respect to far left end of container)

$= (25 + x) = 25 + 25 = 50$ m

(c) For comp II

$P_fV_f = P_2V_2$

$P_f\ell_fA = P_2\ell_2A$

$$(35 - x + y)\ 5 = \frac{30}{7} \times 35$$

$(35 - 25 + y)\ 5 = 150$

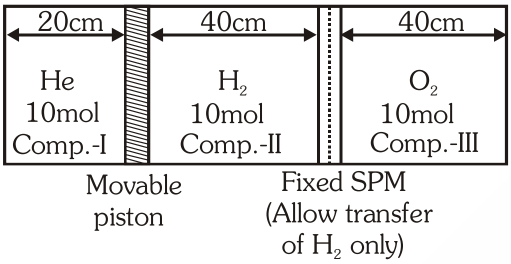
$y = 20$ m

Final position of piston B (with respect to far left end of container)

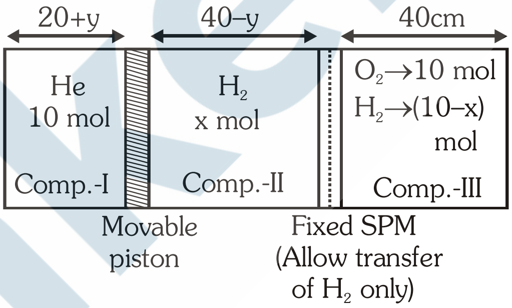
$= (25 + x) + (35 - x + y) = 80$m

Ex.47 Few gases are filled in a container as shown in diagram and allowed to attain equilibrium. Then calculate the moles of H_2 in compartment II.

(Assuming temperature remains constant through out the process.)



Sol. Piston move till pressure on both side becomes equal and H_2 will pass in III compartment till pressure of H_2 in II and III compartment becomes equal let the final position of containers as shown



For H_2:

$$(PH_2)_{II} = (PH_2)_{III}$$

$$\left(\frac{nRT}{V}\right)_{II} = \left(\frac{nRT}{V}\right)_{III}$$

$$\frac{x}{40-y} = \frac{10-x}{40} \quad \text{............(i)}$$

Finally total pressure of gases are equal

$$(P_T)_I = (P_T)_{II} = (P_T)_{III}$$

$$\frac{10}{20+y} = \frac{x}{40-y} = \frac{10-x}{40} \quad \text{..........(ii)}$$

$$\frac{10}{20+y} = \frac{10-x}{40} \quad \Rightarrow \quad x = 10 - \frac{400}{20+y}$$

$$\frac{10}{20+y} = \frac{10 - \frac{400}{20+y}}{40-y}$$

$400 - 10y = 10\,(20 + y) - 400$

$400 - 10y = 200 + 10y - 400$

$600 = 20\,y \Rightarrow y = 30$

$x = 2$

Moles of H_2 in compartment II = x = 2 mol

Moles of H_2 in compartment II = 10 – x = 8 mol

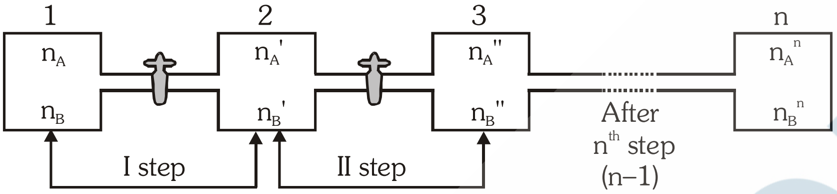
Ex.48 Why a heavier gas from a gas mixture effuses at slower rates ?

Sol. In a gas mixture, the average kinetic energy of each gas $\left(\frac{1}{2}mv^2\right)$ is the same $\left(\frac{3}{2}RT\right)$. Hence, heavier gas has smaller speed.

9.4 APPLICATION OF GRAHAM'S LAW OF DIFFUSION IN ENRICHMENT OF ISOTOPES

❖ **Enrichment factor or Isotopic separation factor :**

When two gases present in a container are allowed to diffuse in another container then gas having lower molecular mass will diffuse more and if this process is continued for large number of steps then we can obtain a mixture which is rich in a gas having lower molecular mass. Hence ultimately in the ultimate (last) container amount of lighter gas is larger as compared to heavier gas.



where, $M_A > M_B$ [similar condition of T and V] & $n_B^n >>>> n_A^n$

Enrichment factor (f) is defined as the ratio of final ratio of moles in the mixture [after n^{th} step] with initial mole ratio of the mixture.

$$f = \frac{\left(\frac{n_A^n}{n_B^n}\right)}{\left(\frac{n_A}{n_B}\right)} = \left(\sqrt{\frac{M_B}{M_A}}\right)^n = \frac{\text{final molar ratio}}{\text{initial molar ratio}}$$

Ex.49 A mixture of N_2 and H_2 has initially mass ratio of 196 : 1 then find after how many steps we can obtain a mixture containing 1 : 14 mole ratio of N_2 and H_2.

Sol.

	N_2	H_2
	196	1
mole	$\frac{196}{28} = 7$	$\frac{1}{2}$

ratio $\frac{n_{N_2}}{n_{H_2}} = \frac{7}{\frac{1}{2}} = \frac{14}{1}$

$$\frac{n'_{N_2}}{n'_{H_2}} = \frac{n_{N_2}}{n_{H_2}}\left(\sqrt{\frac{M_{H_2}}{M_{N_2}}}\right)^n = \frac{1}{14} = \frac{14}{1}\left(\sqrt{\frac{2}{28}}\right)^n \text{ , } n = 4$$

Ex.50 Find the ratio of moles of SO_2 to CH_4 after fifth diffusion steps if their initially mole ratio is 8 : 1.

Sol.

$$\frac{n'_{SO_2}}{n'_{CH_4}} = \frac{n_{SO_2}}{n_{CH_4}}\left(\sqrt{\frac{M_{CH_4}}{M_{SO_2}}}\right)^5$$

$$\frac{n'_{SO_2}}{n'_{CH_4}} = \frac{8}{1}\left(\sqrt{\frac{16}{64}}\right)^5 = \frac{n'_{SO_2}}{n'_{CH_4}} = \frac{1}{4}$$

10. KINETIC THEORY OF GASES

This is a theoretical model for ideal gas which can correlate the experimental facts (like Boyle's law, Charle's law& Avogadro's law etc.). It was presented by ***Bernoulli in 1738*** and developed in 1860 by ***Clausius, Maxwell, Kroning*** *and* ***Boltzmann***. Postulates of kinetic theory of gases are :

(i) All the gases consist of very small molecules or atoms whose volume is negligible compared to volume of container.

(ii) There are no attractive or repulsive forces between the molecules.

(iii) The gaseous molecules are under a continuous state of motion which is unaffected by gravity (the random straight line motion is known as brownian motion)

(iv) Due to the continuous motion, collision between gaseous molecules and with the wall of container occurs. The collision with the wall of container are responsible for pressure exerted by the gas on the wall of container.

(v) The molecule moves with different speed, however the speed of each molecule keep on changing as the collision occur.

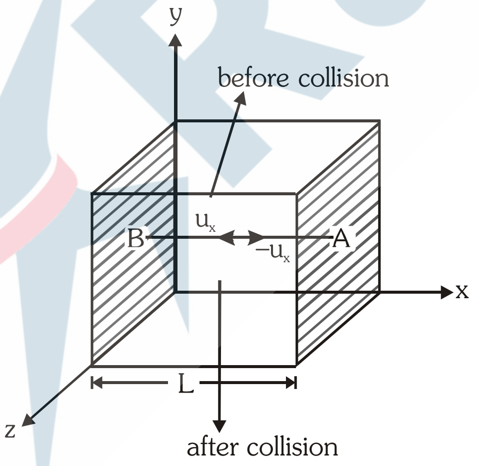
(vi) Collision among gas particles molecules is perfectly elastic, i.e., there is no loss in kinetic energy and moment during such collision.

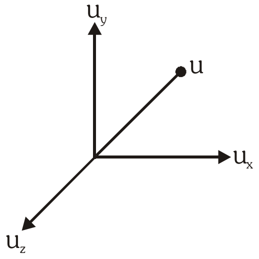
(vii) The average kinetic energy of gas particles will depends on absolute temperature only.

10.1 Kinetic gas equation :

Let us consider a cube of side L, that has N molecules each of mass m moving with velocity u in all direction and thus colliding with one each other and against sides of the container. Velocity u can be resolved into three components u_x, u_y and u_z along there axis such that

$$u^2 = u_x^2 + u_y^2 + u_z^2$$





For a simplest case we consider motion of a molecule along x-axis only in which it moves towards face B with velocity u_x. After collision against face B it moves towards face A with velocity $(-u_x)$ collision being elastic (which results in change in direction but not speed)

$\therefore$ Momentum before collision on face B = mu_x

Momentum after collision on face B = $-mu_x$

Change in momentum due to one collision on face B $= mu_x - (-mu_x) = 2mu_x$

To strike face B again distance travelled = 2L

Time taken to strike face B again $= \frac{2L}{u_x}$ seconds

$\therefore$ Number of collisions per second on face B along x-axis $= \frac{u_x}{2L}$

$\therefore$ Rate of change in momentum due to $\frac{u_x}{2L}$ collisions per second on face B along x-axis.

$$= 2mu_x \cdot \frac{u_x}{2L} = \frac{mu_x^2}{L}$$

Similarly for y-axis change in momentum per second $= \frac{mu_y^2}{L}$ and for z-axis $= \frac{mu_z^2}{L}$

Net force by N molecules on a wall, $F_x = \frac{mu_{x_1}^2}{L} + \frac{mu_{x_2}^2}{L} .... + \frac{mu_{x_N}^2}{L} = \frac{M}{L}.\Sigma u_x^2$

Now pressure $= \frac{\text{Force}}{\text{Area of six faces}} = \frac{\frac{m}{L}.\Sigma u_x^2}{L^2} = \frac{m.\Sigma u_x^2}{L^3} = \frac{m.\Sigma u^2}{V}$ $[L^3 = \text{volume } V]$

$\therefore$ $PV = m.\Sigma u_x^{\ 2}$

As $\Sigma u_x^2 = \Sigma u_y^2 = \Sigma u_z^2$ and $\Sigma u_x^2 + \Sigma u_y^2 + \Sigma u_z^2 = \Sigma u^2$

$$\therefore \quad PV = m.\Sigma u_x^{\ 2} = \frac{1}{3} m.\Sigma u^2$$

$$PV = \frac{1}{3} m \left(\frac{u_1^2 + u_1^2 + ...u_N^2}{N} \right).N$$

$$\therefore \quad PV = \frac{1}{3} mN\, u_{rms}^2$$

This equation is called kinetic gas equation.

10.2 Kinetic energy of gas molecules :

Total translational K.E. of molecules

$$= \frac{1}{2}mu_2^2 + \frac{1}{2}mu_2^2 + ... + \frac{1}{2}m.u_N^{\ 2} = \frac{1}{2}m.\Sigma u^2 = \frac{1}{2}mN.u_{rms}^2 = \frac{3}{2}PV = \frac{3}{2}nRT$$

$\therefore$ Average translational K.E. per mole $= \frac{3}{2}RT$

and $(K.E.)_{\text{per molecule}} = \frac{3}{2}\left(\frac{R}{N_A}\right)T = \frac{3}{2}kT$

Where k = Boltzman constant $= \frac{R}{N_A} = \frac{8.314 J/mol K}{6.02 \times 10^{23}} = 1.3806 \times 10^{-23}\ J\ K^{-1}$

- $(K.E.)_{\text{per molecule}}$ and $(K.E.)_{\text{per mol}}$ is only depend on absolute temperature. It is does not depend on the nature of gas. This conclusion is known as ***"Maxwell's Generalisation"***.

Ex.51 Calculate the kinetic energy of 8 gram methane (CH_4) at 27°C temperature.

Sol. $n = \frac{8}{16} = \frac{1}{2}$, $T = (27° + 273) = 300\ K$, $R = 8.314\ J\ mol^{-1}\ K^{-1}$

$$(K.E.)_{n\ mol} = n \times \frac{3}{2}RT = \frac{1}{2} \times \frac{3}{2} \times 8.314 \times 300 = 1870.65\ J$$

Ex.52 Calculate the pressure exerted by 10^{23} gas molecules, each of mass 10^{-25} kg, in a container of volume $1 \times 10^{-3}\ m^3$ and having root mean square velocity of $10^3\ ms^{-1}$. Also calculate total kinetic energy and Temperature of the gas.

Sol. By kinetic theory

$$P = \frac{1}{3}\frac{mNu^2}{V} = \frac{1 \times 10^{-25} \times 10^{23} \times (10^3)^2}{3 \times 10^{-3}} = 3.33 \times 10^6\ N\ m^{-2}$$

$$\text{Total KE} = \left(\frac{1}{2}mu_{rms}^2\right) \times N = \frac{1}{2} \times 10^{-25} \times (10^3)^2 \times 10^{23} = \frac{1}{2} \times 10^4 = 0.5 \times 10^4\ J$$

$$\text{Also total KE} = \frac{3}{2}nRT,\ \text{where}\ n\ (\text{mole}) = \frac{10^{23}}{N_A} = \frac{10^{23}}{6.023 \times 10^{23}}$$

$$0.5 \times 10^4 = \frac{3}{2} \times \frac{10^{23}}{6.023 \times 10^{23}} \times 8.314 \times T$$

$$\therefore \quad T = \frac{0.5 \times 10^4 \times 2 \times 6.023}{3 \times 8.314} = 2415\ K$$

10.3 Root Mean Square Velocity (u_{rms}) by kinetic gas equation :

$$PV = \frac{1}{3}mN\,u_{rms}^2$$

$$\therefore \quad u_{rms} = \sqrt{\frac{3PV}{mN}} = \sqrt{\frac{3P}{d}} = \sqrt{\frac{3RT}{M}}$$

10.4 Diffrent kind of speed of molecules :

(i) Average or mean speed, $u_{av} = \frac{u_1 + u_2 + \ldots\ldots + u_N}{N} = \sqrt{\frac{8RT}{\pi M}}$

(ii) Root mean square speed, $u_{rms} = \sqrt{\frac{u_1^2 + u_2^2 + \ldots\ldots + u_N^2}{N}} = \sqrt{\frac{3RT}{M}}$

(iii) Most probable speed, $u_{mp} = \sqrt{\frac{2RT}{M}}$

It is the speed at which maximum fraction of molecules are travelling

❖ **Ratio of speeds :**

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

$$= \sqrt{3} : \sqrt{\frac{8}{\pi}} : \sqrt{2} = 1.22 : 1.13 : 1 : 00 = 1.00 : 0.92 : 0.816$$

11. MAXWELL'S DISTRIBUTION OF SPEEDS

It has already been pointed out that a gas is a collection of tiny particles separated from one another by large empty spaces and moving rapidly at random in all directions. In the course of their motion, they collide with one another and also with the walls of the container. Due to frequent collisions, the speeds and directions of motion of the molecules keep on changing. Thus, all the molecules in a sample of gas do not have same speed. Although it is not possible to find out the speeds of individual molecule , yet from probability considerations it has become possible to work out the distribution of molecules in different speed intervals. This distribution is referred to as the Maxwell-Boltzmann distribution in honour of the scientists who developed it. It may be noted that the distribution of speeds remains constant at a particular temperature although individual speeds of molecules may change.

$$dN = 4\pi N \left[\frac{M}{2\pi RT}\right]^{\frac{3}{2}} e^{-\frac{Mu^2}{2RT}} u^2 du = 4\pi N \left[\frac{m}{2\pi kT}\right]^{3/2} e^{\frac{-mu^2}{2KT}} .u^2.du$$

Here, dN = Number of molecules having speeds between u and u + du.

N = Total number of molecules.

M = Molar mass of gas (kg/mol)

u = Root mean square velocity

du = Velocity interval

$$\frac{dN}{N} = 4\pi \left[\frac{M}{2\pi RT}\right]^{\frac{3}{2}} e^{-\frac{Mu^2}{2RT}} u^2 du$$

Here, dN / N = fraction of molecules having speeds between u and u + du.

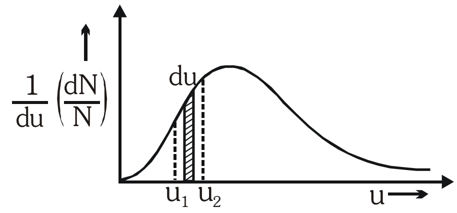
and $\frac{1}{N}\left(\frac{dN}{du}\right)$ = fraction of molecules having speed between u to u + du per unit interval of speed.

= Maxwell distribution function.

According to this expression, the fraction $\frac{dN}{N}$ of molecules depends only on temperature having speeds between u and u + du for a gas of molar mass M. Thus for a given temperature, this fraction has a constant value.

11.1 Properties of Maxwell's graph :

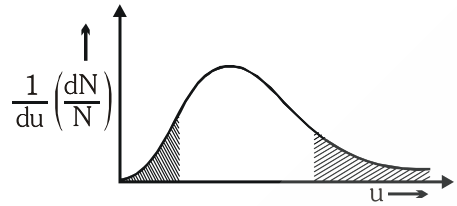
I.



Area between u_1 and u_2 = $\int_{u_1}^{u_2} \frac{1}{du}\left(\frac{dN}{N}\right) du = \int_{u_1}^{u_2} \left(\frac{dN}{N}\right)$

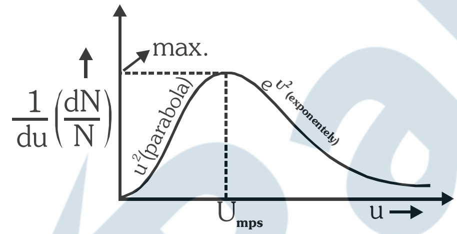
Hence, total fraction of particles with speed between u_1 and u_2
= Area under the curve represents fraction of molecules.

II.



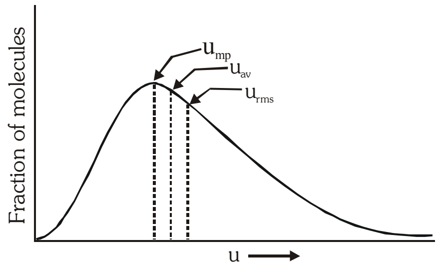
It can be seen from the above figure, that the fraction of molecules having either very low speeds or very high speeds are small in numbers.

III.

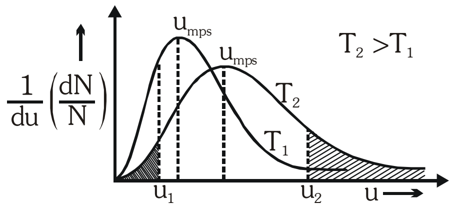


The curve at any temperature is parabolic near the origin, since the factor u^2 is dominant in this region, the exponential function being approximately equal to unity. At high values of u, however, the exponential factor dominates the behaviour of the function, causing it to decrease rapidly in value. As a consequence of the contrasting behaviour of two factors, the product function passes through a maximum at a speed known as the most probable speed (u_{mps}). Thus, the most probable speed is the speed possessed by the maximum fraction of the molecules.

IV Graph between fraction of molecules vs molecular speeds :



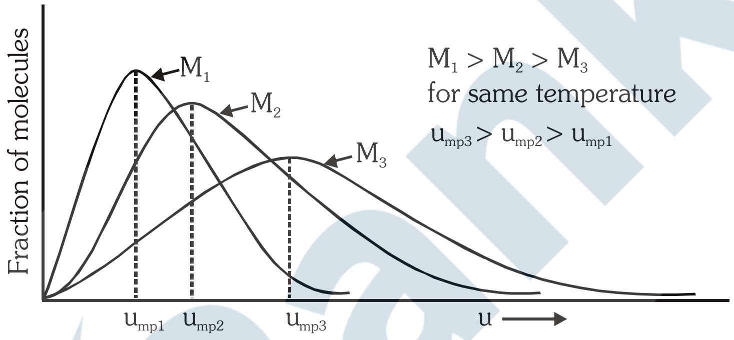
V.



Total area under the curve will be constant and will be unity at all temperatures. The above figure illustrates the distribution of speeds at two temperatures T_1 and T_2. Since the total no. of molecules is same at both temperatures, increase in the K.E. of the molecules results decrease in fraction of molecules having lower speed range and increase in fraction of molecules having higher speed range on increasing the temperature.

On increasing temperature the value of u_{mps}(most probable speed) will increase. Also the curve at the higher temperature T_2 has its u_{mps} shifted to a higher value compared with that for T_1, whereas corresponding fraction of molecules has decreased. But at the same time, the curve near u_{mps} has become broader at the higher temperature indicating the more molecules possess speeds near to most probable speed.

VI.

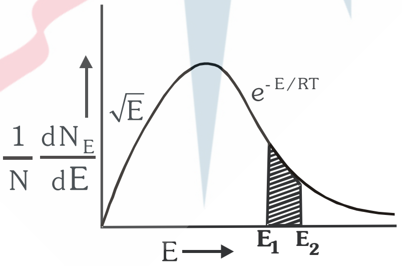


At a given temperature u_{mps} will be more for lighter gas (M_3) but fraction of molecules moving with u_{mps} will be more for heavier gas (M_1).

Note : Effect of M and T are opposite.

11.2 Maxwell Distribution of kinetic energy :

By Maxwell equation : $dN = 4\pi N\left(\frac{M}{2\pi RT}\right)^{3/2} . e^{\frac{-Mu^2}{2RT}} u^2.du = 2\pi\left(\frac{1}{\pi RT}\right)^{3/2} \sqrt{E}.e^{-E/RT}.dE$



The shaded area of this graph indicate the fraction of particles having energy between E_1 and E_2

Ex.53 Four particles have speed 2, 3, 4 and 5 cm/s respectively. Find their avg. & rms speed :

Sol. $$U_{avg.} = \frac{U_1 + U_2 + U_3 + \ldots\ldots.. U_N}{N}$$

$$U_{avg.} = \frac{2+3+4+5}{4} = 3.5\,cm/s$$

$$U_{r.m.s.} = \sqrt{\frac{U_1^2 + U_2^2 + U_3^2 + \ldots\ldots.}{N}}$$

$$u_{rms} = \sqrt{\frac{2^2 + 3^2 + 4^2 + 5^2}{4}} = \frac{\sqrt{54}}{2}\,cm/s$$

Ex.54 At what temperature do the average speed of $CH_{4(g)}$ molecule equal the average speed of O_2 molecule at 300 K ?

Sol. $$(U_{avg})_{CH_4} = (U_{avg})_{O_2}$$

$$\sqrt{\frac{8RT}{\pi \times 16}} = \sqrt{\frac{8 \times R \times 300}{\pi \times 32}}$$

T = 150 K

Ex.55 At 27°C find the ratio of root mean square speeds of ozone to oxygen :-

Sol. $$\frac{U_{rms}(O_3)}{U_{rms}(O_2)} = \sqrt{\frac{\frac{3RT}{M.W_{O_3}}}{\frac{3RT}{M.W_{O_2}}}} = \sqrt{\frac{M.W_{O_2}}{M.W_{O_3}}} = \sqrt{\frac{32}{48}} = \sqrt{\frac{2}{3}}$$

Ex.56 The temperature at which U_{rms} of He becomes equal to U_{mp} of CH_4 at 500 K.

Sol. $$(U_{rms})_{He} = (U_{mp})_{CH_4}$$

$$\sqrt{\frac{3RT_{He}}{M_{He}}} = \sqrt{\frac{2RT_{CH_4}}{M_{CH_4}}}$$

$$\frac{3T}{4} = \frac{2 \times 500}{16}$$

$$T = \frac{250}{3} K$$

Ex.57 Calculate the root mean square speed of H_2 molecules under following condition.

(a) 2 mole of H_2 at 27°C.

(b) 3 mole of H_2 in a 5 lit container at 10^5 Pa.

(c) 4 mole of H_2 at the density of 1 gm/ml at 10^5 Pa.

Sol. (a) $U_{r.m.s.} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\times 8.314\,J/molK\times 300K}{2\times 10^{-3}kg}} = 1934.24$ m/sec.

(b) $U_{r.m.s.} = \sqrt{\frac{3PV}{nM}} = \sqrt{\frac{3\times 10^{5}\,Pa\times 5\times 10^{-3}\,m^{3}}{3\,mol\times 2\times 10^{-3}\,kg}} = 500$ m/sec.

(c) $U_{r.m.s.} = \sqrt{\frac{3P}{d}} = \sqrt{\frac{3\times 10^{5}\,Pa}{10^{3}\,kg/m^{3}}} = 17.32$ m/sec.

Ex.58 Calculate the fraction of N_2 molecules at 1 atm and 27°C whose speeds are in the range of $(U_{mp} - 0.005\,U_{mp})$ to $(U_{mp} + 0.005\,U_{mp})$?

Sol. Most probable speed,

$$U_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2\times 8.314\times 300}{28\times 10^{-3}}} = 422.09 \text{ m/sec}$$

$$du = (U_{mp} + 0.005\,U_{mp}) - (U_{mp} - 0.005\,U_{mp})$$
$$= 2\times 0.005\times U_{mp} = 4.22 \text{ m/sec}$$

From Maxwell's equation :

$$\frac{dN}{N} = 4\pi\left[\frac{M}{2\pi RT}\right]^{\frac{3}{2}} e^{-\frac{MU_{mp}^{2}}{2RT}}\,U_{mp}^{\;2}du$$

$$\frac{dN}{N} = 4\pi\left(\frac{M}{2\pi RT}\right)^{\frac{3}{2}}.e^{-\frac{M}{2RT}\times\frac{2RT}{M}}.U_{mp}^{2}.du$$

$$\frac{dN}{N} = 4\times 3.14\times\left(\frac{28\times 10^{-3}}{2\times 3.14\times 8.314\times 300}\right)^{\frac{3}{2}} e^{-1}\times(422.09)^{2}\times 4.22$$

$$\frac{dN}{N} = 8.3\times 10^{-3}$$

Ex.59 Calculate the fraction of N_2 molecules whose speeds are in the range of U_{mp} to $(U_{mp} + f\times U_{mp})$?

Sol. $$\frac{dN}{N} = 4\pi\left[\frac{M}{2\pi RT}\right]^{\frac{3}{2}} e^{-\frac{MU^{2}}{2RT}}\,U^{2}du$$

Here, $U = U_{mp} = \sqrt{\frac{2RT}{M}}$, $du = f\times U_{mp}$

$$\Rightarrow \quad \frac{dN}{N} = 4\pi\left[\frac{M}{2\pi RT}\right]^{\frac{3}{2}} e^{-\frac{M}{2RT}\times\frac{2RT}{M}}\times\frac{2RT}{M}\times f\times\left(\frac{2RT}{M}\right)^{\frac{1}{2}}$$

$$\frac{dN}{N} = 4\pi\times\frac{1}{\pi\sqrt{\pi}}e^{-1}\times f = \frac{4f}{e\sqrt{\pi}}$$

This fraction does not depend upon U_{mp}, or Temperature and depends only on 'f' factor.

(i) Therefore, we can conclude that at two different temperatures the fraction of molecules between U_{mp_1} to $(U_{mp_1} + f \times U_{mp_1})$ and between U_{mp_2}, to $(U_{mp_2} + f \times U_{mp_2})$ are same.

(ii) Even for two different gases say N_2 and O_2, the fraction of molecules between U_{mp} to $(U_{mp} + f \times U_{mp})$ are same.

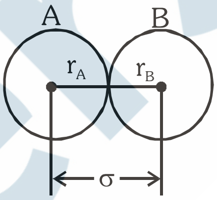
12. COLLISION PARAMETERS :

Assumption :

All the particles (molecules or atoms) have rigid , similar shape and size and are spherical in nature that will not change after collision.

12.1 Collision diameter

Collision diameter : It is the closest distance between the centres of two molecules taking part in collision.



Collision diameter $(\sigma) = r_A + r_B$

12.2 Collision Frequency :

It is the total number of molecular collisions taking place per second per unit volume of the gas. The no. of collisions made by a single molecule with other molecules per unit time **(collision number)** are given by

$$Z_1 = \sqrt{2}\,\pi\sigma^2\, U_{avg} N^*$$

The total number of bimolecular collision per unit time is given as Z_{11} **(collision frequency)**

$$Z_{11} = \frac{1}{2}(Z_1 N^*) = \frac{1}{2} \times N^* \times \sqrt{2}\,\pi\sigma^2 U_{avg} N^*$$

$$Z_{11} = \frac{1}{\sqrt{2}}\pi\sigma^2 U_{avg} N^{*2}$$

(f) If the collisions involve two unlike molecules, the no. of bimolecular collision is given as Z_{12}.

$$Z_{12} = \pi\sigma_{12}^2 \left(\frac{8kT}{\pi\mu}\right)^{\frac{1}{2}} N_1^* N_2^*$$

Where N_1^* and N_2^* are the no. of molecules per unit volume of the two types of gases, σ_{12} is the average diameter of two molecules, that is $\sigma_{12} = \frac{\sigma_1 + \sigma_2}{2}$ & μ is the reduced mass, that is $\mu = \frac{m_1 m_2}{(m_1 + m_2)}$, m_1 & m_2 are the mass of single molecule respectively 1 and 2.

12.3 Mean free path :

The mean free path is the average distance travelled by a molecule between two successive collisions. We can express it as follows :

$$\lambda = \frac{\text{Average distance travelled per unit time}}{\text{No. of collsions made by single molecule per unit time}}$$

$$= \frac{U_{avg}}{Z_1} = \frac{U_{avg}}{\sqrt{2}\pi\sigma^2 U_{avg} N^*} = \frac{1}{\sqrt{2}\pi\sigma^2 N^*}$$

12.4 Wall collision :

It represents the total number of molecules colliding at the wall per unit area per unit time.

$$Z_w = \frac{1}{4}.N^*.u_{av} = \frac{P.N_A}{\sqrt{2\pi MRT}}$$

12.5 Rate of effusion :

If the corss-section area of orifice in the vessel is 'A', then the number of molecules effusing out per unit time is

$$r_{eff.} = Z_w.A = \frac{P.N_A.A}{\sqrt{2\pi MRT}}$$

Ex.60. Calculate λ, Z_1 and Z_{11} for oxygen at 298 K and 10^{-3} mm Hg. Given $\sigma = 3.61 \times 10^{-8}$ cm.

Sol. $N^* = \frac{P}{kT} = \frac{10^{-3} \times 101325}{760 \times 1.38 \times 10^{-23} \times 298} = 0.324 \times 10^{20}$

$$U_{avg} = \sqrt{\frac{8}{\pi}\frac{RT}{M}} = \sqrt{\frac{8}{3.14} \times \frac{8.314 \times 298}{32 \times 10^{-3}}} = 444.138 \text{ m/sec}$$

$$Z_1 = \sqrt{2}\,\pi\,\sigma^2\,U_{avg}N^* = \sqrt{2} \times 3.14 \times 3.61 \times 10^{-10}\text{ m} \times 444.138 \text{ m} \times 0.324 \times 10^{20}$$

$$= 8.326 \times 10^3 \text{ sec}^{-1}$$

$$Z_{11} = \frac{1}{2}Z_1 N^* = \frac{1}{2} \times 8.326 \times 10^3 \text{ sec}^{-1} \times 0.324 \times 10^{20} = 13.488 \times 10^{22} \text{ m}^{-3} \text{ sec}^{-1};$$

$$\lambda = \frac{U_{avg.}}{Z_1} = \frac{444.138 \text{ m/sec}}{8.326 \times 10^3 \text{ sec}^{-1}} = 5.334 \times 10^{-2} \text{ m}$$

Ex.61 Two flask A and B have equal volume. A is maintained at 300 K and B at 600 K while A contains H_2 gas , B has an equal mass of CH_4 gas. Assuming ideal behaviour for both the gases, find the following.

(a) Flask containing greater number of moles

(b) Flask in which pressure is greater

(c) Flask in which U_{avg} of the molecules are greater

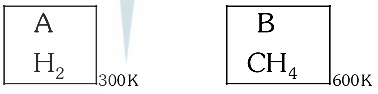
(d) Flask with greater mean free path of molecules (Collision diameters of H_2 & CH_4 may be taken same)

(e) Flask with greater molar kinetic energy.

(f) Flask in which the total kinetic energy is greater

(g) Flask in which Z_1 and Z_{11} are greater

Sol.



(a) $N_{H_2} = \frac{m}{2}N_A$; $N_{CH_4} = \frac{m}{16}N_A$

$\therefore$ molecules of H_2 in flask A > molecules of CH_4 in flask B

(b) $P_AV = n_ART_A$; $P_BV = n_BRT_B$

$$\Rightarrow \quad \frac{P_A}{P_B} = \frac{n_AT_A}{n_BT_B} = \frac{m/2}{m/16} \times \frac{300}{600} = 4$$

$\therefore$ pressure of H_2 in flask A > pressure of CH_4 in flask B

(c) $(U_{avg})_A = \sqrt{\frac{8\,RT_A}{\pi\ M_A}}$; $(U_{avg})_B = \sqrt{\frac{8\,RT_B}{\pi\ M_B}}$

$$\frac{(U_{avg})_A}{(U_{avg})_B} = \sqrt{\frac{T_A}{T_B} \times \frac{M_B}{M_A}} = \sqrt{\frac{300}{600} \times \frac{16}{2}} = 2$$

$\therefore$ U_{avg} of H_2 in flask A > U_{avg} of CH_4 in flask B

(d) $\lambda = \frac{1}{\sqrt{2}\pi\sigma^2 N^*} = \frac{1}{\sqrt{2}\pi\sigma^2 \times P} \times kT$ [where $N^* = P/kT$]

$$\frac{\lambda_A}{\lambda_B} = \frac{T_A}{T_B} \times \frac{P_B}{P_A} = \frac{300}{600} \times \frac{1}{4} = \frac{1}{8}$$

$\therefore$ $\lambda_B > \lambda_A$

(e) molar K.E. = $\frac{3}{2}RT$

$\therefore$ $T_B > T_A$

$\therefore$ KE of CH_4 in flask B > KE of H_2 in flask A

(f) $(KE)_{total} = \frac{3}{2}RT \times\ n$

$$\frac{(KE)_{T,A}}{(KE)_{T,B}} = \frac{(300 \times \frac{m}{2})}{(600 \times \frac{m}{16})} = \frac{1}{2} \times 8 = 4$$

$\therefore$ $(KE)_{T,A} > (KE)_{T,B}$

(g) (i) $Z_1 = \sqrt{2}\pi\sigma^2 U_{avg} N^*$

$$\frac{(Z_1)_A}{(Z_1)_B} = \frac{(U_{avg})_A}{(U_{avg})_B} \times \frac{N_A{}^*}{N_B{}^*} = 2 \times \frac{N_A}{N_B} = 2 \times 8 = 16$$

$\therefore$ $(Z_1)_A > (Z_1)_B\ (Z_1)_A > (Z_1)_B$

(ii) $Z_{11} = \frac{1}{\sqrt{2}}\pi\sigma^2 U_{avg} N^{*2}$

$$\frac{(Z_{11})_A}{(Z_{11})_B} = \frac{(U_{avg})_A}{(U_{avg})_B} \times \frac{(N_A{}^*)^2}{(N_B{}^*)^2} = 2 \times \frac{N_A}{N_B} = 2 \times 8^2 = 128$$

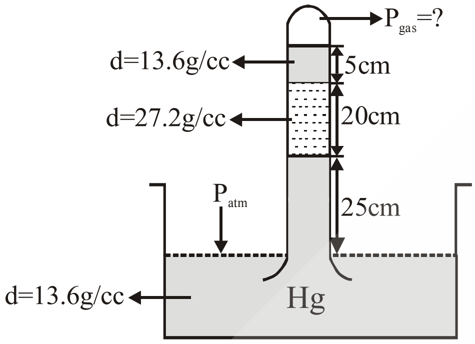
$\therefore$ $(Z_{11})_A > (Z_{11})_B$

EXERCISE S-I

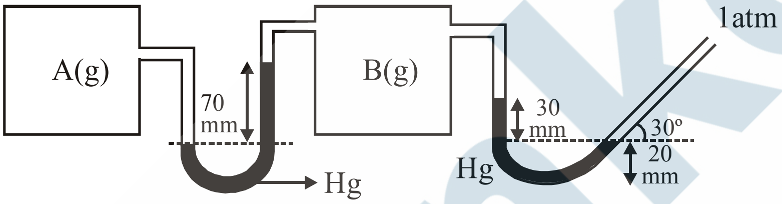
EXPERIMENTAL GAS LAW AND APPLICATION OF IDEAL GAS EQUATION.

1. In the following arrangement find the pressure of gas (in cm of Hg).

(Assume that atmospheric pressure $P_{atm} = 75$ cm of Hg)

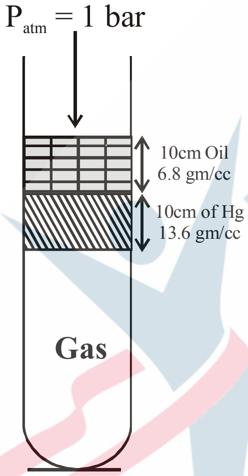


2. At 300K, two gases are filled in two equal sized containers as given.



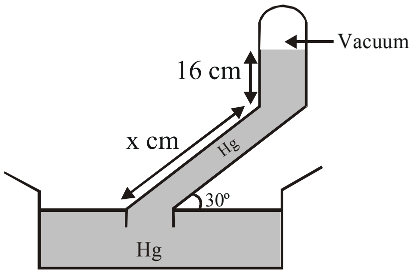
What will be the pressure of A(g) (in mm of Hg).

3.

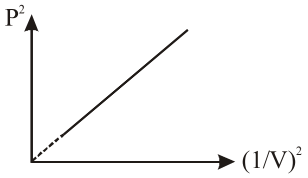


Find pressure of gas in cm of Hg enclosed in tube.

4. Calculate the value of x in the following arrangement.



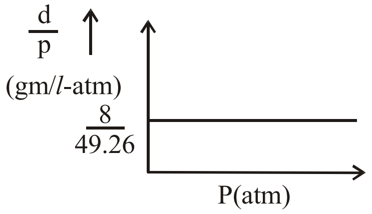
5. Consider the following graph



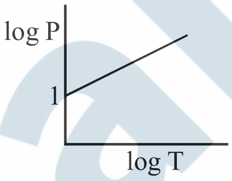
Graph is plotted for 1 mol of gas at 400K, find slope of curve.

[Take : $R = 0.08\ \dfrac{L-atm}{mol-K}$]

6. For an ideal gas, the following graph is obtained at constant temperature of 300K. The molar mass of gas (in gm/mol) is -



7. In constant volume container of 0.821 litre, log P vs log T is plotted as shown in graph. Calculate number of moles of ideal gas present in container :



8. The density of phosphours vapours at 327ºC and 1 atm is 2.52 gm/lit. If molecular formula of phosphours is P_X, then calculate 'X' (Atomic weight of : P = 31)

9. Density of ideal gas at 2.46 atm and 300 K is 0.8 gm/l. Hence gm-molar mass of gas is [R = 0.082L-atm/mol-K]

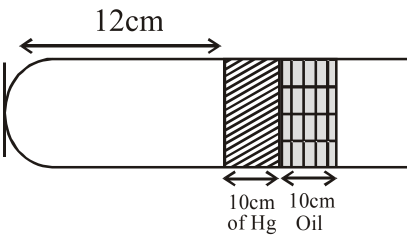
10. A toy balloon originally held 1.0 gm of He gas and had a radius 10 cm. During the night, 0.875 gm of the gas effused from the balloon. Assuming ideal gas behaviour, under these constant P and T conditions, what was the radius of the balloon the next morning.

11. In a hospital respiratory unit the pressure gauge reads 4500 mm Hg for 10 L tank containing compressed O_2 , how many litres of O_2 can be delivered from tank at atmospheric pressure of 750 mm Hg. (Take temperature to be constant at TK)

12. 3.6 gm of an ideal gas was injected into a bulb of internal volume of 8.21 L at pressure P atm and temp T-K. The bulb was then placed in a thermostat maintained at (T+ 15) K.0.6 gm of the gas was let off to keep the original pressure. Find P and T if mol weight of gas is 36.

13. Automobile air bags are inflated with N_2 gas which is formed by the decomposition of solid sodium azide (NaN_3). The other product is Na - metal. Calculate the volume of N_2 gas at 27°C and 1atm formed by the decomposing of 130 gm of sodium azide.

14. While resting, the average human male use 0.2 dm^3 of O_2 per hour at 1 atm & 300 K for each kg of body mass. Assume that all this O_2 is used to produce energy by oxidising glucose in the body. What is the mass of glucose required per hour by a resting male having mass 60 kg. What volume, at 1 atm & 300 K of CO_2 would be produced ($R = 0.08 \dfrac{L-atm}{mol-K}$)

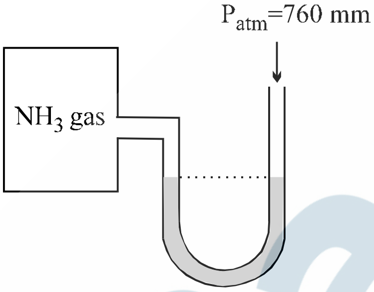
15. 

P_{atm} = 75 cm

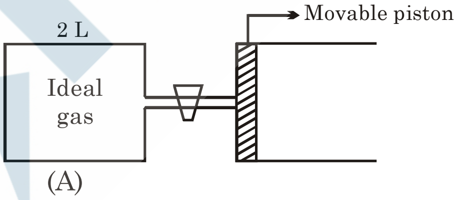
ρ_{oil} = 6.8 gm/cc

If above tube is held vertical with open end upward then find the length of air column.

16. A manometer attached to a flask contains NH_3 gas have no difference in mercury level initially as shown in diagram. After the sparking into the flask, it have difference of 19 cm in mercury level in two columns. Calculate % dissociation of ammonia.



17. An ideal gas is kept in 2L rigid container (A) at 300K and 4 atm. It is connected to another container with friction less movable piston as shown in diagram. Find distance travelled by piston having cross-sectional area 3dm^2 [consider external pressure 1 atm] (Give your answer in dm).



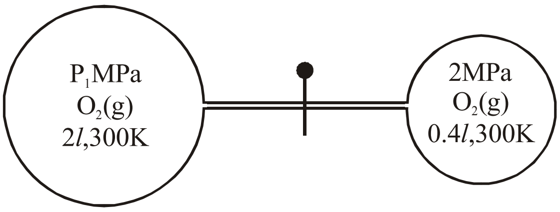
18. An iron cylinder contains helium at a pressure of 250 k pa and 27°C. The cylinder can withstand a pressure of 1×10^6 pa. The room in which cylinder is placed catches fire. Predict whether the cylinder will blow up before it melts or not. [melting point of cylinder = 1800 K]

19. The density of an ideal gas is 4g/L at 127ºC and 2000 torr. Its density at 1000torr and 27ºC is $\left(\dfrac{16}{x}\right) g/L$. The value of 'x' is -

20. Two glass bulbs A and B are connected by a very small tube having a stop cock. Bulb A has a volume of 100 ml and contained the gas, while bulb B was empty on opening the stop cock, the pressure fell down to 40% at constant temperature. Find out the volume of bulb B in mL.

DALTON'S LAW OF PARTIAL PRESSURE

21. If in below diagram after opening valve, final pressure is $\frac{7}{6}$ MPa, than calculate P_1 (in MPa)



22. Calculate the mole fraction of N_2 gas in a mixture of N_2 and O_2. If the partial pressure of O_2 is 63 cm of Hg and the total pressure of the mixture is 90 cm of Hg.

23. The partial pressures of N_2, O_2 and CO_2 in a vessel are 38 cm of Hg, 190 torr and 0.5 atm, respectively . The total pressure of the mixture at the same temperature is.

24. Equal masses of ethane and hydrogen are mixed in an empty container at 25ºC. The fraction of the total pressure exerted by hydrogen is.

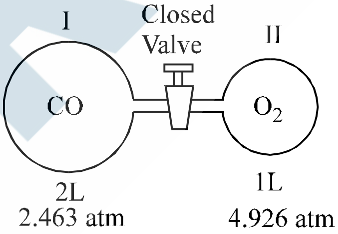
25. A mixture of hydrogen and oxygen at one bar pressure contains 20% , by weight of hydrogen. The partial pressure of hydrogen will be.

26. The mass of pure CH_4 gas to be mixed with 70g of pure CO so that partial pressure of CO is equal to the partial pressure of CH_4 is -

27. A closed vessel contains equal number of nitrogen and oxygen molecules at pressure of P mm. If nitrogen is removed from the system, then the pressure will be.

28. There are n connected container having volume V, 2V, 3V, ..., nV separated by stopcock. All container have same moles of gas at same temperature. If pressure of first container is P, then final pressure when all stop cocks are opened is -

29. Determine final pressure after the valve is left opened for a long time in the apparatus represented in figure. Assume that the temperature is fixed at 300 K. Under the given conditions assume no reaction of CO & O_2.



30. A polythene bag of 3 litre capacity is filled by Helium gas (Occupying 1L at 0.3 atm & 300K) at 300K. Subsequently enough Ne gas is filled to make total pressure 0.4 atm at 300K. Calculate ratio of moles of Ne to He in container.

31 The density of a mixture of O_2 and N_2 gases at 1 atm and 273K is 0.0013 gm/ml. If partial pressure of O_2in the mixture is A then calculate value of 25A.

32 A containers contains air above liquid water. Total pressure was 800 torr. What will be the final pressure if volume is doubled. (Aqueous tension = 40 torr)

33. A certain quantity of a gas occupies a volume of 0.1 litre when collected over water at 27ºC and a pressure 1.67 atm. The same amount of gas occupied 0.14 litre at 1 atm, 7ºC in dry condition. Calculate the aqueous tension (in atm) at 27ºC.

34 1.0×10^{-2} kg of hydrogen and 6.4×10^{-2} kg of oxygen are contained in a 10×10^{-3} m^3 flask at 473 K. Calculate the total pressure of the mixture. If a spark ignities the mixture. What will be the final pressure.

35. Calculate the mass of water vapour present in 16.42 L air 27ºC and 75% relative humidity. Vapour pressure of water at 27ºC is 0.04 atm.

GRAHAM'S LAW OF DIFFUSION AND EFFUSION

36. A gas mixture contains equal number of molecules of N_2 and SF_6, some of it is passed through a gaseous effusion apparatus . Calculate how many molecules of N_2 are present in the product gas for every 100 molecules of SF_6.

37. 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.

38. Two gases NO and O_2 were introduced at the two ends of a one metre long tube simultaneously (tube of uniform cross- section). At what distance from NO gas end , Brown fumes will be seen.

39. At 20ºC two balloons of equal volume and porosity are filled to a pressure of 2 atm, one with 14 kg N_2 & other with 1 kg H_2 . The N_2 balloon leaks to a pressure of $\frac{1}{2}$ atm in one hour. How long will it take for H_2 balloon to leaks to a pressure of $\frac{1}{2}$ atm.

40. One litre of gaseous mixture of CH_4 and H_2 effuses in 200 seconds while one litre of gas 'X' take 10 minutes to effuse in identical conditions. If molar ratio of $CH_4 : H_2$ in mixture is 1 : 2. Find molar mass of gas 'X' in (g mol^{-1}) units ?

41. Pure O_2 diffuses through an aperture in 224 sec, whereas mixture of O_2 and another gas containing 75 % O_2 takes 336 sec to effuse out same volume What is molecular weight of the gas?

42. At a particular fixed temperature the gas A_n is 52% dissociated according to the following reaction $A_n(g) \rightleftharpoons nA(g)$

The equilibrium mixture effuses 1.25 times slower than pure oxygen gas under identical condition. If atomic wt. of A is 32, then find "n" ?

43. H_2 and O_2 are kept in mass ratio 1 : 8 respectively at 6 atm. If small orifice is made then relative rate of effusion of H_2 with respect to O_2 initially is.

44. Calculate relative rate of effusion of SO_2 to CH_4 under given condition

(i) Under similar condition of pressure & temperature

(ii) Through a container containing SO_2 and CH_4 in 3:2 mass ratio

(iii) If the mixture obtained by effusing out a mixture ($n_{SO_2}/n_{CH_4} = 8/1$) after three effusing steps.

KINETIC THEORY OF GASES, MAXWELL DISTRIBUTION OF SPEEDS, COLLISION PARAMETERS

45. Calculate the root mean square speed of H_2 molecules under following conditions.

(a) 2 mole of H_2 at 27ºC

(b) 3 mole of H_2 in a 5 litre container at 10^5 Pa

(c) 4 mole of H_2 at the density of 1gm / ml at 10^5 Pa

46. Root mean square speed of an unknown gas at 727ºC is 10^5 cm/second. Calculate molar mass of unknown gas (in gram/mole) [Take R = $\frac{25}{3}$ J/mole-K].

47. At what temperature in °C, the U_{rms} of SO_2 is equal to the average velocity of O_2 at 27°C.

48. How many times is the rms speed of molecules in 8 gm O_2 gas at 1200 K and 10 bar, relative to rms speed of molecules in 16 gm O_2 gas at 300K and 20 bar ?

49. Average translational kinetic energy of an ideal gas molecule at 27ºC is 3.88×10^{-x} eV. Hence x is

50. When the temperature of an ideal gas is increased from 27°C to 927°C the kinetic energy will be increased by x times. Find the value of x ?

51. A mixture of hydrogen and helium is prepared such that the number of wall collisions per unit time by molecules of each gas is the same. Which gas has the higher concentration?

52. Two flask A and B have equal volume at 100K and 200K and have pressure 4 atm and 1 atm respectively. The flask A contains H_2 gas and B contains CH_4 gas. The collision diameter of CH_4 is twice that of H_2. Calculate ratio of mean free path of CH_4 to H_2.

53 If the mean free path is 10 cm at one bar pressure then its value at 5 bar pressure, if temperature is kept constant.

54. The mean free path of the molecule of certain gas at 300K is 2.6×10^{-5}m. The collision diamter of the molecule is 0.26 nm. Calculate

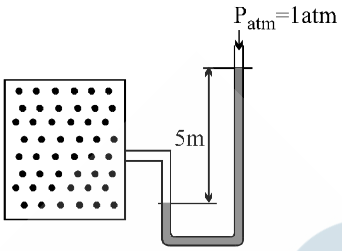
(a) pressure of the gas and

(b) number of molecules per unit volume of the gas.

55. Calculate the temperature at which the maxwell distribution function for an ideal gas is maximum at 332.56 ms^{-1}. The molar mass of gas is $\frac{1000}{8.314}$ gm/mol.

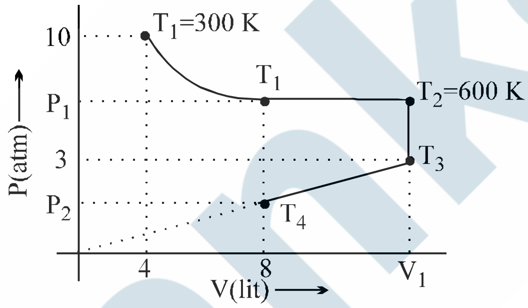
EXERCISE- S2

1. Calculate the number of moles of gas present in the container of volume 10 lit at 300 K. If the manometer containing glycerin shows 5m difference in level as shown in diagram. Given: $d_{glycerin} = 2.72$ gm/ml, $d_{mercury} = 13.6$ gm/ml.



2. The degree of dissociation is 0.4 at 400K and 1 atm for the gaseous reaction $2HI(g) \rightarrow H_2(g) + I_2(g)$. Assume ideal behaviour of all the gases, calcualte the density (in gm/litre) of mixture at 400K and 1 atm [At. wt. of Iodine = 127 ; Use R = 0.08 atm-litre/K-mole]
Fill your answer as sum of digits (excluding decimal places) till you get the single digit answer.

3. Fixed mass of a gas is subjected to the changes as shown is diagram, calculate T_3, T_4, P_1, P_2 and V_1 as shown is diagram. Considering gas obeys PV = nRT equation.



4. A balloon containing 1 mole air at 1 atm initially is filled further with air till pressure increases to 3 atm. The initial diameter of the balloon is 1 m and the pressure at each state is proportion to diameter of the balloon. Calculate

(a) No. of moles of air added to change the pressure from 1 atm to 3 atm.

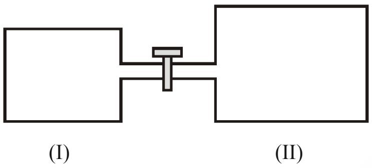
(b) balloon will burst if either pressure increases to 7 atm or volume increases to 36π m^3. Calculate the number of moles of air that must be added after initial condition to burst the balloon.

5. One mole of NH_4Cl (s) is kept in an open container & then covered with a lid. The container is now heated to 600 K where all NH_4Cl (s) dissociates into NH_3 & HCl (g). If volume of the container is 24.63 litres, calculate what will be the final pressure of gases inside the container. Also find whether the lid would stay or bounce off if it can with stand a pressure difference of 5.5 atm. Assume that outside air is at 300 K and 1 atm pressure.

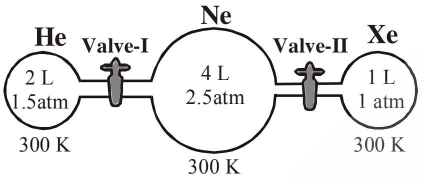
6. One mole of an ideal gas is subjected to a process in which $P = \frac{1}{8.21}V$ where P is in atm & V in litre. If the process is operating from 1 atm to finally 10 atm (no higher pressure achieved during the process) then what would be the maximum temperature obtained & at what instant will it occur in the process.

7. A compound exists in the gaseous state both as a monomer (A) and dimer (A_2). The molecular weight of the monomer is 48. In an experiment, 96 g of the compound was confined in a vessel of volume33.6 litres and heated to 273° C. Calculate the pressure developed, if the compound exists as a dimer to the extent of 50 per cent by weight, under these conditions. (R = 0.082)

8. Two container (I) & (II) with volume 2 litre & 3lt are separated through a stopcock as shown in the diagram. Container (I) contains three gases A, B, & C with mole ratio 1 : 2 : 3 and total pressure 30 atm. If stopcock is opened then calculate the pressure of gas C in container (II). (Assume temperature remains constant)



9. For the following diagram calculate final pressure (in atm) when both valves are opened. Given that temperature (T) is same for each container.



10. At 30ºC dry air [75% N_2 + 25% O_2] is placed over H_2O (l) at 800 torr combined pressure of all 3 gases. If pressure is gradually increased isothermally to 1560 torr, then calcualte partial pressure of O_2 at high pressure in torr.

$[V.P_{H_2O} = 40 \text{ torr at } 30^{\circ} C]$.

Fill your answer as sum of digits (excluding decimal places) till you get the single digit answer..

11. 16 gm of O_2 was filled in a container of capacity 8.21 lit. at 300 K. Calculate

(i) Pressure exerted by O_2

(ii) Partial pressure of O_2 and O_3 if 50 % of oxygen is converted into ozone at same temperature.

(iii) Total pressure exerted by gases if 50% of oxygen is converted into ozone (O_3) at temperature 50 K.

12. A container of capacity 20 L contains N_2(g), water vapour and negligible but sufficient amount of liquid water to maintain equilibrium, at 300K and 1 atm. The liquid water is now decomposed completely into H_2(g) and O_2(g), by any means, without changing the temperature. If the final pressure becomes 1.86 atm, the mass of liquid water present initially (in gm) was (Aqueous tension at 300K = 0.04 atm, R = 0.08 L-atm/K-mole)

13. Find the number of diffusion steps required to separate the isotopic mixture initially containing some amount of H_2 gas and 1 mol of D_2 gas in a container of 3 lit capacity maintained at 24.6 atm & 27 °C to the final mass ratio $\left(\frac{w_{D_2}}{w_{H_2}}\right)$ equal to $\frac{1}{4}$.

14. The average speed of molecules in a sample of ozone gas is 1.84×10^4 cm s^{-1}. The average translational kinetic energy per molecules is xJ. The value of $\frac{x}{2} \times 10^{22}$ is

(Given : $N_A = 6 \times 10^{23}$; $\sqrt{\frac{8}{3\pi}} = 0.92$)

15. H_2 gas is kept inside a container A and container B each having volume 2 litre under different conditions which are described below. Determining the missing values with proper unit.

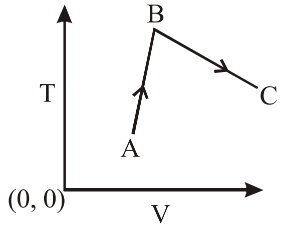
[$R = 8$ J mol^{-1} K^{-1} and $N_A = 6 \times 10^{23}$, N = No. of molecules]

Parameter	**Container A**	**Container B**
P	(i)------	1 atm
T	300K	600 K
N	6×10^{20}	(ii)------
Total Average KE	(iii)------	(iv)------
Ratio U_{mps}	(v)---------------	
Ratio Z_{11}	(vi)---------------	

EXERCISE - O-I

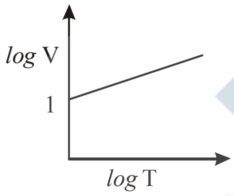
Single Correct :

1. In the given isobaric process shown by graph between T & V.



(A) Moles decreases throughout
(B) Moles first increases then decreases
(C) Moles first decreases then increases
(D) Moles cannot be predicted form given data

2. At constant pressure of 0.821 atm ; log V vs log T is ploted as shown in-
Then number of moles present in experiment -



(A) 1 (B) 10 (C) 100 (D) 0.1

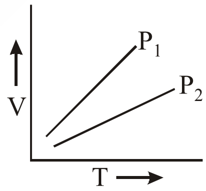
3. A gas at a pressure of 5.0 atm is heated from 0°C to 546°C and simultaneously compressed to one-third of its orginal volume. Hence final pressure is
(A) 10 atm (B) 30 atm (C) 45 atm (D) 5 atm

4. A flask containing air (open to the atmosphere) is heated from 300 K to 500 K. Then % of air escaped to the atmosphere is -
(A) 20.0 (B) 40 (C) 60 (D) 80

5. 10 g of a gas at 1 atm, 273 K occupies 5 litres. The temp. at which the volume becomes double for the same mass of gas at the same pressure is ?
(A) 273K (B) -273^0C (C) 273^0C (D) 546^0C

6. A gas is found to have a formula $[CO]_x$. If its vapour density is 70 the value of x is
(A) 2.5 (B) 3.0 (C) 5.0 (D) 6.0

7. V versus T curves at constant pressure P_1 and P_2 for an ideal gas are shown in Fig. Which is correct



(A) $P_1 > P_2$ (B) $P_1 < P_2$ (C) $P_1 = P_2$ (D) All

8. A container when is empty weighs 50 gm. After certain liquid of density 25 gm/dm^3 is filled its mass becomes equal to 100 gm. The volume of the container will be :
(A) 0.25 dm^3 (B) 0.5 dm^3 (C) 1 dm^3 (D) 2 dm^3

9. A vessel contains mono atomic 'He' at 1 bar and 300 K, determine its number density -
(A) 2.4×10^{25} m^{-3} (B) 6.8×10^{23} m^{-3} (C) 4.8×10^{26} m^{-3} (D) 9.2×10^{27} m^{-3}

10. A rigid container containing 10 gm gas at some pressure and temperature. The gas has been allowed to escape from the container due to which pressure of the gas becomes half of its initial pressure and temperature become $(2/3)^{rd}$ of its initial. The mass of gas (in gms) escaped is

(A) 7.5 (B) 1.5 (C) 2.5 (D) 3.5

11. The density of gas A is twice that of B at the same temperature the molecular weight of gas B is thrice that of A. The ratio of pressure of gas A and gas B will be

(A) 1 : 6 (B) 7 : 8 (C) 6 : 1 (D) 1 : 4

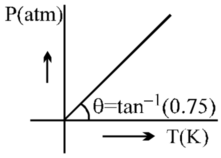
12. In a rigid container NH_3 is kept at certain temperature, if on doubling the temperature it is completely dissociated into N_2 and H_2. Find final pressure to initial pressure ratio :

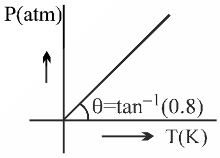
(A) 4 (B) 2 (C) $\frac{1}{2}$ (D) $\frac{1}{4}$

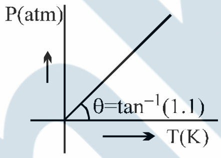
13. Gas A (1 mol) dissociates in a closed rigid container of volume 0.16 lit. as per following reaction.

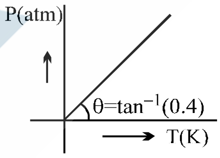
$$2A\,(g) \longrightarrow 3B\,(g) + 2C\,(g)$$

If degree of dissociation of A is 0.4 and remains constant in entire range of temperature, then the correct P vs T graph is [Given R = 0.08 lit-atm/mol/K]

(A)


(B)


(C)


(D)


14. A gaseous reaction,

$$3A \longrightarrow 2B$$

is carried out in a 0.0821 litre closed container initially containing 1 mole of gas A. After sufficient time a curve of P (atm) vs T (K) is plotted and the angle with x-axis was found to be 42.95°. The degree of association of gas A is [Given : tan 42.95 = 0.8]

(A) 0.4 (B) 0.6 (C) 0.5 (D) 0.8

15. 4.0 g of argon has pressure P and temperature T K in a vessel. On keeping the vessel at 50° higher temperature, 0.8 g of argon was given out to maintain the pressure P. The original temperature was :

(A) 73 K (B) 100 K (C) 200 K (D) 510 K

16. The total pressure exerted by a number nonreacting gases is equal to the sum of partial pressure of the gases under the same conditions is known as :

(A) Boyle's law (B) Charle's law (C) Avogadro's law (D) Dalton's law

17. Dalton's law cannot be applied for which gaseous mixture at normal temperatures:

(A) O_2 and N_2 (B) NH_3 and HCl (C) He and N_2 (D) CO_2 and O_2

18. A closed vessel contains helium and ozone at a pressure of P atm. The ratio of He and oxygen atoms is 1 : 1. If helium is removed from the vessel, the pressure of the system will reduce to :

(A) 0.5 P atm (B) 0.75 P atm (C) 0.25 P atm (D) 0.33 P atm

19. At constant temperature 200 cm^3 of N_2 at 720 mm and 400 cm^3 of O_2 at 750 mm pressure are put together in a one litre flask. The final pressure of mixture is

(A) 111 mm (B) 222 mm (C) 333 mm (D) 444 mm

20. If saturated vapours are compressed slowly (temperature remaining constant) to half the initial volume, the vapour pressure will :

(A) Become four times(B) become doubled (C) Remain unchanged (D) Become half

21. A box of 1L capacity is divided into two equal compartments by a thin partiion which are filled with 2g H_2 and 16g CH_4 respectively. The pressure in each compartment is recorded as P atm. The total pressure when partition is removed will be :

(A) P (B) 2P (C) P/2 (D) P/4

22. A vessel has N_2 gas and water vapours at a total pressure of 1 atm. The vapour pressure of water is 0.3 atm. The contents of this vessel are transferred to another vessel having one third of the capacity of original volume, completely at the same temperature the total pressure of this system in the new vessel is -

(A) 3.0 atm (B) 1 atm (C) 3.33 atm (D) 2.4 atm

23. Which gas effuses fastest under identical conditions -

(A) N_2 (B) O_2 (C) Cl_2 (D) CH_4

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

(A) 64 (B) 32 (C) 4.0 (D) 8.0

25. The rate of diffusion of two gases A and B is in the ratio of 1 : 4 and that of B and C in the ratio of 1 : 3 the rate of diffusion of C with respect to A is -

(A) $\frac{1}{12}$ (B) 12 (C) 6 (D) 4

26. A gas X diffuses three times faster than another gas Y the ratio of their densities i.e., $D_x : D_y$ is

(A) 1/3 (B) 1/9 (C) 1/6 (D)1/12

27. Rate of diffusion of a gas is :

(A) directly proportional to its density

(B) directly proportional to its molecular weight

(C) directly proportional to the square of its molecular weight

(D) inversely proportional to the square root of its molecular weight

28. Since the atomic weights of carbon nitrogen and oxygen are 12, 14 and 16 respectively, among the following pairs of gases, the pair that will diffuse at the same rate is :

(A) CO_2 and N_2O (B) CO_2 and N_2O_3

(C) CO_2 and CO (D) CO_2 and NO

29. If the four tubes of a car are filled to the same pressure with N_2, O_2, H_2 and He separately then which one will be filled first :

(A) N_2 (B) O_2 (C) H_2 (D) He

30. The increasing order of effusion among the gases, H_2, O_2, NH_3 and CO_2 is –

(A) H_2, CO_2, NH_3, O_2 (B) H_2, NH_3, O_2, CO_2

(C) H_2, O_2, NH_3, CO_2 (D) CO_2, O_2, NH_3, H_2

31. The rate of diffusion of hydrogen is about–

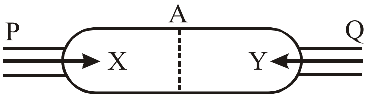
(A) $\frac{1}{2}$ that of Helium (B) 1.4 times that of Helium

(C) twice that of H (D) Four times that of Helium

32. Under identical conditions of pressure and temperature. 4 L of gaseous mixture (H_2 and CH_4) effuses through a hole in 5min whereas 4 L of a gas X of molecular mass 36 takes to 10 min to effuse through the same hole. The mole ratio of $H_2 : CH_4$, in the mixture is -

(A) 1 : 2 (B) 2 : 1 (C) 2 : 3 (D) 1 : 1

33. 3 mole of gas "X" and 2 moles of gas "Y enters from end "P" and "Q" of the cylinder respectively. The cylinder has the area of cross-section A, shown as under -



The length of the cylinder is 150 cm. The gas "X" intermixes with gas "Y" at the point A. If the molecular weight of the gases X and Y is 20 and 80 respectively, then what will be the distance of point A from Q?

(A) 75cm (B) 50cm (C) 37.5 cm (D) 90 cm

34. Under identical experiment conditions which of the following pairs of gases will be most easy to separate by using effusion process -

(A) H_2 and T_2 (B) SO_2 and SO_3 (C) NH_3 and CH_4 (D) $U^{235}O_2$ and $U^{238}O_2$

35. Certain volume of He gas takes 10 sec for its diffusion, how much time will be taken by CH_4 gas to disffuse it's same volume under identical conditions -

(A) 5 sec (B) 10 sec (C) 20 sec (D) 40 sec

36. A football bladder contains equimolar proportions of H_2 and O_2. The composition by mass of the mixture effusing out of punctured football is in the ratio ($H_2 : O_2$)

(A) 1 : 4 (B) $2\sqrt{2} : 1$ (C) $1 : 2\sqrt{2}$ (D) 4 : 1

37. Consider the following pairs of gases A and B.

	A	**B**
(a)	CO	N_2
(b)	O_2	O_3
(c)	$^{235}UF_6$	$^{238}UF_6$

Relative rates of effusion of gases A to B under similar condition is in the order:

(A) a < b < c (B) a < c < b (C) a > b > c (D) a > c > b

38. For the reaction

$$2NH_3(g) \longrightarrow N_2(g) + 3H_2(g),$$

what is the % of NH_3 converted if the mixture diffuses twice as fast as that of SO_2 under similar conditions.

(A) 3.125 % (B) 31.25 % (C) 6.25 % (D) 62.5 %

39. A 4 : 1 molar mixture of He & CH_4 kept in a vessel at 20 bar pressure. Due to a hole in the vessel, gas mixture leaks out. What is the composition of mixture effusing out initially -

(A) 8 : 1 (B) 4 : 1 (C) 1 : 4 (D) 4 : 3

40. Calculate the ratio of rate of effusion of O_2 and H_2 from a container containing 16gm O_2 and 2gm H_2

(A) 1 : 8 (B) 8 : 1 (C) 1 : 4 (D) 4 : 1

41. The number of effusion steps required to convert a mixture of H_2 and O_2 from 240 : 1600 (by mass) to 3072 : 20 (by mass) is

(A) 2 (B) 4 (C) 5 (D) 6

42. The density of the gaseous mixture in a vessel (CH_4 and He) at 2 atmosphere pressure and 300 K is 0.9756 g/lit. If a small pin-hole is made on the wall of the vessel, through which gases effuse, then which of the followings is the correct composition (by volume) of the gases CH_4 and He effusing out initially ?

(A) 1 : 1 (B) 2 : 1 (C) 3 : 1 (D) 1 : 4

43. At STP, the order of root mean square speed of molecules H_2, N_2, O_2 and HBr is :

(A) $H_2 > N_2 > O_2 > HBr$ (B) $HBr > O_2 > N_2 > H_2$

(C) $HBr > H_2 > O_2 > N_2$ (D) $N_2 > O_2 > H_2 > HBr$

44. Four particles have speed 2, 3, 4 and 5 cm/s respectively. Their rms speed is :

(A) 3.5 cm/s (B) $\left(\frac{27}{2}\right)$ cm/s (C) $\sqrt{54}$ cm/s (D) $\left(\frac{\sqrt{54}}{2}\right)$ cm/s

45. A flask has 10 molecules out of which four molecules are moving at 7ms^{-1} & the remaining are moving at same speed of X ms^{-1}. If Urms of the gas is 5 ms^{-1}. The value of 'X' will be

(A) 5 (B) 3 (C) 9 (D) 16

46. If the average velocity of N_2 molecules is 0.3 m/sec. at 27^0C, then the velocity of 0.6 m/sec will take place at :

(A) 273 K (B) 927 K (C) 1000 K (D) 1200 K

47. Which of the following expression does not give root mean square velocity –

(A) $\left(\frac{3RT}{M_w}\right)^{\frac{1}{2}}$ (B) $\left(\frac{3P}{DM_w}\right)^{\frac{1}{2}}$ (C) $\left(\frac{3P}{D}\right)^{\frac{1}{2}}$ (D) $\left(\frac{3PV}{nM_w}\right)^{\frac{1}{2}}$

48. Which one of the following gases would have the highest R.M.S. velocity at 25^0C ?

(A) Oxygen (B) Carbon dioxide (C) Sulphur dioxide (D) Carbon monoxide

49. At what temperature would the rms speed of a gas molecule have twice its value at 100°C ?

(A) 4192 K (B) 1492 K (C) 9142 K (D) 2491 K

50. Two flasks X and Y have capacity 1L and 2L respectively and each of them contains 1 mole of a gas. The temperature of the flask are so adjusted that average speed of molecules in X is twice as those in Y. The pressure in flask X would be

(A) same as that in Y (B) half of that in Y (C) twice of that in Y (D) 8 times of that in Y

51 Temperature at which most probable speed of O_2 becomes equal to root mean square speed of N_2 is [Given : N_2 at 427°C]

(A) 732 K (B) 1200 K (C) 927 K (D) 800 K

52. The density ratio of O_2 and H_2 is 16 : 1. The ratio of their U_{rms} is :-

(A) 4 : 1 (B) 16 : 1 (C) 1 : 4 (D) 1 : 16

53. Which of the gas have highest fraction of molecules at 27°C in most probable speed region -

(A) H_2 (B) N_2 (C) O_2 (D) CO_2

54. The av. K.E./mole of an ideal monoatomic gas at 27^0C is

(A) 900 cal (B) 1800 cal (C) 300 cal (D) None

55. The average kinetic energy of an ideal gas per molecule in SI units at 25^0C will be :

(A) 6.17×10^{-21} kJ (B) 6.17×10^{-21} J (C) 6.17×10^{-20} J (D) 7.16×10^{-20} J

56. At what temperature will be total kinetic energy (KE) of 0.30 mole of He be the same as the total KE of 0.40 mole of Ar at 400 K :

(A) 400 K (B) 373 K (C) 533 K (D) 300 K

57. Average K.E. of CO_2 at 27^0C is E. The average kinetic energy of N_2 at the same temperature will be

(A) E (B) 22E (C) E/22 (D) $E/\sqrt{2}$

58. If a gas expands at constant temperature then :

(A) No. of gaseous molecule decreases (B) kinetic energy of molecule decreases
(C) K.E. remain same (D) K.E. increases

59. Total translational kinetic energy possessed by 8 gm methane at 273°C
(R = 2 Cal/mol-K)

(A) 819 calorie (B) 409.5 calorie (C) 1638 calorie (D) None of these

60. Ideal gas equation in terms of K.E. per unit volume E, is-

(A) $P = \frac{3}{2}RT$ (B) $P = \frac{2}{3}E$ (C) $P = \frac{2}{3}RT$ (D) $P = \frac{3}{2}RT$

61. Three gases A, B and C are at same temperature. If their r.m.s. speed are in the ratio $1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}$ then their molar masses will be in the ratio :

(A) 1 : 2 : 3 (B) 3 : 2 : 1 (C) $1 : \sqrt{2} : \sqrt{3}$ (D) $\sqrt{3} : \sqrt{2} : 1$

62. The following gases are present under similar condition of T, P & V. The longest mean free path stands for

(A) H_2 (B) N_2 (C) O_2 (D) Cl_2

63. At constant volume, Z_{11} is directly proportional to -

(A) $\sqrt{P}$ (B) P (C) T^2 (D) T

64. At constant pressure, Z_{11} is directly proportional to -

(A) $\sqrt{T}$ (B) $\frac{1}{T}$ (C) $\frac{1}{\sqrt{T}}$ (D) $\frac{1}{T^{3/2}}$

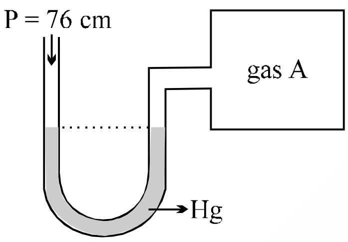
65. On increasing the temperature of an ideal gas at constant volume, the mean free path -

(A) Increases
(B) Decreases
(C) Remains unchanged
(D) May or may not change depending on the size of gas molecules

EXERCISE O-II

One or more may be correct :

1. An open ended mercury manometer is used to measure the pressure exerted by a trapped gas as shown in the figure. Initially manometer shows no difference in mercury level in both columns as shown in diagram.



After sparking 'A' dissociates according to following reaction

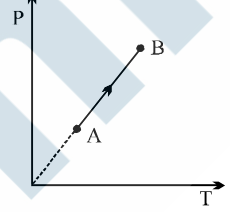
$$2A(g) \longrightarrow 3B(g) + 2C(g)$$

If pressure of Gas "A" decreases to 0.8 atm. Then (Assume temperature to be constant and is 300 K)

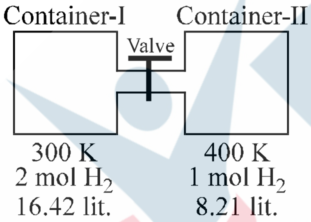
(A) total pressure increased by 1.3 atm
(B) total pressure increased by 0.3 atm
(C) total pressure increased by 22.3 cm of Hg
(D) difference in mercury level is 228 mm.

2. Select the correct option for an ideal gas undergoing a process as shown in diagram.

(A) If 'n' is changing , 'V' must also be changing.
(B) If 'n' is constant , 'V' must be constant.
(C) If 'n' is constant , 'V' must be changing.
(D) If 'n' is changing , 'V' must be constant.



3. Select the correct option(s):



(A) Pressure in container-I is 3 atm before opening the valve.
(B) Pressure after opening the valve is 3.57 atm.
(C) Moles in each compartment are same after opening the valve.
(D) Pressure in each compartment are same after opening the valve.

4. When an equimolar mixture of two gases A and B [$M_A > M_B$] is allowed to effuse through a Pin hole

select incorrect statement -

(A) B comes out at a faster rate
(B) Relative rate of effusion of A increases with time
(C) Rate of effusion of B will always be greater
(D) Initially, with equal molar ratio rate of effusion of B is greater than rate of effusion of A.

5. Select the correct option(s) for an ideal gas

(A) Most probable speed increases with increase in temperature

(B) Fraction of particles moving with most probable speed increases with increase in temperature

(C) Fraction of particles moving with most probable speed are more for Cl_2 than H_2 under similar condition of T, P & V.

(D) Most probable speed is more for Cl_2 than H_2 at same temperature

6. A closed vessel at temperature T contain a mixture of two diatomic gases A and B. Molar mass of A is 16 times that of B and mass of gas A contained in the vessel is 2 times that of B. Which of the following statements are correct-

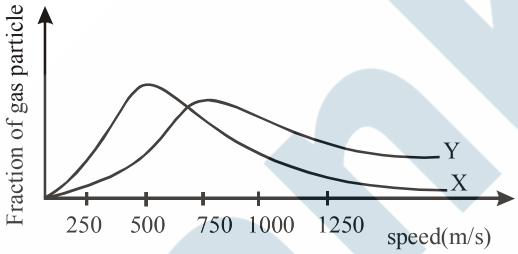
(A) Average kinetic energy per molecule of A is equal to that of B.

(B) Root mean square velocity of B is four times that of A

(C) Pressure exerted by B is eight time of that exerted by A

(D) Number of molecules of B, in the cylinder, is eight time that of A

7. The graph below shows the distribution of molecular speed of two ideal gases X and Y at 200K. on the basis of the below graph identify the correct statements -



(A) If gas X is methane, then gas Y can be CO_2

(B) Fraction of molecules of X must be greater than Y in a particular range of speed at 200K

(C) Under identical conditions rate of effusion of Y is greater than that of X

(D) The molar kinetic energy of gas X at 200K is equal to the molar kinetic energy of Y at 200K

8. Identify the correct statements when a fixed amount of ideal gas is heated in a container fitted with a movable piston always operating at constant pressure.

(A) Average distance travelled between successive collisions will decreases.

(B) Collisions frequency increases since speed of the molecules increases with increase in temperature.

(C) Average relative speed of approach remains unaffected.

(D) Average angle of approach remains unaffected.

9. Choose the correct statement(s) among the following

(A) Average molecular speed of gases increases with decrease in fraction of molecules moving slowly

(B) Rate of effusion of gases increases with increase in collision frequency at constant volume.

(C) Rate of effusion is inversily proportional to molecular weight of gas

(D) Mean free path does not change with change in temperature at constant pressure.

10. Which of the following quantities is the same for all ideal gases at the same temperature :

(A) The kinetic energy of 1 mol

(B) The kinetic energy of 1 g

(C) The number of molecules in 1 mol

(D) The number of molecules in 1 g

11. Choose the correct statement(s) among the following -

(A) The mean free path (λ) of gaseous molecules is directly proportional to temperature of gas at constant volume

(B) The mean free path (λ) of gaseous molecules is inversely proportional to pressure of gas at constant volume

(C) The mean free path (λ) of gaseous molecules is directly proportional to volume of gas at constant T

(D) The mean free path (λ) of gaseous molecules is directly proportional to volume of gas at constant P

12. Which statement is/are correct for postulates of kinetics theory of gases -

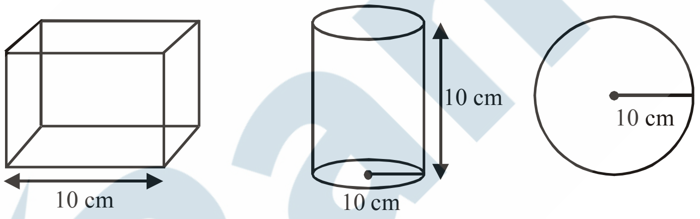
(A) Gases are composed of molecules whose size is negligible compared with the average distance between them

(B) Molecules moves randomly in straight lines in all directions and at various speeds.

(C) When molecules collide with one another the collisions are elastic. In an elastic collision the loss of kinetic energy takes place

(D) The average kinetic energy of a molecule is proportional to the absolute temperature.

13. Three closed containers are filled with equal amount of same ideal gas.



Container-I (Cube) **Container-II (Cylinder)** **Container-III (Sphere)**

If pressure is same in all container then -

(A) $(U_{rms})_3 > (U_{rms})_2 > (U_{rms})_1$ (B) $(U_{rms})_3 = (U_{rms})_2 = (U_{rms})_1$

(C) $\lambda_1 < \lambda_2 < \lambda_3$ ($\lambda \rightarrow$ Mean free path) (D) $(z_1)_1 < (z_1)_2 < (z_1)_3$

14. Which of the following statements is (are) true -

(A) The ratio of the average speed to the rms speed is independent of the temperature

(B) The square of the mean squared speed of the molecule is equal to the mean square speed at a certain temperature

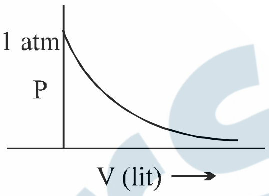
(C) Mean kinetic energy of the gas molecules at any given temperature is independent of the mean speed

(D) The difference between rms speed and average speed at any temperature for different gases diminished as larger molar masses are considered

Paragraph for Q.15 & 17

Question No. 18 to 20 are based on the following Passage. Read it carefully & answer the questions that follow

On the recently discovered 10th planet it has been found that the gases follow the relationship $Pe^{V/2} = nCT$ where C is constant other notation are as usual (V in lit., P in atm and T in Kelvin). A curve is plotted between P and V at 500 K & 2 moles of gas as shown in figure



15. The value of constant C is

(A) 0.01 (B) 0.001 (C) 0.005 (D) 0.002

16. Find the slope of the curve plotted between P Vs T for closed container of volume 2 lit. having same moles of gas

(A) $\frac{e}{2000}$ (B) 2000 e (C) 500 e (D) $\frac{2}{1000e}$

17. If a closed container of volume 200 lit. of O_2 gas (ideal gas) at 1 atm & 200 K is taken to planet. Find the pressure of oxygen gas at the planet at 821 K in same container

(A) $\frac{10}{e^{100}}$ (B) $\frac{20}{e^{50}}$ (C) 1 atm (D) 2 atm

Paragraph for Question 18 to 20

The constant motion and high velocities of gas particles lead to some important practical consequences. One such consequence is that as minimum rapidly when they come in contact. The mixing of different gases by random molecular motion and with frequent collisions is called diffusion A similar process in which gas molecules escape through a tiny hole into a vaccume is called effusion.

18 Helium gas at 1 atm and SO_2 at 2 atm pressure, temperature being the same, are released separately at the same moment into 1 m long evacuated tubes of equal diameters. If helium reaches the other end of the tube in t sec, what distance SO_2 would traverse in the same time interval in the other tube ?

(A) 25 cm (B) 50 cm (C) 60 cm (D) 75 cm

19 4 g of H_2 effused through a pinhole in 10 sec at constant temperature and pressure. The amount of oxygen effused in the same time interval and at the same conditions of temperature and pressure would be :

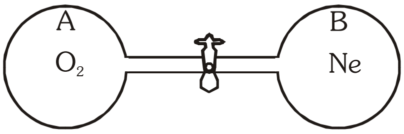
(A) 4 g (B) 8 g (C) 16 g (D) 32 g

20 For 10 min. each at 27°C, from two identical bulbs helium and an unknown gas X at equal pressures are leaked into a common vessel of 3 L capacity. The resulting pressure is 4.1 atm and the mixture contains 0.4 mol of helium. The molar mass of gas X is :

(A) 16 (B) 32 (C) 64 (D) None of these

Paragraph for Question 21 to 22

Initially, flask A contained oxygen gas at 27°C and 950 mm of Hg, and flask B contained neon gas at 27°C and 900 mm. Finally, the two flasks were joined by means of a narrow tube of negligible volume equipped with a stopcork and gases were allowed to mixup freely. The final pressure in the combined system was found to be 910 mm of Hg.



21 What is the correct relationship between volumes of the two flasks ?

(A) $V_B = 3V_A$ (B) $V_B = 4V_A$ (C) $V_B = 5V_A$ (D) $V_B = 4.5V_A$

22 How many moles of gas are present in flask A in the final condition, if volume of flask B is 304 litre ? ($R = 0.08$ atm L mol^{-1} K^{-1})

(A) 7.58 (B) 3.79 (C) 15.16 (D) None of these

TABLE TYPE QUESTION :

Column-I (Gases at different) conditions)	**Column-II (Value of speed (m/s)**	**Column-III**
(A) CH_4 at 27°C	(P) $U_{rms} = 342.5$	(I) Molar K.E. = 3750 Joule
(B) SO_2 at 27°C	(Q) $U_{mp} = 1100$	(II) Molar K.E. = 5000 Joule
(C) 4 gm He at 1 atm and 24.6 litre	(R) $U_{rms} = 685$	(III) Average K.E. per gram = 937.5 Joule
(D) 32 gm O_2 at 127°C	(S) $U_{rms} = 550$	(IV) Average K.E. per gram = 234 Joule.

(**Given :** $R = \frac{25}{3}\frac{J}{mol \times K}$, $\sqrt{30} = 5.48$, $\sqrt{\frac{2}{3}} = 0.8$, $\sqrt{5} = 2.2$)

23. Which of the following is correct

(A) A ; R ; 4 (B) A ; R ; 2 (C) A ; Q ; 4 (D) B ; R ; 1

24. Which of the following is correct

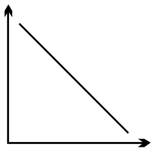
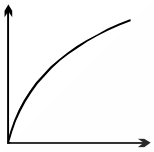
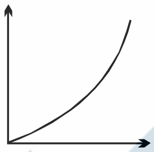
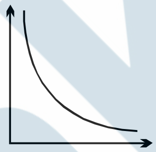
(A) B ; Q ; 1 (B) B ; Q ; 2 (C) B ; P ; 1 (D) C ; S ; 3

25. Which of the following is correct

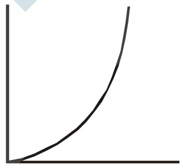
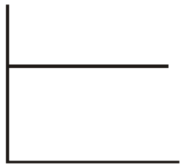
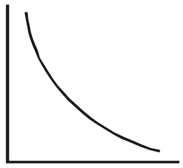
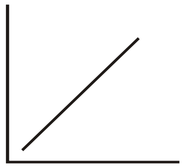
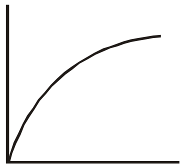
(A) C ; Q ; 3 (B) D ; R ; 2 (C) D ; S ; 1 (D) D ; S ; 4

Match the column:

26. Match the entries in column I with entries in Column II and then pick out correct options.

	Column I		**Column II**
(A)	$\frac{1}{V^2}$ vs P for ideal gas at constant T and n.	(P)	
(B)	V vs $\frac{1}{T}$ for ideal gas at constant P and n	(Q)	
(C)	log P vs log V for ideal gas at constant T and n.	(R)	
(D)	V vs $\frac{1}{P^2}$ for ideal gas at constant T and n.	(S)	

27. Match the column-

	Column-I **(For an ideal gas at constant pressure)**		**Column-II** **(correct graph)**
(A)	V v/s T	(P)	
(B)	TV v/s $\left(\frac{1}{T^2}\right)$	(Q)	
(C)	$\frac{V}{T}$ v/s V	(R)	
(D)	TV v/s T	(S)	
		(T)	

EXERCISE : JEE-MAINS

1. According to the kinetic theory of gases, in an ideal gas, between two successive collisions a gas molecule travels - **[AIEEE-2003]**

(1) In a straight line path (2) with an accelerated velocity

(3) In a circular path (4) In a wavy path

2. What volume of hydrogen gas, at 273K and 1 atm, pressure will be consumed in obtaining 21.6g of elemental boron (atomic mass = 10.8) from the reduction of boron trichloride by hydrogen ? **[AIEEE-2003]**

(1) 44.8 L (2) 22.4 L (3) 89.6 L (4) 67.2 L

3. As the temperature is raised from 20°C to 40°C, the average kinetic energy of neon atoms changes by factor of which of the following ? **[AIEEE-2004]**

(1) 1/2 (2) $\sqrt{(313/293)}$ (3) 313/293 (4) 2

4. Equal masses of methane and oxygen are mixed in an empty container at 25°C. The fraction of the total pressure exerted by oxygen is - **[AIEEE-2008]**

(1) 2/3 (2) $\frac{1}{3}\times\frac{273}{298}$ (3) $\frac{1}{3}$ (4) $\frac{1}{2}$

5. The molecular velocity of any gas is :- **[AIEEE-2011]**

(1) inversely proportional to the square root of temperature

(2) inversely proportional to absolute temperature

(3) directly proportional to square of temperature

(4) directly proportional to square root of temperature

6. α, v and u represent most probable velocity, average velocity and root mean square velocity respectively of a gas at a particular temperature. The correct order among the following is -**[JEE(Main)-2012]**

(1) $\alpha > u > v$ (2) $v > u > \alpha$ (3) $u > v > \alpha$ (4) $u > \alpha > v$

7. An open vessel at 300 K is heated till $\frac{2}{5}$th of the air in it is expelled. Assuming that the volume of the vessel remains constant, the temperature to which the vessel is heated is :- **[JEE(Main-online)-2012]**

(1) 750 K (2) 400 K (3) 500 K (4) 1500K

8. For 1 mol of an ideal gas at constant temperature T, the plot of (log P) against(log V) is a (P : Pressure, V : Volume) :- **[JEE(Main-online)-2012]**

(1) Straight line parallel to x-axis (2) Curve starting at origin

(3) Straight line with a negative slope (4) Straight line passing through origin

9. The relationship among most probable velocity, average velocity and root mean square velocity is respectively :- **[JEE(Main-online)-2012]**

(1) $\sqrt{2}:\sqrt{8/\pi}:\sqrt{3}$ (2) $\sqrt{2}:\sqrt{3}:\sqrt{8/\pi}$ (3) $\sqrt{3}:\sqrt{8/\pi}:\sqrt{2}$ (4) $\sqrt{8/\pi}:\sqrt{3}:\sqrt{2}$

10. Which one of the following is the wrong assumption of kinetic theory of gases ?

[JEE(Main-online)-2013]

(1) All the molecules move in straight line between collision and with same velocity.
(2) Molecules are separated by great distances compared to their sizes.
(3) Pressure is the result of elastic collision of molecules with the container's wall.
(4) Momentum and energy always remain conserved.

11. By how many folds the temperature of a gas would increase when the root mean square velocity of the gas molecules in a container of fixed volume is increased from 5×10^4 cm/s to 10×10^4 cm/s ?

[JEE(Main-online)-2013]

(1) Four (2) three (3) Two (4) Six

12. For gaseous state, if most probable speed is denoted by C, average speed by $\bar{C}$ and mean square speed by C, then for a large number of molecules the ratios of these speeds are :-

[JEE(Main-offline)-2013]

(1) $C : \bar{C} : C = 1.225 : 1.128 : 1$ (2) $C : \bar{C} : C = 1.128 : 1.225 : 1$
(3) $C : \bar{C} : C = 1 : 1.128 : 1.225$ (4) $C : \bar{C} : C = 1 : 1.225 : 1.128$

13. A gaseous compound of nitrogen and hydrogen contains 12.5%(by mass) of hydrogen. The density of the compound relative to hydrogen is 16. The molecular formula of the compound is :

[JEE(Main-online)-2014]

(1) NH_2 (2) NH_3 (3) N_3H (4) N_2H_4

14. The initial volume of a gas cylinder is 750.0 mL. If the pressure of gas inside the cylinder changes from 840.0 mm Hg to 360.0 mm Hg, the final volume the gas will be **[JEE(Main-online)-2014]**

(1)1.750 L (2) 7.50 L (3) 3.60 L (4) 4.032 L

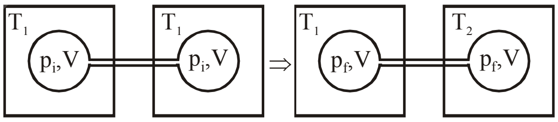
15. The temperature at which oxygen molecules have the same root mean square speed as helium atoms have at 300 K is : **[JEE(Main-online)-2014]**

(Atomic masses : He = 4 u, O = 16 u)

(1) 1200 K (2) 600 K (3) 300 K (4) 2400 K

16. Which of the following is not an assumption of the kinetic theory of gases ?
(1) Gas particles have negligible volume. **[JEE-Mains (online)-2015]**
(2) A gas consists of many identical particles which are in continual motion.
(3) At high pressure, gas particles are difficult to compress.
(4) Collisions of gas particles are perfectly elastic.

17. 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 :- **[JEE-Mains-2016]**



(1) $2p_i\left(\frac{T_1T_2}{T_1+T_2}\right)$ (2) $p_i\left(\frac{T_1T_2}{T_1+T_2}\right)$ (3) $2p_i\left(\frac{T_1}{T_1+T_2}\right)$ (4) $2p_i\left(\frac{T_2}{T_1+T_2}\right)$

18. At 300 K, the density of a certain gaseous molecule at 2 bar is double to that of dinitrogen (N_2) at 4 bar. The molar mass of gaseous molecule is:- **[JEE-Mains-2017(ONLINE)]**

(1) 28 g mol^{-1} (2) 56 g mol^{-1} (3) 224 g mol^{-1} (4) 112 g mol^{-1}

19. Assuming ideal gas behaviour, the ratio of density of ammonia to that of hydrogen chloride at same temperature and pressure is : **[JEE-Mains-2018(ONLINE)]**

(Atomic wt. of Cl = 35.5 u)

(1) 0.64 (2) 1.64 (3) 1.46 (4) 0.46

EXERCISE : JEE-ADVANCED

1. Calculate the total pressure in a 10 litre cylinder which contains 0.4 g He, 1.6 g oxygen and 1.4 g of nitrogen at 27ºC. Also calculate the partial pressure of He gas in the cylinder. Assume ideal behavious for gases. **[JEE 1997]**

2. 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 : **[JEE 1998]**

   (A) $\frac{P_A}{P_B}\left(\frac{M_A}{M_B}\right)^{1/2}$ (B) $\left(\frac{M_A}{M_B}\right)\left(\frac{P_A}{P_B}\right)^{1/2}$ (C) $\frac{P_A}{P_B}\left(\frac{M_B}{M_A}\right)^{1/2}$ (D) $\frac{M_A}{M_B}\left(\frac{P_B}{P_A}\right)^{1/2}$

3. An evacuated glass vessel weighs 50.0 g when empty, 148.0 gm when filled with a liquid of density 0.98 g /mL and 50.5 g when filled with an ideal gas at 760 mm Hg at 300 k . Determine the molecular weight of the gas . **[JEE 1998]**

4. The pressure exerted by 12 g of an ideal gas at temperature t ºC in a vessel of volume V is one atmp . When the temperature is increased by 10 degrees at the same volume, the pressure increases by 10 %. Calculate the temperature 't' and volume 'V'. [molecular weight of gas = 120] **[JEE 1999]**

5. One mole of N_2 gas at 0.8 atmp takes 38 sec to diffuse through a pin hole, whereas one mole of an unknown compound of Xenon with F at 1.6 atmp takes 57 sec to diffuse through the same hole . Calculate the molecular formula of the compound.(At. wt. Xe = 138, F = 19) **[JEE 1999]**

6. The r.m.s. velocity of hydrogen is $\sqrt{7}$ times the r.m.s. velocity of nitrogen. If T is the temperature of the gas : **[JEE 2000]**

   (A) $T(H_2) = T(N_2)$ (B) $T(H_2) > T(N_2)$

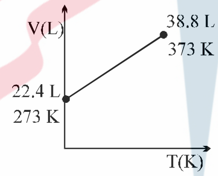
   (C) $T(H_2) < T(N_2)$ (D) $T(H_2) = \sqrt{7}\ T(N_2)$

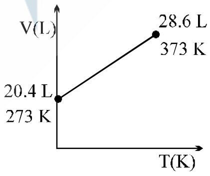
7. **Statement-1 :** The pressure of a fixed amount of an ideal gas is proportional to its temperature. **Statement-2 :** Frequency of collision and their impact both increase in proportion to the square root of temperature. True/False. **[JEE 2000]**

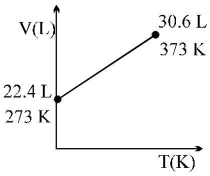
8. The root mean square velocity of an ideal gas at constant pressure varies with density as

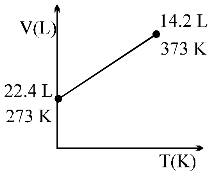
   (A) d^2 (B) d (C) $d^{1/2}$ (D) $1/d^{1/2}$ **[JEE 2001]**

9. Which one of the following V, T plots represents the behaviour of one mole of an ideal gas at one atmp? **[JEE 2002]**

   (A)


   (B)


   (C)


   (D)


10. The average velocity of gas molecules is 400 m/sec. Calculate its (rms) velocity at the same temperature. **[JEE 2003]**

11. The ratio of the rate of diffusion of helium and methane under identical condition of pressure and temperature will be

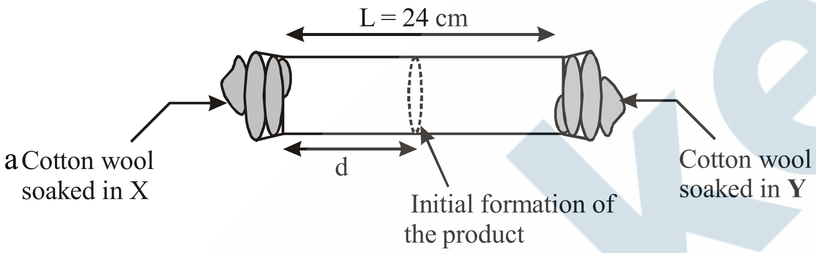
    (A) 4 (B) 2 (C) 1 (D) 0.5 **[JEE 2005]**

12. At 400 K, the root mean square (rms) speed of a gas X (molecular weight = 40) is equal to the most probable speed of gas Y at 60 K. The molecular weight of the gas Y is **[JEE 2009]**

13. To an evacuated vessel with movable piston under external pressure of 1 atm., 0.1 mol of He and 1.0 mol 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 **[JEE 2011]**

Paragraph for Question 14 & 15

X and Y are two volatile liquids with molar weights of 10g mol^{-1} and 40g 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 cm, as shown in the figure. The tube is filled with an inert gas at 1 atmosphere pressure and a temperature of 300K. Vapours of X and Y react to form a product which is first observed at a distance d 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. **[JEE 2014]**



14 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

15. The experimetnal 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 to 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

16. 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 (Figure 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 (Figure 2), the volume (in m^3) of the compartment A after the system attains equilibrium is____. **[JEE 2018]**

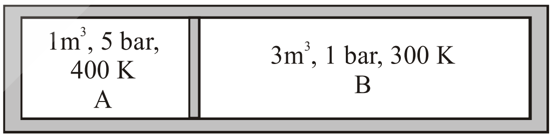


Figure 1

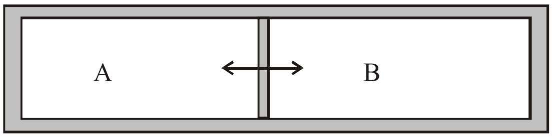


Figure 2

ANSWER KEY

EXERCISE # S-1

1. Ans.(5)
2. Ans. (800)
3 Ans. (90)
4 Ans.(120)
5. Ans.(1024)
6. Ans.(4)
7. Ans. (100)
8. Ans.(4)
9. Ans (8)
10. Ans.5 cm.
11. Ans. (50)
12. Ans.P = 0.075 atm , T = 75 K
13. Ans.73.9 litre
14. Ans.15 gm ; 12 dm^3
15. Ans. (10)
16. Ans. 25%
17. Ans.(2)
18. Ans. yes cylinder will blow up
19. Ans.(6)
20. Ans.(150)
21. Ans. 1 MPa
22. Ans. (0.3)
23. Ans.(1.25 atm)
24. Ans.(15:16)
25. Ans.(0.8 bar)
26. Ans.(40g)
27. Ans.(0.5 P mm)
28. Ans. $\frac{2P}{(n+1)}$
29. Ans. 3.284 atm
30. Ans. (3)
31 Ans. (7)
32. Ans. (420)
33. Ans.(0.17 atm)
34. Ans. 27.18 atm, 19.41 atm
35. Ans. 0.36 gm
36. Ans. 228
37. Ans. (2 : 1)
38. Ans. 508 mm
39. Ans. 16 min = 0.267 hr
40. Ans.(60)
41. Ans. 192
42. Ans. (4)
43. Ans.(8)
44. Ans.(i) $\frac{1}{2}$; (ii) $\frac{3}{16}$; (iii) $\frac{1}{2}$
45. Ans. (a) 1934.24 m/sec (b) 500 m/sec , (c) 17.32 m/sec.
46. Ans. (25)
47. Ans. 236.5
48. Ans.(2)
49. Ans. (2)
50. Ans. (4)
51. Ans. He
52 Ans.(2)
53 Ans.(2)
54. Ans.(a) 530.6 Pa, (b) $1.281 \times 10^{23} m^{-3}$
55. Ans.(800 K)

EXERCISE- S-2

1. Ans. 0.94 mole
2. Ans.(4)
3. Ans. (i) $P_1 = 5$ atm; (ii) $T_3 = 360$ K; (iii) $V_1 = 16$ lit.; (iv) $P_2 = 1.5$ atm ; (v) $T_4 = 90$ K
4. Ans. $P \propto d$; $P = kd$ & $k = \frac{1\,\text{atm}}{1\,\text{meter}}$; (a) 80; (b) 1295 moles
5. Ans. 6 atm, No
6. Ans. 10,000 K
7. Ans. 2 atmp
8. Ans (6)
9. Ans.(2)
10. Ans (380)
11. (i) 1.5 atm;

    (ii) O_2=0.75 atm, O_3 = 0.5 atm;

    (iii) 0.208 atm
12. Ans. (9)
13. Ans. (4)
14. Ans.(8)
15. Ans. (i) 0.012 atm; (ii) 2.5×10^{22}; (iii) 3.6 J; (iv) 300 J; (v) $\frac{1}{\sqrt{2}}$; (vi) $0.4 \times 10^{-3} : 1$

EXERCISE - O-I

1. Ans.(C)
2. Ans.(C)
3. Ans.(C)
4. Ans.(B)
5. Ans.(C)
6. Ans.(C)
7. Ans.(B)
8. Ans. (D)
9. Ans.(A)
10. Ans.(C)
11. Ans.(C)
12. Ans. (A)
13. Ans.(B)
14. Ans.(B)
15. Ans. (C)
16. Ans.(D)
17. Ans.(B)
18. Ans. (C)
19. Ans.(D)
20. Ans.(C)
21. Ans.(A)
22. Ans.(D)
23. Ans.(D)
24. Ans.(A)
25. Ans.(B)
26. Ans.(B)
27. Ans.(D)
28. Ans.(A)
29. Ans.(C)
30. Ans.(D)
31. Ans.(B)
32. Ans.(D)
33. Ans.(C)
34. Ans.(A)
35. Ans.(C)
36. Ans.(A)
37. Ans.(B)
38. Ans.(C)
39. Ans.(A)
40. Ans.(A)
41. Ans.(C)
42. Ans.(A)
43. Ans.(A)
44. Ans.(D)
45. Ans.(B)
46. Ans.(D)
47. Ans.(B)
48. Ans.(D)
49. Ans.(B)
50. Ans.(D)
51. Ans.(B)
52. Ans.(C)
53. Ans.(D)
54. Ans.(A)
55. Ans.(B)
56. Ans.(C)
57. Ans.(A)
58. Ans.(C)
59. Ans.(A)
60 Ans.(B)
61. Ans.(A)
62. Ans. (A)
63. Ans.(A)
64. Ans.(D)
65. Ans.(C)

EXERCISE - O-II

1.	Ans.(B,D)	2.	(A,B)	3.	Ans.(A,D)	4.	Ans. (C)
5.	Ans.(A,C)	6.	Ans. (A,B,C,D)	7.	Ans. (C,D)	8.	Ans. (D)
9.	Ans. (A, B)	10.	Ans.(A,C)	11.	Ans.(C,D)	12.	Ans.(A, B, D)
13.	Ans (A, C)	14.	Ans.(A,C,D)				
15.	Ans.(B)	16	Ans.(D)	17.	Ans.(A)	18	Ans.(B)
19	Ans.(C)	20	Ans.(C)	21	Ans. (B)	22.	Ans. (B)
23.	Ans.(A)	24.	Ans.(C)				
25.	Ans.(A)	26.	Ans.(A) R, (B) S, (C) P, (D) Q				
27.	(A)-S; (B)- R ; (C) - Q; (D) – P						

EXERCISE - JEE-MAINS

1.	Ans (1)	2.	Ans (4)	3.	Ans(3)	4.	Ans(3)
5.	Ans(4)	6.	Ans(3)	7.	Ans.(3)		
8.	Ans.(3)	9.	Ans.(1)	10.	Ans.(1)	11.	Ans.(1)
12.	Ans (3)	13.	Ans.(4)	14.	Ans.(1)	15.	Ans.(4)
16.	Ans. (3)	17.	Ans. (4)	18.	Ans.(4)	19.	Ans.(4)

EXERCISE - JEE-ADVANCED

1.	Ans.0.492 atmp ; 0.246 atmp	2.	Ans.(C)
3.	Ans.123	4.	–173°C , 0.82 L
5.	Ans.XeF_6	6.	Ans.(C)
7.	Ans.Both statements are correct	8.	Ans.(D)
9.	Ans.(C)	10.	Ans.434.17 m/sec
11.	Ans.(B)	12	Ans.(4)
13.	Ans.(7)	14	Ans.(C)
15	Ans.(D)	16	Ans.(2.22)