IDEAL GASES

CONTENTS

JEE(Advanced) Syllabus

Gaseous and liquid states : Absolute scale of temperature, ideal gas equation; Deviation from ideality, van der Waals equation; Kinetic theory of gases, average, root mean square and most probable velocities and their relation with temperature; Law of partial pressures; Vapour pressure; Diffusion of gases, Graham's Law.

JEE(Main) Syllabus

Three states of matter, gaseous state, gas laws (Boyle's Law and Charles Law), Avogadro's Law, Grahams' Law of diffusion, Dalton's law of partial pressure, ideal gas equation, Kinetic theory of gases, real gases and deviation from ideal behaviour, vander Waals' equation, liquefaction of gases and critical points, Intermolecular forces; liquids and solids.

Ideal Gases

Introduction :

Matter as we know broadly exists in three states.

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

- Inter molecular attractive forces.
- The molecular motion / random motion.

Matter

Properties	Solid state	Liquid state	Gaseous state
Attractive force	• large	• Smaller	• Almost zero
Thermal motion	• Almost zero	• Greater	• Random motion
Volume	• Fixed volume	• Fixed volume	• varies with container
Geometry	• Definite	• Not definite	• Not definite

In this chapter the properties and behaviour of the gases will be analysed and discussed in detail. These properties are measured with the help of the gas laws as proposed Boyle, Charles, Gay lussac etc.

Section (A) : Ideal gas equation & gas laws

Th1 Boyle's law and measurement of pressure :

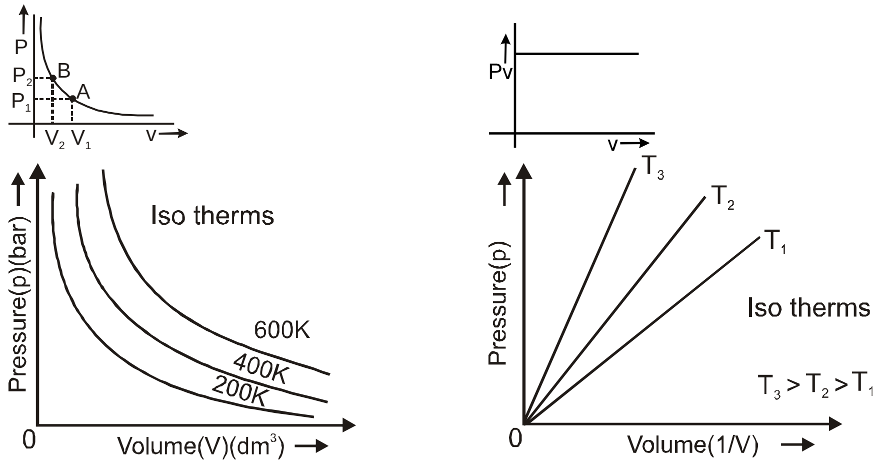
D1 **Statement :** For a fixed amount of gas at constant temperature, the volume occupied by the gas is inversely proportional to the pressure applied on the gas or pressure of the gas.

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

Hence PV = constant.

This constant will be dependent on the amount of the gas and temperature of the gas.

F1 $P_1V_1 = P_2V_2$



Application of Boyles Law: For the two points 'A' and 'B' $P_1V_1 = K$ & $P_2V_2 = K$

Hence it follows that $P_1V_1 = P_2V_2$.

Units

Volume	Pressure	Temperature
Volume of the gas is the Volume of the container S.I. unit $\rightarrow m^3$ C.G.S. unit $\rightarrow cm^3$ $1\ \ell = 10^{-3}\ m^3$ $1\ \ell = 10^3\ cm^9$ $1\ dm^3 = 1\ \ell = 10^{-3}\ m^3$ $1\ ml = 10^{-3}\ \ell = 1\ cm^3 = 1cc$	Pressure = N/m^2 = Pa $\rightarrow$ S.I. unit C.G.S unit = dyne-cm^2 Convert $1N/m^2$ into dyne/cm^2 $\frac{1N}{1m^2} = \frac{10^5\ dyne}{10^4\ cm^2}$ $1\ N/m^2 = 10\ dyne/cm^2$ $1\ atm = 1.013 \times 10^5\ N/m^2$ $1\ bar = 1 \times 10^5\ N/m^2$ 1 atm = 760 mm of Hg = 760 torr	Kelvin scale $\rightarrow$ Boiling point = 373 K ice point = 273 K Farenheit scale $\rightarrow$ B.P. = 212ºF ice point = 32ºF Celcius scale $\rightarrow$ B.P. = 100ºC ice point = 0ºC $\frac{C-0}{100-0} = \frac{K-273}{373-273} = \frac{F-32}{212-32} = \frac{R-R(0)}{R(100)-R(0)}$ where R = Temperature on unknown scale.

Atmospheric pressure :
The pressure exerted by atmosphere on earth's surface at sea level is called 1 atm.
1 atm = 1.013 bar
$1\ atm = 1.013 \times 10^5\ N/m^2 = 1.013\ bar = 760\ torr$

Solved Examples

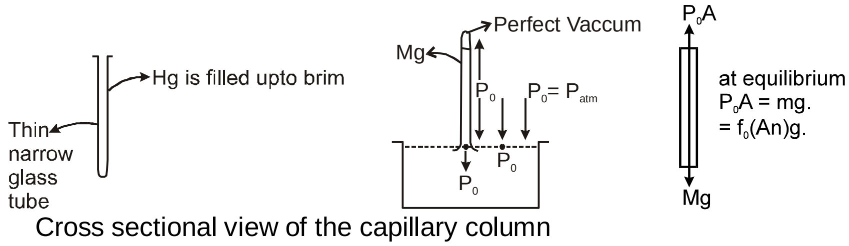
Ex-1. A rubber balloon contains some solid marbles each of volume 10 ml. A gas is filled in the balloon at a pressure of 2 atm and the total volume of the balloon is 1 litre in this condition. If the external pressure is increased to 4atm the volume of Balloon becomes 625 ml. Find the number of marbles present in the balloon.

Sol. Let the no. of marbles be = n.
volume of marble = 10 n ml.
volume of balloon earlier = 1000 ml.
later = 625 ml.
Now for the gas inside the balloon temperature and amount of the gas is constant, hence Boyles law can be applied

$$P_1V_1 = P_2V_2$$
$$4 \times (625 - 10n) = 2 \times (1000 - 10n)$$
$$625 \times 4 = 2000 - 20n + 40n$$
$$625 \times 4 - 2000 = 20n$$
$$\frac{625 \times 4 - 2000}{20} = n. \qquad \frac{125}{5} = n \ ; \qquad n = 25$$

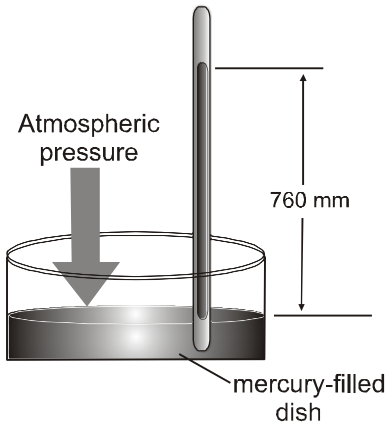
Th2 Measurement of Pressure

Barometer: A barometer is an instrument that is used for the measurement of pressure.The construction of the barometer is as follows



Cross sectional view of the capillary column

A mercury barometer is used to measure atmospheric pressure by determining the height of a mercury column supported in a sealed glass tube. The downward pressure of the mercury in the column is exactly balanced by the outside atmospheric pressure that presses down on the mercury in the dish and pushes it up the column.



A thin narrow calibrated capillary tube is filled 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.

Applying force balance, we get,

$P_{atm} \times A = m \times g$ ('A' is the cross-sectional area of the capillary tube)

If 'ρ' is the density of the fluid, then $m = \rho \times v$

Hence, $P_{atm} \times A = (\rho \times g \times h) \times A$ $(v = A \times h)$

('h' is the height to which mercury has risen in the capillary)

F2 or, $P_{atm} = \rho gh$

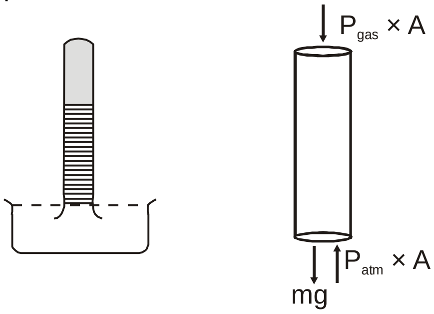
☞ Normal atmospheric pressure which we call 1 atmosphere (1 atm), is defined as the pressure exerted by the atmosphere at mean sea level. It comes out to be 760 mm of Hg = 76 cm of Hg. (at mean sea level the reading shown by the barometer is 76 cm of Hg)

$1 \text{ atm} = (13.6 \times 10^3) \times 9.8 \times 0.76 = 1.013 \times 10^5$ Pascal.

1 torr = 1 mm of Hg.

1 bar = 10^5 N/m^2 (Pa)

Faulty Barometer: An ideal barometer will show a correct reading only if the space above the mercury column is vacuum, but in case if some gas column is trapped in the space above the mercury column, then the barometer is classified as a faulty barometer. The reading of such a barometer will be less than the true pressure.



For such a faulty barometer

$P_0A = Mg + P_{gas} A$

$P_0 = \rho gh + P_{gas}$ or $\rho gh = P_0 - P_{gas}$

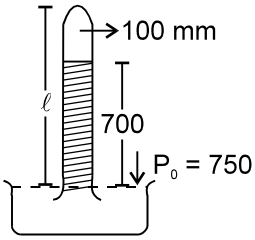
Solved Examples

Ex-2. The reading of a faulty barometer is 700 mm of Hg. When actual pressure is 750 mm of Hg. The length of the air column trapped in this case is 10 cm. Find the actual value of the atmospheric pressure when reading of this barometer is 750 mm of Hg. Assume that the length of the Barometer tube above mercury surface in the container remains constant.

Sol. $P_0 = P_{gas} + 700\ \rho g$

∴ $P_{gas} = 750\ \rho g - 700\ \rho g = 50\ \rho g$

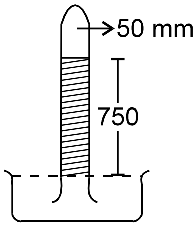
Now for the gas column in the capillary, amount and temperature are constant hence $P_1V_1 = P_2V_2$



$(50\ \rho g)\ (100\ A) = P'_{gas} \times (50\ A)$

$\therefore \quad P'_{gas} = 100\ \rho g$

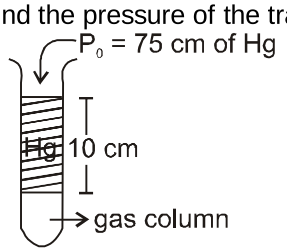
Now, applying force balance in the new conditions:



$P'_{atm} = P'_{gas} + 750\ \rho g = 100\ \rho g + 750\ \rho g = 850\ \rho g$

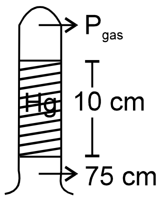
Hence, the atmospheric pressure is now, 850 mm of Hg.

Ex-3. In each of the following examples, find the pressure of the trapped gas.



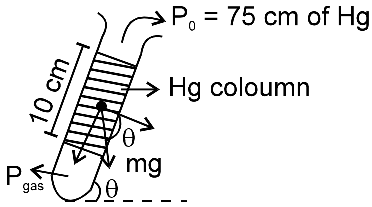
Sol. Total pressure of gas column = 75 + 10 = 85 cm of Hg.

Ex-4.



Sol. P_{gas} = 65 cm of Hg.

Ex-5.



$P_g = 75 + 10 \cos \theta$.

Sol. From the above problem, it can be generalised that, applying force balance every single time is not necessary. If we are moving up in a fluid, then substract the vertical length, and while moving down add the vertical length.

D2 Charles 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.

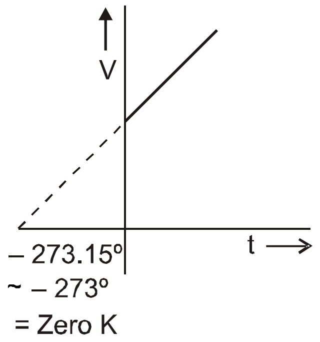
$V \propto T$ or $V = kT$

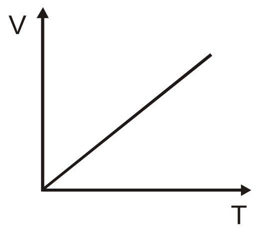
$\frac{V}{T}$ = constant where 'k' is a proportionality constant and is

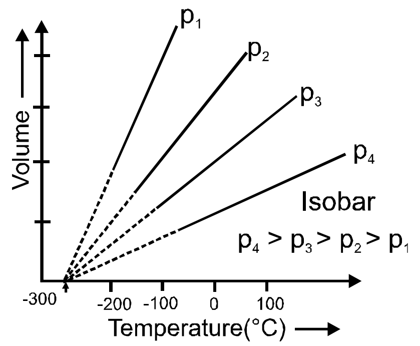
Dependent on amount of gas and pressure.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ Temperature on absolute scale, Kelvin scale or ideal gas scale.

$V = a + bt$ Temperature on centigrade scale.







Relation : $T = t + 273$

- Since volume is proportional to absolute temperature. The volume of a gas should be theoretically zero at absolute zero temperature.
- Infact no substance exists as gas at a temperature near absolute zero, though the straight line plots can be extra plotted 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.

Solved Examples

Ex-6. If the temperature of a particular amount of gas is increased from 27ºC to 57ºC, find final volume of the gas, if initial volume = 1 lt and assume pressure is constant.

Sol. $\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow \frac{1}{(273+27)} = \frac{V_2}{(273+57)}$ So $V_2 = 1.1$ lt.

Ex-7. An open container of volume 3 litre contains air at 1 atmospheric pressure. The container is heated from initial temperature 27ºC or 300 K to tºC or (t + 273) K the amount of the gas expelled from the container measured 1.45 litre at 17ºC and 1 atm.Find temperature t.

Sol. $\therefore$ $T_1 = 300$ K

It can be assumed that the gas in the container was first heated to (t + 273), at which a volume 'ΔV' escaped from the container.

Hence applying charles law : $\frac{3}{300} = \frac{3+\Delta V}{t+273}$

Now, this volume 'ΔV' which escapes when the container get cooled

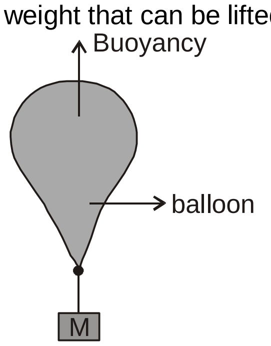
$\therefore$ $\frac{\Delta V}{t+273} = \frac{1.45}{290}$

Solve the two equations and get the value of ΔV and t.

Determine Δ V & calculate t that will be the answer.

Th3 Calculation of pay load :

Pay load is defined as the maximum weight that can be lifted by a gas filled balloon.



For maximum weight that can be lifted, applying force balance

$F_{buoyancy} = M_{balloon} \times g + M_{pay\ load} \times g$

$\Rightarrow \quad \rho_{air}$ v.g. = ρ_{gas} v.g + Mg + mg.

mass of balloon = m
volume of balloon = v
density of air = ρ_{air}
density of gas inside the balloon = ρ_{gas}

net force on balloon = 0
(at equilibrium / when balloon is incoming with constant speed)

Solved Examples

Ex-8. A balloon of diameter 20 m weights 100 kg. Calculate its pay-load, if it is filled with He at 1.0 atm and 27ºC. Density of air is 1.2 kg m^{-3}. [R = 0.0082 dm^3 atm K^{-1} mol^{-1}]

Sol. Weight of balloon = 100 kg = 10×10^4 g

Volume of balloon = $\frac{4}{3}\pi r^3 = \frac{4}{3} \times \frac{22}{7} \times \left(\frac{20}{2} \times 100\right)^3$ = 4190×10^6 cm^3 = 4190×10^3 litre

Weight of gas (He) in balloon = $\frac{PVM}{RT} = \frac{1 \times 4190 \times 10^3 \times 4}{0.082 \times 300}$ = 68.13×10^4 g $\left(\because \quad PV = \frac{w}{M}RT\right)$

$\therefore$ Total weight of gas and balloon = $68.13 \times 10^4 + 10 \times 10^4 = 78.13 \times 10^4$ g

Weight of air displaced = $\frac{1.2 \times 4190 \times 10^6}{10^3}$ = 502.8×10^4 g

$\therefore$ Pay load = wt. of air displaced – (wt. of balloon + wt. of gas)

$\therefore$ Pay load = $502.8 \times 10^4 - 78.13 \times 10^4$ = **424.67×10^4 g**

D3 Gay-lussac's law :

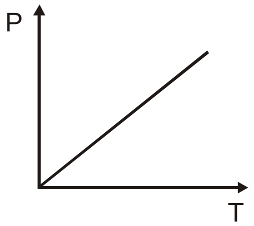
For a fixed amount of gas at constant volume, pressure of the gas is directly proportional to temperature of the gas on absolute scale of temperature.

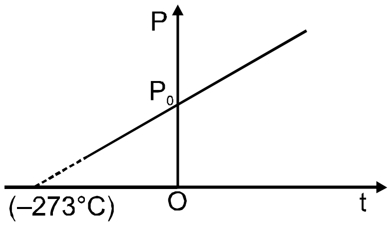
$P \propto T$

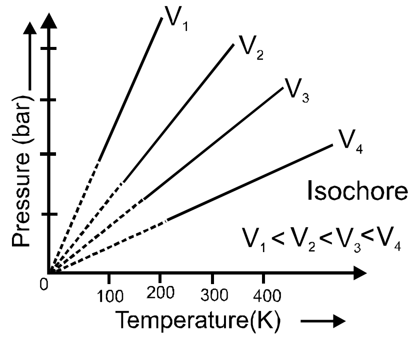
$\frac{P}{T}$ = constant $\rightarrow$ dependent on amount and volume of gas

F3 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $\rightarrow$ temperature on absolute scale

Originally, the law was developed on the centigrade scale, where it was found that pressure is a linear function of temperature $P = P_0 + bt$ where 'b' is a constant and P_0 is pressure at zero degree centigrade.







Ex. PV = K $\Rightarrow$ V = K_1/P

$\frac{V}{T} = K_2 \Rightarrow V = K_2 T$

$\frac{K_1}{P} = K_2 T$

$\underbrace{PT = \frac{K_1}{K_2} = \text{const.}}$ $\Rightarrow P \propto = \frac{1}{T} \Rightarrow$?

where are we wrong ?

This is wrong because we are varying temperature &
$K_1 = f(1)$ thus K_1 will change according to temperature

So $\frac{K_1}{K_2}$ will be a function of temp & not constant.

Solved Examples

Ex-9. The temperature of a certain mass of a gas is doubled. If the initially the gas is at 1 atm pressure. Find the % increase in pressure ?

Sol. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; $\frac{1}{T} = \frac{P_2}{2T}$

% increase = $\frac{2-1}{1} \times 100 = 100\%$

Ex-10. The temperature of a certain mass of a gas was increased from 27°C to 37°C at constant volume. What will be the pressure of the gas.

Sol. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; $\frac{P}{300} = \frac{P_2}{310}$; $P_2 = \frac{31}{30}P$

D4 Avogadro's Hypothesis :

For similar values of pressure & temperature equal number of molecules of different gases will occupy equal volume.

$N_1 \longrightarrow V$ (volume of N_1 molecules at P & T of one gas)

$N_1 \longrightarrow V$ (volume of N_1 molecules at P & T of second gas)

$\Rightarrow$ Molar volume & volume occupied by one mole of each and every gas under similar conditions will be equal.

One mole of any gas or a combination or gases occupies 22.413996 L of volume at STP.

*The previous standard is still often used, and applies to all chemistry data more than decade old, in this definition **Standard Temperature and Pressure STP** denotes the same temperature of 0°C (273.15K), but a slightly higher pressure of 1 atm (101.325 kPa) .*

Standard Ambient Temperature and Pressure (SATP)**, conditions are also used in some scientific works. SATP conditions means 298.15 K and 1 bar (i.e. exactly 10^5 Pa) At SATP (1 bar and 298.15 K), the molar volume of an ideal gas is 24.789 L mol^{-1}* ***(Ref. NCERT)

Th4 Equation of State :

Combining all the gas relations in a single expression which discribes relationship between pressure, volume and temperature, of a given mass of gas we get an expression known as equation of state.

$\frac{PV}{T}$ = constant (dependent on moles of the gas n).

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

Ideal gas Equation : $\frac{PV}{nT}$ = constant [universal constant]

= R (ideal gas constant or universal gas constant)

R = 8.314 J/Kmole ≈ 25/3
= 1.987 cal/mole ≈ 2
= 0.08 Latm/mole ≈ 1/12

Solved Examples

Ex-11. Some spherical balloons each of volume 2 litre are to be filled with hydrogen gas at one atm & 27°C from a cylinder of volume 4 litres. The pressure of the H_2 gas inside the cylinder is 20 atm at 127°C. Find number of balloons which can be filled using this cylinder. Assume that temperature of the cylinder is 27°C.

Sol. No. of moles of gas taken initially = $\dfrac{20 \times 4}{R \times 400}$ = 2.43 L

No. of moles of gas left in cylinder = $\dfrac{1 \times 4}{R \times 300}$ = 0.162L

No. of moles of gas to be filled in balloons = 2.43 – 0.162 = 2.268

Let we have 'n' balloons that we can fill

No. of moles of gas that can be filled in 1 balloon = $\dfrac{1 \times 2}{0.082 \times 300}$ = 0.081

$\therefore$ 0.081 × n = 2.268

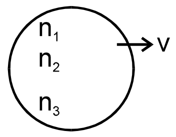
n = 28 balloons.

Section (B) : Daltons law of partial pressures

Th5 Daltons law of partial pressure :

Partial pressure :

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



Partial pressure of first component gas

$P_1 = \dfrac{n_1RT}{v}$; $P_2 = \dfrac{n_2RT}{v}$; $P_3 = \dfrac{n_3RT}{v}$

Total pressure = $P_1 + P_2 + P_3$.

D5 Daltons law :

For a *non reacting* gaseous mixture total pressure of the mixture is the summation of partial pressure of the different component gases.

F4 $P_{Total} = P_1 + P_2 + P_3 = \dfrac{(n_1 + n_2 + n_3)RT}{v}$

$\dfrac{P_1}{P_T} = \dfrac{n_1}{n_T}$ = x_1 (mole fraction of first component gas)

$\dfrac{P_2}{P_T} = \dfrac{n_2}{n_T}$ = x_2 (mole fraction of second component gas)

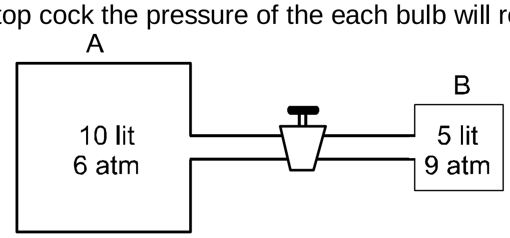
$\dfrac{P_3}{P_T} = \dfrac{n_3}{n_T}$ = x_3 (mole fraction of third component gas)

Section (C) : Mixing of Gases

Solved Examples

Ex-12. The stop cock connecting the two bulbs of volume 5 litre and 10 litre containing as ideal gas at 9 atm and 6 atm respectively, is opened. What is the final pressure if the temperature remains same.

Sol. After the opening of the stop cock the pressure of the each bulb will remain same.



At the beginning, the no. of moles of gas in A = $\dfrac{10 \times 6}{RT}$

At the beginning, the no. of moles of gas in B = $\dfrac{5 \times 9}{RT}$

$\therefore$ Total no. of mole at the beginning = $\dfrac{105}{RT}$

Total no. of mole of gas before opening the stop cock

Total no. of moles of gas after opening stop cock = $\frac{105}{RT}$

$\therefore$ Pressure after the opening of the stop cock

$$P = \frac{105}{RT} \times \frac{RT}{V_{total}} = \frac{105}{10+5} = 7 \text{ atm}$$

Th6 Analysis of gaseous mixture :

D6 Vapour Density : Vapour density of any gas is defined as the density of any gas with respect to density of the H_2 gas under identical conditions of temperature T and pressure P.

$$\text{Vapour density} = \frac{\text{density of gas at T \& P}}{\text{density of } H_2 \text{ under same P \& T}}$$

$$P = \frac{m}{V}.\frac{RT}{M} \quad \Rightarrow \quad P = \rho\frac{RT}{M} \qquad \rho = \frac{PM}{RT}$$

$$\text{Vapour density} = \frac{PM_{gas}RT}{RT \quad PM_{H_2}} = \frac{M_{gas}}{M_{H_2}} = \frac{M_{gas}}{2}$$

F5 $M_{gas} = 2 \times$ vapour density

Average molecular mass of gaseous mixture :

total mass of the mixture divided by total no. of moles in the mixture

$$M_{mix} = \frac{\text{Total mass of mixture}}{\text{Total no. of moles in mixture}}$$

If we have 'n_1', 'n_2' and 'n_3' are moles of three different gases having of molar mass 'M_1', 'M_2' and 'M_3' respectively.

$$M_{min} = \frac{n_1M_1 + n_2M_2 + n_3M_3}{n_1 + n_2 + n_3}$$

Solved Examples

Ex-13. Calculate the mean molar mass of a mixture of gases having 7 g of Nitrogen, 22 g of CO_2 and 5.6 litres of CO at STP.

Sol. Moles of N_2 = 7/28 = 1/4

Moles of CO_2 = 22/44 = 1/2

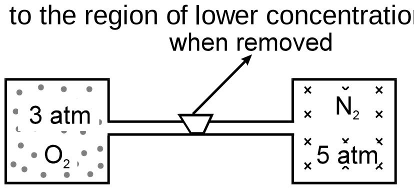
Moles of CO = 5.6 / 22.4 = 1/4

Mean molar mass = $M_{min} = \frac{n_1M_1 + n_2M_2 + n_3M_3}{n_1 + n_2 + n_3}$ = (7 + 7 + 22) / 1 = 36

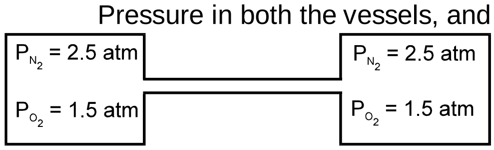
Section (D) : Graham's law of diffusion

Th7 Graham's Law of Diffusion/Effusion :

D7 Diffusion : Net spontaneous flow of gaseous molecules from region of high concentration (higher partial pressure) to the region of lower concentration or lower partial pressure



$\rightleftharpoons$ flow will be from both sides, N_2 will try to equalise its partial Pressure in both the vessels, and so will O_2.



Graham's Law :

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

- Rate of diffusion $r \propto \frac{1}{\sqrt{d}}$ d = density of gas

F6 $\frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} = \frac{\sqrt{M_2}}{\sqrt{M_1}} = \sqrt{\frac{V.D_2}{V.D_1}}$ V.D is vapour density

r = volume flow rate = $\frac{dV_{out}}{dt}$

r = mole flow rate = $\frac{dn_{out}}{dt}$

r = distance travelled by gaseous molecule per unit time = $\frac{dx}{dt}$

- The general form of the grahams law of diffusion can be stated as follows, when one or all of the parameters are varied.

F7 rate $\propto \frac{P}{\sqrt{TM}}$ A ; P – Pressure, A – area of hole, T – Temp. , M – mol. wt.

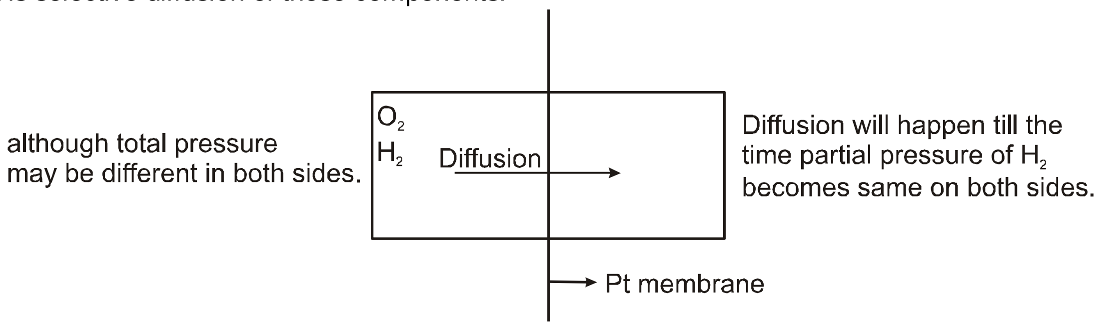
- If partial pressure of gases are not equal.
  Then rate of diffusion is found to be proportional to partial pressure & inversely proportional to square root of molecular mass.

$r \propto P$

$r \propto \frac{1}{\sqrt{M}}$; $\frac{r_1}{r_2} = \frac{P_1}{P_2}\sqrt{\frac{M_2}{M_1}}$

Selective diffusion :

If one or more than one components of a mixture are allowed to diffuse and others are not allowed then it is selective diffusion of those components.

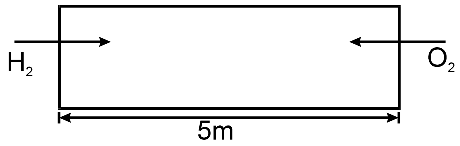


☞ **Platinum allows only H_2 gas to pass through**

Effusion : (forced diffusion) a gas is made to diffuse through a hole by the application of external pressure.

Solved Examples

Ex-14. In a tube of length 5 m having 2 identical holes at the opposite ends. H_2 & O_2 are made to effuse into the tube from opposite ends under identical conditions. Find the point where gases will meet for the first time.



Sol. $\dfrac{r_1}{r_2} = \dfrac{ax}{dt} \times \dfrac{dt}{dx} = \sqrt{\dfrac{m_2}{m_1}} = \dfrac{dx_1}{dx_2} = \sqrt{\dfrac{32}{2}}$

$\dfrac{dx_1}{dx_2} = 4 \quad \Rightarrow \quad \dfrac{\text{distance travelled by } H_2}{\text{distance travelled by } O_2} = 4$

$\dfrac{x}{(5-x)} = 4 \quad \Rightarrow \quad x = (5 – x)\,4 \quad \Rightarrow \quad x = 20 – 4x$

$5x = 20 \quad \Rightarrow \quad x = 4$ from H_2 side

Ex-15. Assume that you have a sample of hydrogen gas containing H_2, HD and D_2 that you want to separate into pure components (H = ^1H and D = ^2H). What are the relative rates of diffusion of the three molecules according to Graham's law ?

Sol. Since D_2 is the heaviest of the three molecules, it will diffuse most slowly, and let we call its relative rate 1.00. We can then compare HD and H_2 with D_2.

Comparing HD with D_2, we have

$$\frac{\text{Rate of HD diffusion}}{\text{Rate of } D_2 \text{ diffusion}} = \sqrt{\frac{\text{Molecular mass of } D_2}{\text{Molecular mass of HD}}} = \sqrt{\frac{4.0 \text{ amu}}{3.0 \text{ amu}}} = 1.15$$

Comparing H_2 with D_2 we have

$$\frac{\text{Rate of } H_2 \text{ diffusion}}{\text{Rate of } D_2 \text{ diffusion}} = \sqrt{\frac{\text{Mass of } D_2}{\text{Mass of } H_2}} = \sqrt{\frac{4.0 \text{ amu}}{2.0 \text{ amu}}} = 1.41$$

Thus, the relative rates of diffusion are $H_2(1.41) > HD\ (1.15) > D_2(1.00)$.

Section (E) : Kinetic theory of gases

Th8 Kinetic Theory of Gases :

Postulates / assumptions of KTG :

- A gas consists of tiny spherical particles called molecules of the gas which are identical in shape & size (mass)
- The volume occupied by the molecules is negligible in comparision to the total volume of the gas.

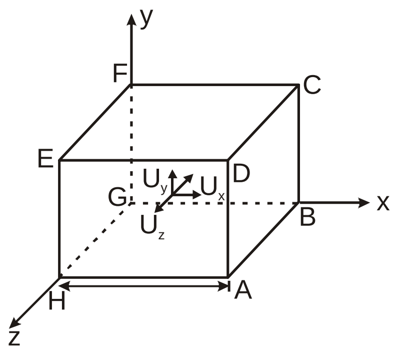
  For an ideal gas, volume of the ideal gas molecule $\simeq 0$.
- Gaseous molecules are always in random motion and collide with other gaseous molecules & with the walls of the container.
- Pressure of the gas is due to these molecular collisions among themselves and with walls of the container
- These collisions are elastic in nature
- Molecular attraction forces are negligible. Infact, for an ideal gas attractive or repulsive forces are equal to zero.
- Newton's laws of motion are applicable on the motion of the gaseous molecules.
- Effect of gravity is negligible on molecular motion.
- The average K.E. of gaseous molecules is proportional to the absolute temperature of the gas.

  $\dfrac{1}{2} M (\overline{u^2}) \propto T$ (bar is for average)

  Kinetic equation of gaseous state (expression for pressure of gas).

Der.1 m = mass of one molecule

$\vec{u} = u_x \hat{i} + u_y \hat{j} + u_z \hat{k}$



Consider collision with face ABCD

inital $\vec{P}_i = mu_x\hat{i}$; final $\vec{P}_f = -mu_x\hat{i}$

change in momentum due to collision $= 2\,U_x m$

time taken between two successive collision with face ABCD = t = $\dfrac{2\ell}{\mu_x}$

frequency of collisions (f) = $\dfrac{1}{t} = \dfrac{U_x}{2\ell}$

change in momentum in one sec. = force = 2 m $\dfrac{U_x \times U_x}{2\ell} = \dfrac{2mU_x^2}{\ell}$

force due to all the molecules = $\dfrac{m}{\ell}\{U_{x_1}^2 + U_{x_2}^2 + ... + U_{x_N}^2\}$

average value of $U_N^2 = \overline{U_N^2} = \dfrac{Ux_1^2 + U_{x_2}^2 + ...U_{x_N}^2}{N}$

$F_x = \dfrac{m}{\ell}\{N \quad \overline{U_x^2}\}$

all the three directions are equal as the motion is totally random in all directions, hence

$\overline{U_x^2} = \overline{U_y^2} = \overline{U_z^2}$

$\overline{U^2} = \dfrac{U_1^2 + U_2^2 + U_3^2 + ... + U_N^2}{N} = \overline{U_x^2} + \overline{U_y^2} + \overline{U_z^2} = 3\overline{U_x^2}$

$F = \dfrac{m}{\ell}.N\dfrac{1}{3}\overline{U^2}$

Pressure = $\dfrac{F_x}{\ell^2} = \dfrac{1}{3}\dfrac{mN}{\ell^3}\overline{U^2}$ The volume of the container 'V' = ℓ^3

$\therefore$ $PV = \dfrac{1}{3}mN\overline{U^2}$ Kinetic equation of gases

where $\overline{U^2}$ is mean square speed

root mean square speed = $U_{rms} = \sqrt{\overline{U^2}} = \sqrt{\left(\dfrac{U_1^2 + U_2^2 + U_3^2 + ...\ \ U_N^2}{N}\right)}$

Th9 Verification of Gaseous Laws Using Kinetic Equation :

F8

- From postulates ; $PV = \dfrac{1}{3}mN\overline{U^2}$

  $\dfrac{1}{2}m\overline{U^2} \propto T = \lambda\,T$ Where 'λ' is a proportionality constant

  $PV = \dfrac{2}{3}\left(\dfrac{1}{2}m\overline{U^2}\right)N$; $PV = \dfrac{2}{3}\lambda\,NT$ (N = Total number of molecules)

- Boyle's Law : N : constant
  T : constant
  PV = constant

- Charles law : N : constant
  P : constant
  $V \propto T$
- Kinetic energy of gaseous molecule (translational K.E.)
  To calculate λ we have to use ideal gas equation (experimental equation)
  PV = nRT
  kinetic equation $PV = nRT = \frac{2}{3}\lambda\, NT = \frac{2}{3}\lambda\,(nN_A)\,T$ (n = number of moles of gas)

on comparing $\lambda = \frac{3}{2} \times \frac{R}{N_A}$

$\lambda = \frac{3}{2}K$ where $K = \frac{R}{N_A}$ = Boltzmann constant

F9 Average K.E. of molecules = $\frac{1}{2}m\overline{U^2} = \lambda T$

Average K.E. = $\frac{3}{2}KT$ (only dependent on temperature not on nature of the gas.)

F10 Average K.E. for one mole = $N_A\left(\frac{1}{2}m\overline{U^2}\right) = \frac{3}{2}KN_AT = \frac{3}{2}RT$

- **Root mean square speed :**
  $U_{rms} = \sqrt{\overline{U^2}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{mN_A}}$ Where m-mass of one molecule
- Dependent on nature of gas i.e. mass of the gas

F11 $U_{rms} = \sqrt{\frac{3RT}{M}}$ M = molar mass

- **Average speed :**
  $U_{av} = U_1 + U_2 + U_3 + \ldots\ldots\ldots\ldots U_N$

F12 $U_{av} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{\pi m}}$ K is Boltzmman constant

- **Most probable speed:** The speed possessed by maximum number of molecules at the given temperature

F13 $U_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{m}}$

Velocity can be decribed by maximum number of molecule.

Molecular speed

Most probable speed	Average speed	Root mean square
$\sqrt{\frac{2KT}{m}} = \sqrt{\frac{2RT}{M}}$	$\sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{m}}$	$\sqrt{\frac{3RT}{M}} = \sqrt{\frac{3KT}{m}}$

$U_{mp} : U_{av} : U_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$

Solved Examples

Ex-16. In a container of capacity 1 litre there are 10^{23} molecules each of mass 10^{-22} gm. If root mean square speed is 10^5 cm/sec then calculate pressure of the gas.

Sol. $PV = \frac{1}{3} mN U_{rms}^2$

$P = ?$; $V = 10^{-3}\ m^3$

$m = 10^{-25}$ kg ; $N = 10^{23}$

$\sqrt{\overline{U^2}} = 10^5$ cm/sec $= 10^3$ m/sec

$\overline{U^2} = 10^6\ m^2/sec^2$

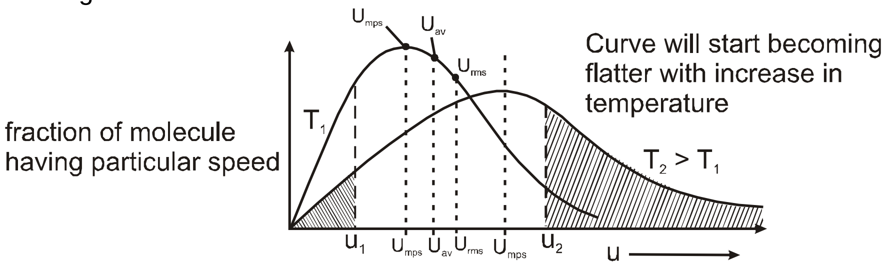
$P \times 10^{-3} = \frac{1}{3} \times 10^{-25} \times 10^{23} \times 10^6$

$P = \frac{1}{3} \times 10^{-2} \times 10^6 \times 10^3$; $P = \frac{1}{3} \times 10^7$ pascals

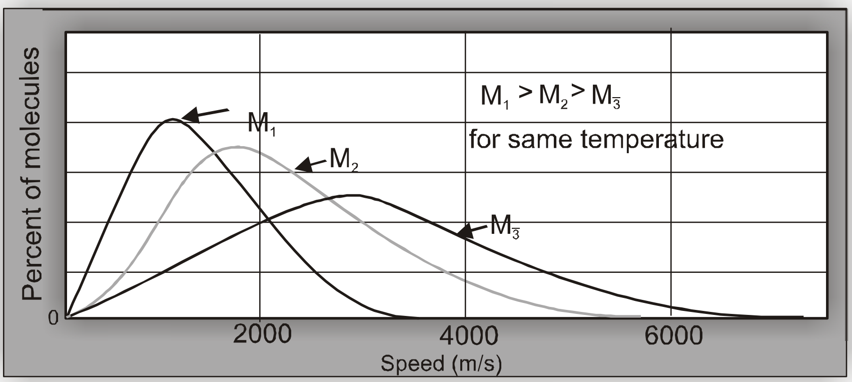
Th10 Maxwell's distributions of molecular speeds :

Postulates/Assumptions of speed distributions

- **It is based upon theory of probability.**
- **It gives the statistical averages of the speed of the whole collection of gas molecules.**
- Speed of gaseous molecules of may vary from 0 to ∞. The maxwell distribution of speed can be plotted against fraction of molecules as follows.



- The area under the curve will denote fraction of molecules having speeds between zero and infinity
- Total area under the curve will be constant and will be unity at all temperatures.
- Area under the curve between zero and u_1 will give fraction of molecules racing speed between 0 to u_1. This fraction is more at T_1 and is less at T_2.
- The peak corresponds to most probable speed.
- At higher temperature, fraction of molecules having speed less than a particular value decreases.
- For Gases with different molar masses will have following graph at a given temperature.



Section (F) : Eudiometry

Th11 Eudiometry :

The analysis of gaseous mixtures is called eudiometry. The gases are identified by absorbing them in specified and specific reagents.

Some Common Facts :

- Liquids and solutions can absorb gases.
- If a hydrocarbon is burnt, gases liberated will be CO_2 & H_2O. [H_2O is seperated out by cooling the mixture & CO_2 by absorption by aqueous KOH]
- If organic compound contains S or P, then these are converted into SO_2 & P_4O_{10} by burning the organic compound.
- If nitrogen is present, then it is converted into N_2.
  [The only exception : if organic compound contains – NO_2 group then NO_2 is liberated]
- If mixture contains N_2 gas & this is exploded with O_2 gas, do not assume any oxide formation unless specified.
- Ozone is absorbed in turpentine oil and oxygen in alkaline pyragallol.

Solved Examples

Ex-17. Carbon dioxide gas (CO_2) measuring 1 litre is passed over heated coke the total volume of the gases coming out becomes 1.6 litre. Find % conversion of CO_2 into carbon monoxide.

Sol. $CO_2 + C \longrightarrow 2CO$ $\qquad CO_2 \qquad CO$

1 $\qquad$ 0 $\qquad$ at time t $\qquad 1 - x \qquad 2x$

Initial volume = 1 litre

final volume = 1.6 litre $\qquad$ Final volume = (1 + x) litres

1 + x = 1.6

x = 0.6

x = 0.6

$\frac{0.6}{1} \times 10 = 60\%$ of CO_2 will be converted into CO

Ex-18. 100 ml of hydrocarbon is mixed with excess of oxygen and exploded. On cooling, the mixture was reported to have a contraction of 250 ml. The remaining gas when passed through a solution of aqueous KOH, the mixture shows a further contraction of 300 ml. Find molecular formula of the hydrocarbon.

Sol. $C_xH_y + \left(x + \frac{Y}{4}\right) O_2 \longrightarrow x\,CO_2 + \frac{y}{2} H_2O$

100 ml $\qquad x\,100 \qquad \frac{y}{2}100.$

mixture contains CO_2 , H_2O & excess O_2

on cooling, H_2O is separated, volume of H_2O = 250 ml

$\frac{y}{2} \times 100 = 250$; $y = 5$,

as KOH absorbs CO_2, hence 300 ml contraction is because of CO_2 that has been absorbed.

Volume of $CO_2 = 100\,x = 300$; $\quad x = 3$

Empirical formula = C_3H_5 ; $\quad$ molecular formula = C_6H_{10}.

Note: If water is already condensed out then total contraction in reaction mixture = {volume of reactants} – {volume of products + volume of unused species excluding volume of H_2O}.

Ex-19. 100 ml of an hydrocarbon is burnt in excess of oxygen in conditions so that water formed gets condensed out the total contraction in volume of reaction mixture was found to be 250 ml when the reaction mixture is further exposed to aqueous KOH a further contraction of 300 ml is observed find molecular formula of hydrocarbon.

Sol. $C_xH_y + O_2 \longrightarrow CO_2 + H_2O$

100 ml $\qquad$ excess $\qquad$ 300 ml

By POAC on 'C' atoms

$x \times 100 = 300$

$x = 3$

POAC on 'H' atoms

$y \times 100 = 2 \times$ moles of H_2O

POAC on O atoms

$2 \times v = 2 \times 300 + 1 \times H_2O$ {V = volume of O_2 consumed}

$2 \times v = 600 + 50\,y$

$v = \frac{600 + 50y}{2}$ volume of O_2 consumed

The total volume contraction is 250 ml.

Hence, $100 + V - 300 = 250$

$-200 + V = 250$

$2 \times 450 - 600 = 50\,y$

$\frac{300}{50} = y = 6$

Hydro carbon will be C_3H_6

Alternative :

Using balanced chemical equation

	C_xH_y	+ $\left(\frac{x+y}{4}\right)O_2$ $\longrightarrow$	xCO_2	+ $\frac{y}{2}H_2O$
t = 0	100 ml	V	0	0
t	0	$V - 100\left(x + \frac{y}{4}\right)$	100 x ml	$\frac{100\,y}{2}$
		volume remained		

$V - 100\left(x + \frac{y}{4}\right) + 100x + 50y$

$-100 - V = 250$

$-25y + 50y = 150$

$25y = 150$

$y = 6$

Summary

A gas is a collection of atoms or molecules moving independently through a volume that is largely empty space. Collisions of the randomly moving particles with the walls of their container exert a force per unit area that we perceive as pressure. The SI unit for pressure is the pascal, but the atmosphere and the millimeter of mercury are more commonly used. The physical condition of any gas is defined by four variables; pressure (P), temperature (T), volume (V) and molar amount (n). The specific relationship among these variables are called the gas laws :

Boyle's law : The volume of a gas varies inversely with its pressure. That is, $V \propto 1/P$ or $PV = k$ at constant n. T.

Charles Law : The volume of a gas varies directly with its Kelvin temperature. That is, $V \propto T$ or $V/T = k$ at constant n, P

Avogadro's Law : The volume of a gas varies directly with its molar amount. That is, $V \propto n$ or $V/n = k$ at constant T,P.

The three individual gas laws can be combined into a single ideal gas law, PV = nRT. If any three of the four variables P, V, T and n are known, the fourth can be calculated. The constant R in the equation is called the gas constant and has the same value for all gases. At standard temperature and pressure (STP; 1 atm and 0°C), the standard molar volume of an ideal gas is 22.414 L.

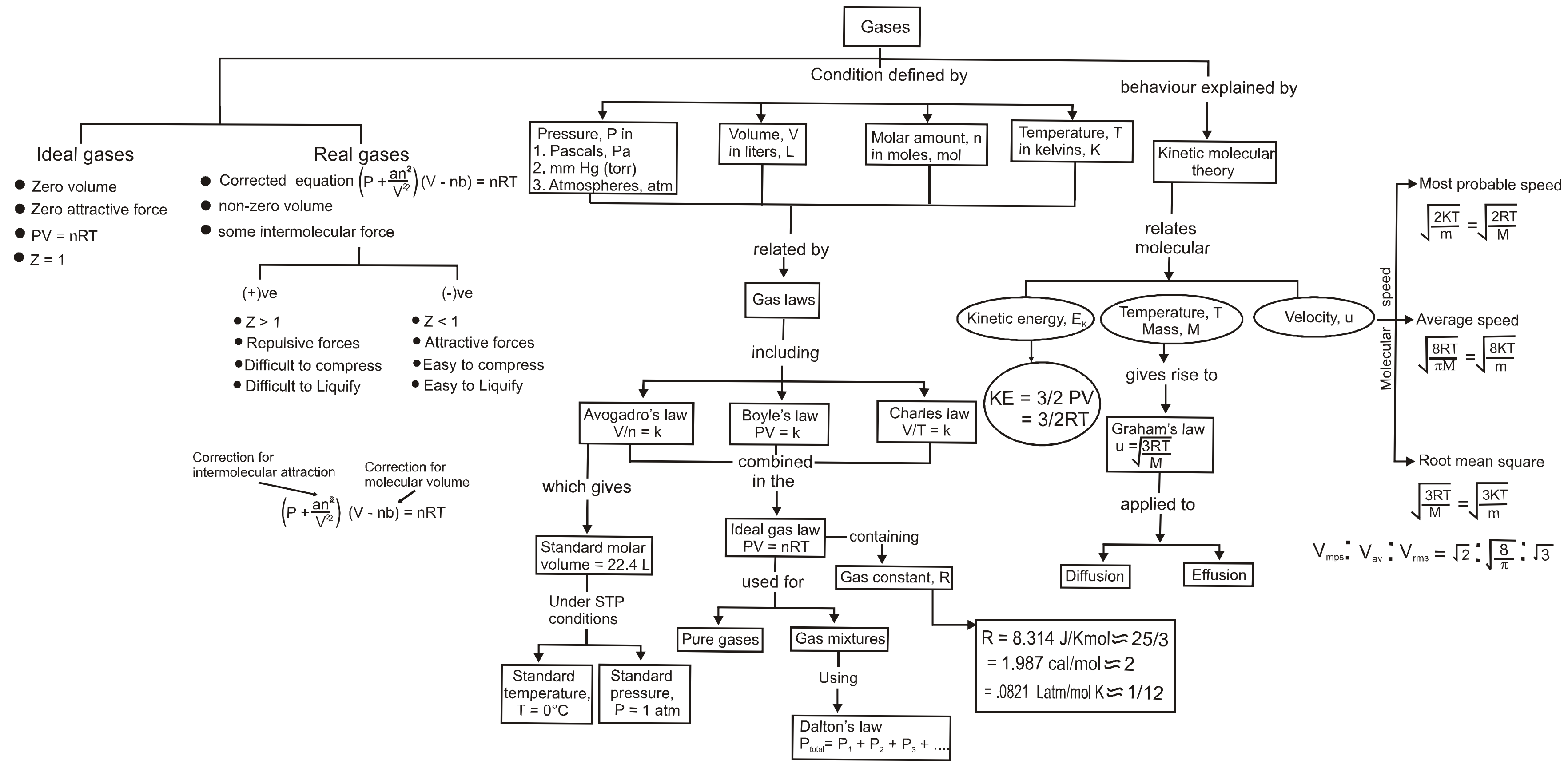
The gas laws apply to the mixture of gases as well as to pure gases According to Dalton's law of partial pressures, the total pressure exerted by a mixture of gases in a container is equal to the sum of the partial pressure of each individual gas would exert alone.

The behaviour of gases can be accounted for using a model called the kinetic-molecular theory, a group of five postulates:

1. A gas consists of tiny particles moving at random.
2. The volume of the gas particles is negligible as compared with the total volume.
3. There are no forces between particles, either attractive or repulsive.
4. Collisions of gas particles are elastic.
5. The average kinetic energy of gas particles is proportional to their absolute temperature.

The connection between temperature and kinetic energy obtained from the kinetic- molecular theory makes it possible to calculate the average speed of a gas particle at any temperature. An important practical consequence of this relationship is Graham' law, which states that the rate of a gas effusion or spontaneous passage through a pinhole in a membrane depends inversely on the square root of the molar mass of gas.

Real gases differ in their behaviour from that predicted by the ideal gas law, particularly at higher pressure, where gas particles are forced close together and intermolecular forces become significant.


Gases
Condition defined by
behaviour explained by
Ideal gases
Zero volume
Zero attractive force
PV = nRT
Z = 1
Real gases
Corrected equation $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$
non-zero volume
some intermolecular force
(+)ve
Z > 1
Repulsive forces
Difficult to compress
Difficult to Liquify
(-)ve
Z < 1
Attractive forces
Easy to compress
Easy to Liquify
Correction for intermolecular attraction
Correction for molecular volume
$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$
Pressure, P in
1. Pascals, Pa
2. mm Hg (torr)
3. Atmospheres, atm
Volume, V in liters, L
Molar amount, n in moles, mol
Temperature, T in kelvins, K
related by
Gas laws
including
Avogadro's law V/n = k
Boyle's law PV = k
Charles law V/T = k
combined in the
which gives
Standard molar volume = 22.4 L
Under STP conditions
Standard temperature, T = 0°C
Standard pressure, P = 1 atm
Ideal gas law PV = nRT
containing
Gas constant, R
used for
Pure gases
Gas mixtures
Using
Dalton's law $P_{total} = P_1 + P_2 + P_3 + ...$
R = 8.314 J/Kmol ≃ 25/3
= 1.987 cal/mol ≃ 2
= .0821 Latm/mol K ≃ 1/12
Kinetic molecular theory
relates molecular
Kinetic energy, E_K
Temperature, T Mass, M
Velocity, u
KE = 3/2 PV = 3/2RT
gives rise to
Graham's law $u = \sqrt{\frac{3RT}{M}}$
applied to
Diffusion
Effusion
Molecular speed
Most probable speed
$\sqrt{\frac{2KT}{m}} = \sqrt{\frac{2RT}{M}}$
Average speed
$\sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{m}}$
Root mean square
$\sqrt{\frac{3RT}{M}} = \sqrt{\frac{3KT}{m}}$
$V_{mps} : V_{av} : V_{rms} = \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$

MISCELLANEOUS SOLVED PROBLEMS (MSPs)

1. The diameter of a bubble at the surface of a lake is 4 mm and at the bottom of the lake is 1 mm. If atmospheric pressure is 1 atm and the temperature of the lake water and the atmosphere are equal. What is the depth of the lake ?
(The density of the lake water and mercury are 1 g/ml and 13.6 g/ml respectively. Also neglect the contribution of the pressure due to surface tension)

Sol. $P_1V_1 = P_2V_2$

$\therefore$ (760 mm × 13.6 × g) $\frac{4}{3}\pi$ (4 mm/2)^3 = (760 mm × 13.6 × g + h × 1 × g) $\frac{4}{3}\pi$ (1 mm/2)^3

760 × 13.6 × 64 = (760 × 13.6 + h)

h = 64 × 760 × 13.6 – 760 × 13.6

h = 63 × 760 × 13.6 mm

h = $\frac{63 \times 760 \times 13.6}{1000 \times 1000}$ km = 0.6511 km = **651.1 m Ans.**

2. A gas is initially at 1 atm pressure. To compress it to 1/4 th of initial volume, what will be the pressure required ?

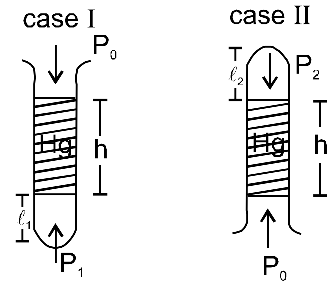
Sol. P_1 = 1 atm $\quad$ V_1 = V

P_2 = ? $\quad$ V_2 = V/4

$P_1V_1 = P_2V_2$ $\quad$ at const. T & n

$P_2 = \frac{P_1V_1}{V_2} = \frac{1\ \text{atm} \times V}{V/4}$ = **4 atm Ans.**

3. A gas column is trapped between closed end of a tube and a mercury column of length (h) when this tube is placed with its open end upwards the length of gas column is (ℓ_1), the length of gas column becomes (ℓ_2) when open end of tube is held downwards. Find atmospheric pressure in terms of height of Hg column.



Sol. For gas $\quad$ $P_1 = (P_0 + h)$ $\quad$ $P_2 = (P_0 – h)$

$V_1 = \pi r^2\ell_1$ $\quad$ $V_2 = \pi r^2\ell_2$

at const T. and moles.

$P_1V_1 = P_2V_2$; $(P_0 + h)\ \pi r^2\ell_1 = (P_0 – h)\ \pi r^2\ell_2$

$P_0\ell_2 + h\ell_1 = P_0\ell_2 – h\ell_2$

$P_0\ell_2 – P_0\ell_1 = h\ell_1 + h\ell_2$

$P_0 = \frac{h\,(\ell_1 + \ell_2)}{(\ell_2 - \ell_1)}$ cm of Hg column **Ans.**

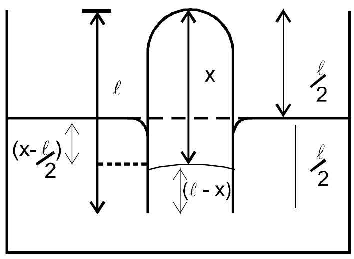
4. If water is used in place of mercury then what should be minimum length of Barometer tube to measure normal atmospheric pressure.

Sol. $P_{Hg} = P_{H_2O} = P_{atm}$.

0.76 m × 13.6 × g = h_{H_2O} × 1 × g;

h_{H_2O} = 0.76 × 13.6 = **10.336 m Ans.**

5. A tube of length 50 cm is initially in open atmosphere at a pressure 75 cm of Hg. This tube is dipped in a Hg container upto half of its length. Find the level of mercury column in side the tube.



Sol. If after dipping the tube, the length of air column be x cm (situation shown in the adjoining figure).
Then by using, $P_iV_i = P_fV_f$

We have, 75 cm Hg × ℓA = P_f × x × A $\quad$ .... (1) (ℓ = 50 cm)

& also, P_f = 75 cm Hg + (x – $\frac{\ell}{2}$) $\quad$ .... (2)

(2) & (1) $\Rightarrow$ $[75 + (x - 25)] \times x = 75 \times 50$

$\Rightarrow$ $x^2 + 50x - 3750 = 0$

$\therefore$ $x = 41.14$ or -91.14

But, x can't be – ve $\therefore$ $x = 41.14$

$\therefore$ Mercury column inside the tube = (50 – 41.14) cm **= 8.86 cm Ans.**

6. An open container of volume V contains air at temperature 27ºC or 300 K.The container is heated to such a temperature so that amount of gas coming out is 2/3 of **(a)** amount of gas initially present in the container. **(b)** amount of gas finally remaining in the container.
Find the temperature to which the container should be heated.

Sol. (a) Here, P & V are constant, n & T are changing. Let, initially the amount of gas present be n & temp is 27ºC or 300K. Finally amount of gas present in container = $n - \frac{2}{3}n = \left(\frac{1}{3} \times n\right)$ & final temperature be T.

Then using $n_1T_1 = n_2T_2$, we have, $n \times 300 = \frac{n}{3} \times T_2 \Rightarrow T_2 = 900K$ i.e., final temp = **900K Ans.**

(b) Let there be x moles of gas remaining in the container, $\frac{2}{3}$ of x come out

$\therefore$ $(\frac{2}{3}x + x) = n \Rightarrow \frac{5x}{3} = n \;\; \therefore x = \frac{3n}{5}$

$\therefore$ Using $n_1 T_1 = n_2 T_2$ $\quad n \times 300\text{ K} = \frac{3n}{5} \times T_2$

$\therefore$ $T_2 = 500K$

Final temperature = **500 K Ans.**

7. Find the lifting power of a 100 litre balloon filled with He at 730 mm and 25°C. (Density of air = 1.25 g /L).

Sol. Since, PV = nRT

$PV = \frac{W}{M}RT \quad \therefore \quad W = \frac{PVM}{RT} = \frac{730}{760} \times \frac{100 \times 4}{0.082 \times 298}\,g$

i.e., Wt. of He = 15.72 g

Wt. of air displaced = 100 × 1.25 g/L = 125 g

$\therefore$ Lifting power of the balloon = 125 g – 15.72 g = **109.28 g Ans.**

8. A weather balloon filled with hydrogen at 1 atm and 300 K has volume equal to 12000 litres. On ascending it reaches a place where temperature is 250 K and pressure is 0.5 atm. The volume of the balloon is :

(A) 24000 litres (B) 20000 litres (C) 10000 litres (D) 12000 litres

Sol. Using $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$; $\frac{1\text{ atm} \times 12000\text{ L}}{300\text{ K}} = \frac{0.5\text{ atm} \times V_2}{250\text{ K}}$

$\therefore$ $V_2 = 20{,}000$ L

Hence, Ans. (B)

9. Four one litre flasks are separately filled with the gases, O_2, F_2, CH_4 and CO_2 under the same conditions. The ratio of number of molecules in these gases :

(A) 2 : 2 : 4 : 3 (B) 1 : 1 : 1 : 1 (C) 1 : 2 : 3 : 4 (D) 2 : 2 : 3 : 4

Sol. According to Avogadro's hypothesis.

All the flasks contains same no. of molecules

$\therefore$ Ratio of no. of molecules of O_2, F_2, CH_4 & CO_2

= 1 : 1 : 1 : 1 **Hence, (B)**

10. A sample of water gas has a composition by volume of 50% H_2, 45% CO and 5% CO_2. Calculate the volume in litres at STP at which water gas which on treatment with excess of steam will produce 5 litre of H_2. The equation for the reaction is:

$$CO + H_2O \longrightarrow CO_2 + H_2$$

Sol. If x L CO in needed then volume of H_2 in water gas = $\left(\frac{x}{0.45} \times 50\%\right)$ L = $\left(\frac{x}{0.45} \times \frac{1}{2}\right)$ L = $\frac{x}{0.9}$ L

But, from equation : $CO + H_2O \longrightarrow CO_2 + H_2$

& Gay-Lussac's law, we get, that the volume of H_2

Produced = volume of CO taken.

$\therefore$ Volume of H_2 due to reaction = x L

$\therefore$ Total volume of H_2 = $\left(\frac{x}{0.9}+x\right)$ L = 5 L

$\Rightarrow$ $\frac{1.9x}{0.9}$ = 5 L

$\therefore$ x = $\frac{0.9\times5}{1.9}$ $\therefore$ Volume of water gas = $\frac{x}{0.45}$ L = $\frac{0.9\times5}{1.9\times0.45}$ L = **5.263 L Ans.**

11. The partial pressure of hydrogen in a flask containing two grams of hydrogen and 32 gm of sulphur dioxide is :

(A) 1/16th of the total pressure (B) 1/9th of the total pressure
(C) 2/3 of the total pressure (D) 1/8th of the total pressure

Sol. $n_{H_2} = \frac{2g}{2g/mol}$ = 1 mol. ; $n_{SO_2} = \frac{32g}{64g/mol}$ = 0.5 mol

$\therefore$ $P_{H_2} = \frac{n_{H_2}}{\left(n_{H_2}+n_{SO_2}\right)}$ × P_T = $\frac{1}{(1+0.5)}$ × P_T = $\frac{2}{3}P_T$. **Hence, Ans. (C)**

12. Equal volume of two gases which do not react together are enclosed in separate vessels. Their pressures are 10 mm and 400 mm respectively. If the two vessels are joined together, then what will be the pressure of the resulting mixture (temperature remaining constant) :

(A) 120 mm (B) 500 mm (C) 1000 mm (D) 205 mm

Sol. Let, vol of containers be V & temperature be T

P_1 = 10mm P_2 = 400mm

$\therefore$ $n_1 = \frac{P_1V}{RT}$ & $n_2 = \frac{P_2V}{RT}$

$\therefore$ $n_1 + n_2 = \frac{(P_1+P_2)\times V}{RT}$

After joining two containers final vol = (V + V) = 2V (for gases)

$P_{final} = \frac{(n_1+n_2)RT}{V_{final}} = \frac{(P_1+P_2)\times V}{RT} \times \frac{RT}{2V} = \frac{(P_1+P_2)}{2} = \frac{(10+400)mm}{2}$ = 205 mm.

Hence, Ans. (D)

13. 5 ml of H_2 gas diffuses out in 1 sec from a hole. Find the volume of O_2 that will diffuse out from the same hole under identical conditions in 2 sec.

Sol. Rate of diffusion of H_2 = $\frac{5ml}{1\ \ sec}$ = 5ml/s = r_{H_2} (say)

$\therefore$ $r_{O_2} = r_{H_2} \times \frac{1}{4}$ = 5ml/s × $\frac{1}{4}$ $\therefore$ Volume of O_2 diffused in 2.0 seconds = $\frac{5}{4}$ × 2 ml = **2.5 ml Ans.**

14. A vessel contains H_2 & O_2 in the molar ratio of 8 : 1 respectively. This mixture of gases is allowed to diffuse through a hole, find composition of the mixture coming out of the hole.

Sol. Here, $n_{H_2} : n_{O_2}$ = 8 : 1 & $\frac{r_{H_2}}{r_{O_2}} = \frac{r_{H_2}}{r_{O_2}}\sqrt{\frac{M_{O_2}}{M_{H_2}}}$

$\Rightarrow$ $\frac{r_{H_2}}{r_{O_2}} = \frac{8}{1} \times \sqrt{\frac{32}{2}} = \frac{32}{1}$ $\Rightarrow$ $\frac{(\text{no. of moles of } H_2 \text{ coming out})/\Delta t}{(\text{no. of moles of } O_2 \text{ coming out})/\Delta t} = \frac{32}{1}$

Required composition of $H_2 : O_2$ coming out = **32 : 1 Ans.**

15. If for two gases of molecular weights M_A and M_B at temperature T_A and T_B; $T_AM_B = T_BM_A$, then which property has the same magnitude for both the gases.

(A) Density (B) Pressure (C) KE per mol (D) RMS speed

Sol. Given that $T_A M_B = T_B M_A$ $\Rightarrow$ $\frac{T_A}{M_A} = \frac{T_B}{M_B}$

But, r.m.s. = $\sqrt{\frac{3RT}{M}}$

r.m.s_A = $\sqrt{\dfrac{3RT_A}{M_A}}$ & r.m.s_B = $\sqrt{\dfrac{3RT_B}{M_B}}$

r.m.s_A = r.m.s_B **Ans. (D)**

16. It has been considered that during the formation of earth H_2 gas was available at the earth. But due to the excessive heat on the earth this had been escaped. What was the temperature of earth during its formation? (The escape velocity is 1.1×10^6 cm/s)

Sol. Escape velocity of H_2 should be equal to average velocity of H_2.

$\therefore$ Avg velocity of H_2 = 1.1×10^6 cm/s = 1.1×10^4 m/s

But, avg. velocity = $\sqrt{\dfrac{8RT}{\pi M}}$ $\Rightarrow$ $1.1 \times 10^4 = \sqrt{\dfrac{8 \times 8.314 \times T}{\pi \times 2 \times 10^{-3}}}$ $\left(M_{H_2} = 2g = 2 \times 10^{-3} kg\right)$

$\therefore$ T = $\dfrac{\left(1.1 \times 10^4\right)^2 \times \pi \times 2 \times 10^{-3}}{8 \times 8.314}$ K = 11430.5 K = **11157.5ºC Ans.**

17. A gaseous mixture containing CO, methane CH_4 & N_2 gas has total volume of 40 ml. This mixture is exploded with excess of oxygen on cooling this mixture a contraction of 30 ml is observed & when this mixture is exposed to aqueous KOH a further contraction of 30 ml is observed. Find the composition of the mixture.

Sol. Let vol of CO be x mL, vol of CH_4 be y mL, vol of N_2 be z mL.

On explosion with excess of oxygen the following reactions takes place

$CO(g) + \frac{1}{2}O_2(g) \longrightarrow CO_2(g)$ (By Gaylussac's law of combing volume)

x mL x mL

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

y mL y mL 2 ymL

N_2 remains unreacted

On cooling H_2O (g) liquifies hence volume reduction of 30 mL is observed

2y = 30 y = 15

But, vol of CO_2 obtained = (x + y) mL

This is absorbed in KOH & vol reduction of 30 mL is observed.

x + y = 30 $\Rightarrow$ x = 30 – y = (30 – 15) = 15

and, x + y + z = 40 $\Rightarrow$ z = 40 – x – y = 40 – 15 – 15 = 10

Composition of mixture is

Vol. of CO = **15 mL,** vol of CH_4 = **15 mL,** vol of N_2 = **10 mL** **Ans.**

CHECK LIST

Theories (Th)

Th-1 Critical constant of a gas ☐

Th-1: Boyle's law and measurement of pressure ☐

Th-2: Measurement of Pressure ☐

Th-3: Calculation of pay load ☐

Th-4: Equation of State ☐

Th-5: Daltons law of partial pressure ☐

Th-6: Analysis of gaseous mixture ☐

Th-7: Graham's Law of Diffusion/Effusion ☐

Th-8: Kinetic Theory of Gases ☐

Th-9: Verification of Vander Waal's Equations ☐

Th-10: Maxwell's distributions of molecular speeds ☐

Th-11: Eudiometry ☐

Definitions (D)

D-1. Statement ☐

D-2. Charles law ☐

D-3. Gay-lussac's law ☐

D-4. Avogadro's Hypothesis ☐

D-5. Laltons Law ☐

D-6. Vapour Density ☐

D-7. Diffusion ☐

Formulae (F)

F-1. $P_1V_1 = P_2V_2$ ☐

F-2. $P_{atm} = \rho gh$ ☐

F-3. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ → Temperature on absolute scale ☐

F-4. $P_{Total} = P_1 + P_2 + P_3$ ☐

F-5. $M_{gas} = 2 \times$ vapour density ☐

F-6. $\frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} = \frac{\sqrt{M_2}}{\sqrt{M_1}} = \sqrt{\frac{V.D_2}{V.D_1}}$ ☐

F-7. Rate $\propto \frac{P}{\sqrt{TM}}$ A ☐

F-8. $PV = \frac{1}{3} mN \overline{U^2}$ ☐

F-9. Average K.E. of molecules $= \frac{3}{2}$ K T ☐

F-10. $N_A \left(\frac{1}{2}m \quad \overline{U^2}\right) = \frac{3}{2} K N_A T = \frac{3}{2} RT$ ☐

F-11. $U_{rms} = \sqrt{\frac{3RT}{M}}$ ☐

F-12. $U_{av} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{\pi m}}$ ☐

F-13. $U_{MPS} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{m}}$ ☐

Table (Tab.)

Tab-1. Units of V, P & T ☐

Derivation (Deri.)

Deri-1. Derivation of Kinetic Gas Equation ☐

Exercise-1

✍ **Marked questions are recommended for Revision.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Ideal gas equation & gas laws

Commit to memory :

Boyle's law : $P_1V_1 = P_2V_2$ — P_1 & P_2 are pressure of gas

Charles law : $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ — V_1 & V_2 are Volume of gas

Gay-lussac's law : $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ — T_1 & T_2 are Temperature of gas

Ideal Gas Equation : PV = nRT — n = number of moles of gas

A-1. A gas occupies 100.0 mL at 50°C and 1 atm pressure. The gas is cooled at constant pressure so that volume is reduced to 50.0 mL. What is the final temperature of the gas.

A-2. A sample of gas at 27ºC and 1.00 atm pressure occupies 2.50 L. What temperature is required to adjust the pressure of that gas to 1.50 atm after it has been transferred to a 2.00 L container?

A-3. Assuming the same pressure in each case, calculate the mass of hydrogen required to inflate a balloon to a certain volume V at 127ºC if 8 g helium is required to inflate the balloon to half the volume, 0.50 V, at 27ºC.

A-4.✍ A quantity of an ideal gas is collected in a graduated tube over the mercury in a barometer type arrangement. The volume of gas at 20ºC is 50 ml and the level of mercury is 100 mm above the outside of the mercury level. The atmospheric pressure is 750 mm. Volume of gas at STP is : (Take R = 0.083 lt. atm/K/mole)

A-5. A quantity of hydrogen is confined in a chamber of constant volume. When the chamber is immersed in a bath of melting ice, the pressure of the gas is 1000 torr. (a) What is the Celsius temperature when the pressure manometer indicates an absolute pressure of 400 torr? (b) What pressure will be indicated when the chamber in brought to 100ºC ?

A-6.✍ An open vessel at 27ºC is heated until $(3/5)^{th}$ of the air in it has been expelled. Assuming that the volume of the vessel remains constant. Find out.
(a) The temperature at which vessel was heated.
(b) Volume of the air (measured at 300 K) escaped out if vessel is heated to 900 K.
(c) The temperature at which half of the air escapes out.

A-7. A gas cylinder contains 320 g oxygen gas at 24.6 atm pressure and 27ºC. What mass of oxygen would escape if first the cylinder were heated to 133ºC and then the valve were held open until the gas pressure was 1.00 atm, the temperature being maintained at 133ºC ? (R = 0.0821 L. atm/K/mole)

Section (B) : Daltons law of partial pressures

Commit to memory :

Daltons law : $P_{Total} = P_1 + P_2 + P_3 = \frac{(n_1+n_2+n_3)RT}{v}$

$P_1 = \frac{n_1RT}{v}$; $P_2 = \frac{n_2RT}{v}$; $P_2 = \frac{n_3RT}{v}$ — P_1, P_2 & P_3 are partial pressure of gases

P_{Total} = Total pressure of Gaseous mixture

B-1. A mixture of gases at 760 torr contains 55.0% nitrogen, 25.0% oxygen and 20.0% carbon dioxide by mole. What is the partial pressure of each gas in torr ?

B-2. What will be pressure exerted by a mixture of 3.2 g of methane and 4.4 g of carbon dioxide contained in a 9 dm^3 flask at 27°C ?

B-3. Oxygen and cyclopropane at partial pressures of 570 torr and 170 torr respectively are mixed in a gas cylinder. What is the ratio of the number of moles of cyclopropane to the number of moles of oxygen?

B-4. At the top of a mountain the thermometer reads –23ºC and the barometer reads 700 mm Hg. At the bottom of the mountain the temperature is 27ºC and the pressure is 750 mm Hg. Compare the density of the air at the top with that at the bottom.

B-5. A container holds 22.4 litre of a gas at 1 atmospheric pressure and at 0ºC. The gas consists of a mixture of argon, oxygen and sulphur dioxide in which :
(a) Partial pressure of SO_2 = (Partial pressure O_2) + (Partial pressure of Ar).
(b) Partial pressure of O_2 = 2 × partial pressure of Ar.
Calculate the density of the gas mixture under these conditions.

B-6. A mixture of nitrogen and water vapours is admitted to a flask which contains a solid drying agent. Immediately after admission, the pressure of the flask is 760 mm. After some hours the pressure reached a steady value of 745 mm.
(a) Calculate the composition, in mol and per cent of original mixture.
(b) If the experiment is done at 20ºC and the drying agent increases in weight by 0.15 g, what is the volume of the flask ? (The volume occupied by the drying agent may be ignored) ?

Section (C) : Mixing of Gases

Commit to memory :
On mixing of gases $n_{final} = n_1 + n_2 + n_3 + ...$

C-1. A volume V of a gas at a temperature T_1 and a pressure p is enclosed in a sphere. It is connected to another sphere of volume V/2 by a tube and stopcock. The second sphere is initially evacuated and the stopcock is closed. If the stopcock is opened the temperature of the gas in the second sphere becomes T_2. The first sphere is maintained at a temperature T_1. What is the final pressure p_1 within the apparatus?

C-2. If a 2 litre flask of N_2 at 20°C and 70 cm P is connected with a 3 litre of another flask of O_2 at the same temperature and 100 cm P. What will be the final pressure after the gases have throughly mixed at the same temperature as before? Also calculate the mole % of each gas in the resulting mixture. The volume of stopcock may be neglected.

C-3. Two flask of equal volume have been joined by a narrow tube of negligible volume. Initially both flasks are at 300 K containing 0.60 mole of O_2 gas at 0.5 atm pressure. One of the flask is then placed in a thermostat at 600 K. Calculate final pressure and the number of O_2 gas in each flask.

Section (D) : Graham's law of diffusion

Commit to memory :

$\frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} = \frac{\sqrt{M_2}}{\sqrt{M_1}} = \sqrt{\frac{V.D_2}{V.D_1}}$ V.D is vapour density

Rate $\propto \frac{P}{\sqrt{TM}}$ A

r = volume flow rate = $\frac{dV_{out}}{dt}$

r = moles flow rate = $\frac{dn_{out}}{dt}$

r = distance travelled by gaseous molecules per unit time = $\frac{dx}{dt}$

r = pressure change rate = $\frac{dp}{dt}$

P – Pressure,
A – area of hole,
T – Temp., M – mol. wt.

D-1. The rates of diffusion of two gases A and B are in the ratio 1 : 4. If the ratio of their masses present in the mixture is 2 : 3. The ratio of their mole fraction is: ($9^{1/3} = 2.08$)

D-2. For 10 minute each, at 0ºC, from two identical holes nitrogen and an unknown gas are leaked into a common vessel of 4 litre capacity. The resulting pressure is 2.8 atm and the mixture contains 0.4 mole of nitrogen. What is the molar mass of unknown gas? (Use R = 0.082 L-atm/mol-K)

D-3. The pressure in a vessel that contained pure oxygen dropped from 2000 torr to 1500 torr in 40 min as the oxygen leaked through a small hole into a vacuum. When the same vessel was filled with another gas, the pressure dropped from 2000 torr to 1500 torr in 80 min. What is the molecular weight of the second gas ?

D-4. A gaseous mixture contains oxygen and another unknown gas in the molar ratio of 4 : 1 diffuses through a porous plug in 245 seconds. Under similar conditions same volume of oxygen takes 220 sec to diffuse. Find the molecular mass of the unknown gas.

Section (E) : Kinetic theory of gases

Commit to memory :

$PV = \frac{1}{3} mN\, \overline{U^2}$ Kinetic equation of gases $\qquad U_{rms} = \sqrt{\frac{3RT}{M}}$ M = molar mass

$U_{av} = \sqrt{\frac{8RT}{\pi M}} \qquad U_{MPS} = \sqrt{\frac{2RT}{M}}$ T = Temperature

E-1. Suppose a gas sample in all have 6×10^{23} molecules. Each $1/3^{rd}$ of the molecules have rms speed 10^4 cm/sec, 2×10^4 cm/sec and 3×10^4 cm/sec. Calculate the rms speed of gas molecules in sample.

E-2. The root mean square speed of gas molecules at a temperature 27 K and pressure 1.5 bar is 1×10^4 cm/sec. If both temperature and pressure are raised three times, calculate the new rms speed of gas molecules.

E-3. At what temperature would the most probable speed of CO_2 molecules be twice that at 127ºC.

E-4. At what temperature will hydrogen molecules have the same root mean square speed as nitrogen molecules have at 35ºC ?

Section (F) : Eudiometry

Commit to memory :
Some Common Facts :

- If a hydrocarbon is burnt, gases liberated will be CO_2 & H_2O. [H_2O is seperated out by cooling the mixture & CO_2 by absorption by aqueous KOH]
- If organic compound contains S or P, then these are converted into SO_2 & P_4O_{10} by burning the organic compound.
- If nitrogen is present, then it is converted into N_2.
  [The only exception: if organic compound contains $-NO_2$ group then NO_2 is liberated]
- If mixture contains N_2 gas & this is exploded with O_2 gas, do not assume any oxide formation unless specified.
- Ozone is absorbed in turpentine oil and oxygen in alkaline pyragallol.

F-1. 1 litre of a mixture of CO and CO_2 is taken. This mixture is passed through a tube containing red hot charcoal. The volume now becomes 1.6 litres. The volumes are measured under the same conditions. Find the composition of the mixture by volume.

F-2. 40 ml of ammonia gas, taken in an eudiometer tube, was subjected to sparks till the volume did not further change. The volume was found to increase by 40 ml. 40 ml of oxygen gas then mixed and the mixture was further exploded. The gases remained were 30 ml. Deduce the formula of ammonia. (Ammonia contain N and H only).

F-3. When 100 ml of a O_2–O_3 mixture was passed through turpentine, there was reduction of volume by 20 ml. If 100 ml of such a mixture is heated, what will be the increase in volume? **[Hint:** O_3 is absorbed by turpentine**]**

F-4. 60 ml of a mixture of nitrous oxide (N_2O) and nitric oxide (NO) was exploded with excess of hydrogen. If 38 ml of N_2 was formed, calculate the volume of each gas in the mixture.

F-5. A mixture of formic acid and oxalic acid is heated with concentrated H_2SO_4. The gases produced are collected and on its treatment with KOH solution the volume of the gas decreased by one-sixth. Calculate the molar ratio of the two acids in the original mixture. [**Hint :** H_2SO_4 is a dehydrating agent. HCOOH produces H_2O and CO; $H_2C_2O_4$ produces H_2O, CO_2 and CO]

F-6. A sample of a gaseous hydrocarbon occupying 1.12 litres at NTP when completely burnt in air produced 2.2 g of CO_2 and 1.8 g of H_2O. Calculate the weight of the compound taken and the volume of O_2 at NTP required for its burning. Find the molecular formula of the hydrocarbon.

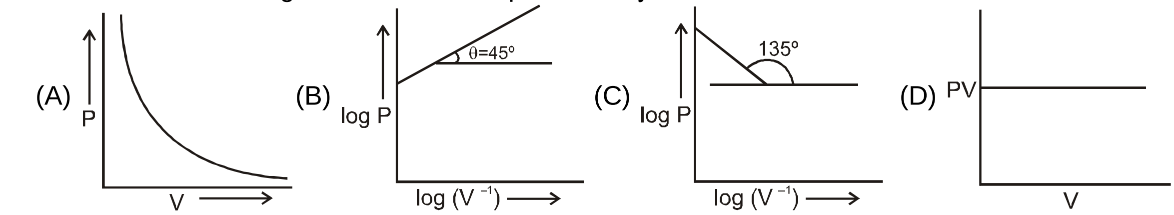
PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Ideal gas equation & gas laws

Commit to memory :

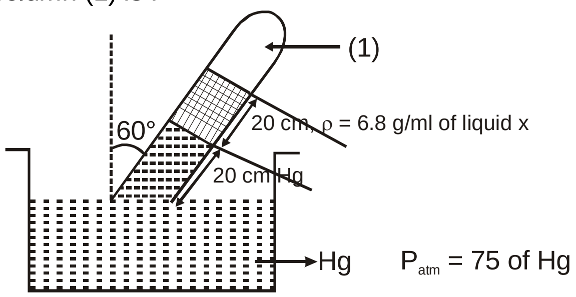
Boyle's law :	$P_1V_1 = P_2V_2$	P_1 & P_2 are pressure of gas
Charles law :	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	V_1 & V_2 are Volume of gas
Gay-lussac's law :	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	T_1 & T_2 are Temperature of gas
Ideal Gas Equation :	$PV = nRT$	n = number of moles of gas

A-1. Which of the following curve does not represent Boyle's law?



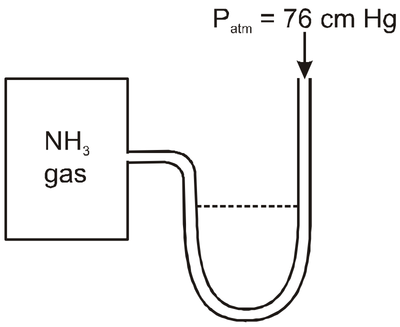
A-2. The density of liquid gallium at 30ºC is 6.095 g/mL. Because of its wide liquid range (30 to 2400ºC), gallium could be used as a barometer fluid at high temperature. What height (in cm) of gallium will be supported on a day when the mercury barometer reads 740 torr? (The density of mercury is 13.6 g/mL).
(A) 322 (B) 285 (C) 165 (D) 210

A-3. Pressure of the gas in column (1) is :



(A) 60 cm of Hg (B) 55 cm of Hg (C) 50 cm of Hg (D) 45 cm of Hg

A-4. A manometer attached to a flask contains with ammonia gas have no difference in mercury level initially as shown in diagram. After sparking into the flask, ammonia is partially dissociated as $2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$ now it have difference of 6 cm in mercury level in two columns, what is partial pressure of $H_2(g)$ at equilibrium?



(A) 9 cm Hg (B) 18 cm Hg (C) 27 cm Hg (D) None of these

A-5. A gas is heated from 0°C to 100°C at 1.0 atm pressure. If the initial volume of the gas is 10.0 L, its final volume would be :
(A) 7.32 L (B) 10.00 L (C) 13.66 L (D) 20.00 L

A-6. If the pressure of a gas contained in a closed vessel is increased by 0.4% when heated by 1ºC its initial temperature must be :
(A) 250 K (B) 250ºC (C) 25ºC (D) 25 K

A-7. A thin balloon filled with air at 47ºC has a volume of 3 litre. If on placing it in a cooled room its volume becomes 2.7 litre, the temperature of room is :
(A) 42ºC (B) 100ºC (C) 15ºC (D) 200ºC

A-8. A balloon weighing 50 kg is filled with 685 kg of helium at 1 atm pressure and 25°C. What will be its pay load if it displaced 5108 kg of air ?
(A) 4373 kg (B) 4423 kg (C) 5793 kg (D) none of these

A-9. If a mixture containing 3 moles of hydrogen and 1 mole of nitrogen is converted completely into ammonia, the ratio of initial and final volume under the same temperature and pressure would be :
(A) 3 : 1 (B) 1 : 3 (C) 2 : 1 (D) 1 : 2

A-10. SO_2 at STP contained in a flask was replaced by O_2 under identical conditions of pressure, temperature and volume. Then the weight of O_2 will be _______ of SO_2.
(A) half (B) one fourth (C) twice (D) four times.

A-11. Under what conditions will a pure sample of an ideal gas not only exhibit a pressure of 1 atm but also a concentration of 1 mol litre $^{-1}$. [R = 0.082 litre atm mol^{-1} K^{-1}]
(A) at S.T.P. (B) when V = 22.42 L
(C) when T = 12 K (D) impossible under any condition

A-12. An amount of 1.00 g of a gaseous compound of boron and hydrogen occupies 0.820 liter at 1.00 atm and at 3ºC. The compound is (R = 0.0820 liter atm mole^{-1} K^{-1}; at. wt: H = 1.0, B = 10.8)
(A) BH_3 (B) B_4H_{10} (C) B_2H_6 (D) B_3H_{12}

A-13. A 0.5 dm^3 flask contains gas A and 1 dm^3 flask contains gas B at the same temperature. If density of A = 3 g/dm^3 and that of B = 1.5 g/dm^3 and the molar mass of A = 1/2 of B, the ratio of pressure exerted by gases is :
(A) $\frac{P_A}{P_B} = 2$ (B) $\frac{P_A}{P_B} = 1$ (C) $\frac{P_A}{P_B} = 4$ (D) $\frac{P_A}{P_B} = 3$

A-14. A and B are two identical vessels. A contains 15 g ethane at 1atm and 298 K. The vessel B contains 75 g of a gas X_2 at same temperature and pressure. The vapour density of X_2 is :
(A) 75 (B) 150 (C) 37.5 (D) 45

A-15. The density of neon will be highest at :
(A) STP (B) 0°C, 2 atm (C) 273°C. 1 atm (D) 273°C. 2 atm

A-16. A small bubble rises from the bottom of a lake, where the temperature and pressure are 8°C and 6.0 atm,to the water's surface,where the temperature is 25°C and pressure is 1.0 atm. Calculate the final volume of the bubble if its initial volume was 2 mL.
(A) 14 mL (B) 12.72 mL (C) 11.31 mL (D) 15 mL

Section (B) : Daltons law of partial pressures

Commit to memory :

Daltons law : $P_{Total} = P_1 + P_2 + P_3 = \frac{(n_1 + n_2 + n_3)RT}{v}$

$P_1 = \frac{n_1RT}{v}$; $P_2 = \frac{n_2RT}{v}$; $P_2 = \frac{n_3RT}{v}$ P_1, P_2 & P_3 are partial pressure of gases

P_{Total} = Total pressure of Gaseous mixture

B-1. Equal weights of ethane & hydrogen are mixed in an empty container at 25ºC, the fraction of the total pressure exerted by hydrogen is:
(A) 1: 2 (B) 1: 1 (C) 1: 16 (D) 15: 16

B-2. A mixture of hydrogen and oxygen at one bar pressure contains 20% by weight of hydrogen. Partial pressure of hydrogen will be
(A) 0.2 bar (B) 0.4 bar (C) 0.6 bar (D) 0.8 bar

B-3. A compound exists in the gaseous phase both as monomer (A) and dimer (A_2). The atomic mass of A is 48 and molecular mass of A_2 is 96. In an experiment 96 g of the compound was confined in a vessel of volume 33.6 litre and heated to 273ºC. The pressure developed if the compound exists as dimer to the extent of 50% by weight under these conditions will be :
(A) 1 atm (B) 2 atm (C) 1.5 atm (D) 4 atm

B-4. The total pressure of a mixture of oxygen and hydrogen is 1.0 atm. The mixture is ignited and the water is removed. The remaining gas is pure hydrogen and exerts a pressure of 0.40 atm when measured at the same values of T and V as the original mixture. What was the composition of the original mixture in mole percent ?
(A) $x_{O_2} = 0.2;\ x_{H_2} = 0.8$ (B) $x_{O_2} = 0.4;\ x_{H_2} = 0.6$
(C) $x_{O_2} = 0.6;\ x_{H_2} = 0.4$ (D) $x_{O_2} = 0.8;\ x_{H_2} = 0.2$

Section (C) : Mixing of Gases

Commit to memory :
On mixing of gases $n_{final} = n_1 + n_2 + n_3 + ...$

C-1. Two glass bulbs A and B are connected by a very small tube having a stop cock. Bulb A has a volume of 100 cm^3 and contained the gas, while bulb B was empty. On opening the stop cock, the pressure fell down to 40 %. The volume of the bulb B must be :
(A) 75 cm^3 (B) 125 cm^3 (C) 150 cm^3 (D) 250 cm^3

C-2. Two glass bulbs A (of 100 mL capacity), and B (of 150 mL capacity) containing same gas are connected by a small tube of negligible volume. At particular temperature the pressure in A was found to be 20 times more than that in bulb B. The stopcock is opened without changing the temperature. The pressure in A will :
(A) drop by 75% (B) drop 57% (C) drop by 25% (D) will remain same

C-3. A 100 ml vessel containing $O_2(g)$ at 1.0 atm and 400 K is connected to a 300 ml vessel containing NO(g) at 1.5 atm and 400 K by means of a narrow tube of negligible volume where gases react to form NO_2 . Final pressure of mixture will be –
(A) 1.125 atm (B) 0.125 atm (C) 1 atm (D) 1.5 atm

Section (D) : Graham's law of diffusion

Commit to memory :

$\frac{r_1}{r_2} = \frac{\sqrt{d_2}}{\sqrt{d_1}} = \frac{\sqrt{M_2}}{\sqrt{M_1}} = \sqrt{\frac{V.D_2}{V.D_1}}$ V.D is vapour density

Rate $\propto \frac{P}{\sqrt{TM}} A$

r = volume flow rate = $\frac{dV_{out}}{dt}$

r = moles flow rate = $\frac{dn_{out}}{dt}$

r = distance travelled by gaseous molecules per unit time = $\frac{dx}{dt}$

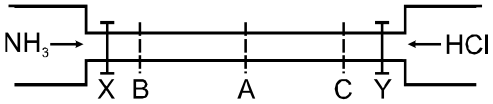
r = pressure change rate = $\frac{dp}{dt}$

P – Pressure,
A – area of hole,
T – Temp. , M – mol. wt.

D-1. The rates of diffusion of SO_3, CO_2, PCl_3 and SO_2 are in the following order :
(A) $PCl_3 > SO_3 > SO_2 > CO_2$ (B) $CO_2 > SO_2 > PCl_3 > SO_3$
(C) $SO_2 > SO_3 > PCl_3 > CO_2$ (D) $CO_2 > SO_2 > SO_3 > PCl_3$

D-2. 20 ℓ of SO_2 diffuses through a porous partition in 60 seconds. Volume of O_2 diffuse under similar conditions in 30 seconds will be :
(A) 12.14 ℓ (B) 14.14 ℓ (C) 18.14 ℓ (D) 28.14 ℓ

D-3. See the figure-1 :



The valves of X and Y are opened simultaneously. The white fumes of NH_4Cl will first form at:
(A) A (B) B (C) C (D) A, B and C simultaneously

D-4. X ml of H_2 gas effuses through a hole in a container in 5 sec. The time taken for the effusion of the same volume of the gas specified below under identical conditions is :
(A) 10 sec. He (B) 20 sec. O_2 (C) 25 sec. CO_2 (D) 55 sec. CO_2

D-5. Three identical footballs are respectively filled with nitrogen, hydrogen and helium at same pressure. If the leaking of the gas occurs with time from the filling hole, then the ratio of the rate of leaking of gases ($r_{N_2} : r_{H_2} : r_{He}$) from three footballs under identical conditions (in equal time interval) is :
(A) $\left(1:\sqrt{14} : \sqrt{7}\right)$ (B) $\left(\sqrt{14} : \sqrt{7}:1\right)$ (C) $\left(\sqrt{7}:1 : \sqrt{14}\right)$ (D) $\left(1:\sqrt{7} : \sqrt{14}\right)$

Section (E) : Kinetic theory of gases

Commit to memory :

$PV = \frac{1}{3} mN\, \overline{U^2}$ Kinetic equation of gases $\qquad U_{rms} = \sqrt{\frac{3RT}{M}}$ M = molar mass

$U_{av} = \sqrt{\frac{8RT}{\pi M}}$ $\qquad U_{MPS} = \sqrt{\frac{2RT}{M}}$ T = Temperature

E-1. Temperature at which r.m.s. speed of O_2 is equal to that of neon at 300 K is :
(A) 280 K (B) 480 K (C) 680 K (D) 180 K

E-2. The R.M.S. speed of the molecules of a gas of density 4 kg m^{-3} and pressure 1.2×10^5 N m^{-2} is :
(A) 120 m s^{-1} (B) 300 m s^{-1} (C) 600 m s^{-1} (D) 900 m s^{-1}

E-3. The mass of molecule A is twice that of molecule B. The root mean square velocity of molecule A is twice that of molecule B. If two containers of equal volume have same number of molecules, the ratio of pressure P_A/P_B will be :
(A) 8 : 1 (B) 1 : 8 (C) 4 : 1 (D) 1 : 4

E-4. The kinetic energy of N molecules of O_2 is x joule at –123ºC. Another sample of O_2 at 27ºC has a kinetic energy of 2x. The latter sample contains _______ molecules of O_2.
(A) N (B) N/2 (C) 2 N (D) 3 N

E-5. The average kinetic energy (in joules of) molecules in 8.0 g of methane at 27º C is :
(A) 6.21×10^{-20} J/molecule (B) 6.21×10^{-21} J/molecule
(C) 6.21×10^{-22} J/molecule (D) 3.1×10^{-22} J/molecule

E-6. According to kinetic theory of gases, for a diatomic molecule :
(A) The pressure exerted by the gas is proportional to the mean velocity of the molecule.
(B) The pressure exerted by the gas is proportional to the r.m.s. velocity of the molecule.
(C) The r.m.s. velocity of the molecule is inversely proportional to the temperature.
(D) The mean translational K.E. of the molecule is proportional to the absolute temperature.

E-7. The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K the root-mean-square velocity of the gas molecules is v, at 480 K it becomes :
(A) 4v (B) 2v (C) v/2 (D) v/4

E-8. The ratio between the r.m.s. velocity of H_2 at 50 K and that of O_2 at 800 K is:
(A) 4 (B) 2 (C) 1 (D) 1/4

E-9. Which of the following expression correctly represents the relationship between the average kinetic energy of CO and N_2 molecules at the same temperature.
(A) $\bar{E}(CO) > \bar{E}(N_2)$ (B) $\bar{E}(CO) < \bar{E}(N_2)$ (C) $\bar{E}(CO) = \bar{E}(N_2)$
(D) Cannot be predicted unless volumes of the gases are given

E-10. Helium atom is two times heavier than a hydrogen molecule. At 298 K, the average kinetic energy of a helium atom is
(A) two times that of a hydrogen molecules (B) same as that of a hydrogen molecules
(C) four times that of a hydrogen molecules (D) half that of a hydrogen molecules

Section (F) : Eudiometry

Commit to memory :
Some Common Facts :

- If a hydrocarbon is burnt, gases liberated will be CO_2 & H_2O. [H_2O is seperated out by cooling the mixture & CO_2 by absorption by aqueous KOH]
- If organic compound contains S or P, then these are converted into SO_2 & P_4O_{10} by burning the organic compound.
- If nitrogen is present, then it is converted into N_2.
  [The only exception : if organic compound contains $–NO_2$ group then NO_2 is liberated]
- If mixture contains N_2 gas & this is exploded with O_2 gas, do not assume any oxide formation unless specified.
- Ozone is absorbed in turpentine oil and oxygen in alkaline pyragallol.

F-1. The volume of CO_2 produced by the combustion of 40 ml of gaseous acetone in excess of oxygen is :
(A) 40 ml (B) 80 ml (C) 60 ml (D) 120 ml

F-2. 500 ml of a hydrocarbon gas burnt in excess of oxygen yields 2500 ml of CO_2 and 3 lts of water vapours. All volume being measured at the same temperature and pressure. The formula of the hydrocarbon is :
(A) C_5H_{10} (B) C_5H_{12} (C) C_4H_{10} (D) C_4H_8

F-3. 15 ml of a gaseous hydrocarbon was required for complete combustion in 357ml of air (21% of oxygen by volume) and the gaseous products occupied 327 ml (all volumes being measured at NTP). What is the formula of the hydrocarbon ?
(A) C_3H_8 (B) C_4H_8 (C) C_5H_{10} (D) C_4H_{10}

F-4. 7.5 ml of a gaseous hydrocarbon was exploded with 36 ml of oxygen. The volume of gases on cooling was found to be 28.5 ml, 15 ml of which was absorbed by KOH and the rest was absorbed in a solution of alkaline pyrogallol. If all volumes are measured under same conditions, the formula of hydrocarbon is
(A) C_3H_4 (B) C_2H_4 (C) C_2H_6 (D) C_3H_6

F-5. A gaseous alkane is exploded with oxygen. The volume of O_2 for complete combustion to CO_2 formed is in the ratio 7/4. The molecular formula of alkane is :
(A) C_2H_4 (B) C_2H_6 (C) CH_4 (D) C_4H_{12}

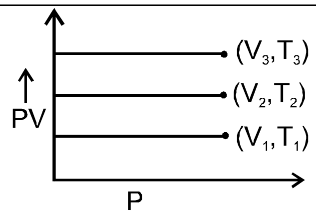
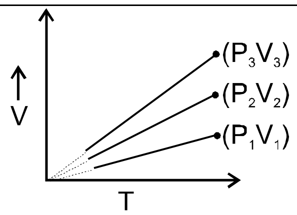
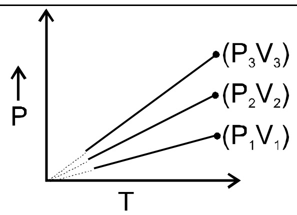
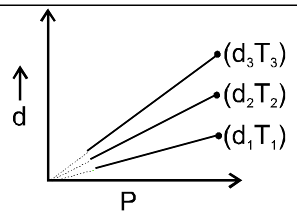
F-6. LPG is a mixture of n-butane & iso-butane. The volume of oxygen needed to burn 1 kg of LPG at NTP would be :
(A) 2240 Lt. (B) 2510 Lt. (C) 1000 Lt. (D) 500 Lt.

F-7. If in an experiment 100 ml of ozonised oxygen was reduced in volume to 40 ml (at the same temperature and pressure) when treated with turpentine, what would be the increase in volume if the original sample was heated until no further change occurred and then brought back to the same temerature and pressure ?
(A) 20 ml (B) 30 ml (C) 40 ml (D) 10 ml

F-8. A mixture of methane and carbon monoxide requires 1.7 times its volume of oxygen for complete combustion. What is the ratio of CH_4 : CO by volume in the mixture ? [All volume are measured at the same temperature and pressure]
(A) 1 : 1 (B) 1 : 2 (C) 2 : 1 (D) 4 : 1

PART - III : MATCH THE COLUMN

1. For a fixed amount of the gas match the two column :

	Column - I		Column - II
(A)		(p)	$T_1 > T_2 > T_3$
(B)		(q)	$P_1 > P_2 > P_3$
(C)		(r)	$V_1 > V_2 > V_3$
(D)		(s)	$d_1 > d_2 > d_3$

2. Single option match maxtix :

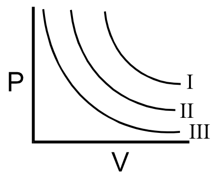
	Column - I		Column - II
(A)	$P_1V_1 = P_2V_2 = P_3V_3 = \ldots\ldots\ldots\ldots$	(p)	Kinetic equation of ideal gases.
(B)	$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{V_3}{T_3} = \ldots.$ at constant pressure.	(q)	Boyle's law
(C)	$r \propto \sqrt{\frac{1}{d}}$	(r)	Dalton's law of partial pressures at constant temperature
(D)	$P = P_1 + P_2 + P_3 + \ldots\ldots\ldots$	(s)	Graham's law
(E)	$PV = \frac{1}{3}mnc^2$	(t)	Charles' law

Exercise-2

Marked questions are recommended for Revision.

PART - I : ONLY ONE OPTION CORRECT TYPE

1. I, II, III are three isotherms respectively at T_1, T_2 and T_3 as shown in graph. Temperature will be in order:



(A) $T_1 = T_2 = T_3$ (B) $T_1 < T_2 < T_3$
(C) $T_1 > T_2 > T_3$ (D) $T_1 > T_2 = T_3$

2. A 40 ml of a mixture of H_2 and O_2 at 18ºC and 1 atm pressure was sparked so that the formation of water was complete. The remaining pure gas had a volume of 10 ml at 18ºC and 1 atm pressure. If the remaining gas was H_2, the mole fraction of H_2 in the 40 ml mixture is :
(A) 0.75 (B) 0.5 (C) 0.65 (D) 0.85

3. On the surface of the earth at 1 atm pressure, a balloon filled with H_2 gas occupies 500 mL. This volume is 5/6 of its maximum capacity. The balloon is left in air. It starts rising. The height above which the balloon will burst if temperature of the atmosphere remains constant and the pressure decreases 1 mm for every 100 cm rise of height is
(A) 120 m (B) 136.67 m (C) 126.67 m (D) 100 m

4. A vessel of volume 5 litre contains 1.4 g of nitrogen at a temperature 1800 K. The pressure of the gas if 30% of its molecules are dissociated into atoms at this temperature is :
(A) 4.05 atm (B) 2.025 atm (C) 3.84 atm (D) 1.92 atm

5. Two closed vessel A and B of equal volume containing air at pressure P_1 and temperature T_1 are connected to each other through a narrow open tube. If the temperature of one is now maintained at T_1 and other at T_2 (where $T_1 > T_2$) then that what will be the final pressure?
(A) $\frac{T_i}{2P_1T_2}$ (B) $\frac{2P_1T_2}{T_1+T_2}$ (C) $\frac{2P_1T_1}{T_1-T_2}$ (D) $\frac{2P_1}{T_1+T_2}$

6. Two flasks of equal volume are connected by a narrow tube (of negligible volume) all at 27ºC and contain 0.70 mole of H_2 at 0.5 atm. One of the flask is then immersed into a bath kept at 127ºC, while the other remains at 27ºC. The final pressure in each flask is :
(A) Final pressure = 0.5714 atm (B) Final pressure = 1.5714 atm
(C) Final pressure = 0.5824 atm (D) None of these

7. Two flasks of equal volume are connected by a narrow tube (of negligible volume) all at 27ºC and contain 0.70 moles of H_2 at 0.5 atm. One of the flask is then immersed into a bath kept at 127ºC, while the other remains at 27ºC. The number of moles of H_2 in flask 1 and flask 2 are :
(A) Moles in flask 1 = 0.4, Moles in flask 2 = 0.3 (B) Moles in flask 1 = 0.2, Moles in flask 2 = 0.3
(C) Moles in flask 1 = 0.3, Moles in flask 2 = 0.2 (D) Moles in flask 1 = 0.4, Moles in flask 2 = 0.2

8. One litre of a gaseous mixture of two gases effuses in 311 seconds while 2 litres of oxygen takes 20 minutes. The vapour density of gaseous mixture containing CH_4 and H_2 is :
(A) 4 (B) 4.3 (C) 3.4 (D) 5

9. Pure O_2 diffuses through an aperture in 224 second, whereas mixture of O_2 and another gas containing 80% O_2 diffuses from the same in 234 second. The molecular mass of gas will be:
(A) 51.5 (B) 48.6 (C) 55 (D) 46.6

10. A straight glass tube as shown, has 2 inlets X & Y at the two ends of 200 cm long tube. HCl gas through inlet X and NH_3 gas through inlet Y are allowed to enter in the tube at the same time and under the identical conditions. At a point P inside the tube both the gases meet first. The distance of point P from X is :
(A) 118.9 cm (B) 81.1 cm (C) 91.1 cm (D) 108.9 cm

11. A teacher enters a classroom from front door while a student from back door. There are 13 equidistant rows of benches in the classroom. The teacher releases N_2O, the laughing gas, from the first bench while the student releases the weeping gas ($C_6H_{11}OBr$) from the last bench. At which row will the students starts laughing and weeping simultaneously.
(A) 7 (B) 10 (C) 9 (D) 8

12. A certain volume of argon gas (Mol. Wt. = 40) requires 45 s to effuse through a hole at a certain pressure and temperature. The same volume of another gas of unknown molecular weight requires 60 s to pass through the same hole under the same conditions of temperature and pressure. The molecular weight of the gas is :
(A) 53 (B) 35 (C) 71 (D) 120

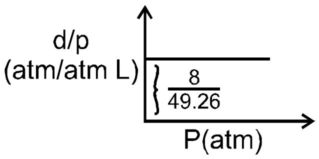
13. A sample of an ideal gas was heated from 30ºC to 60ºC at constant pressure. Which of the following statement(s) is/are true.
(A) Kinetic energy of the gas is doubled (B) Boyle's law will apply
(C) Volume of the gas will be doubled (D) None of the above

14. 10 ml of a gaseous hydrocarbon was exploded with excess of O_2. On cooling the reaction mixture volume was reduced by 10 ml while on adding KOH volume was reduced by 20 ml. Molecular formula of hydrocarbon is :
(A) CH_4 (B) C_4H_6 (C) C_2H_4 (D) C_2H_2

15. A mixture of methane, propane and carbon monoxide contain 36.5% propane by volume. If its 200 ml are burnt in excess of O_2, the volume of CO_2 formed is :
(A) 173 ml (B) 346 ml (C) 200 ml (D) 519 ml

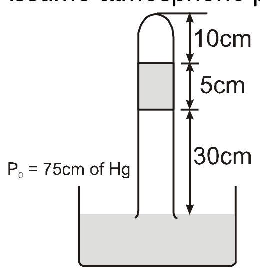
PART - II : SINGLE OR DOUBLE INTEGER TYPE

1. From the graph of $\frac{d}{p}$ vs p at a constant tempreture of 300 K calculate molar mass of gas.

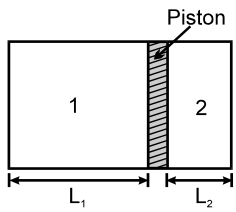


2. 10 moles of an ideal gas is subjected to an isochoric process (volume const.) and a graph of log (p) v/s log (T) is plotted where p is in (atm) & T is in kelvin. If volume of the container is 82.1 ml then calculate the sume of a, b & c where a = slope of graph, b = x intercept of graph, c = y intercept of graph.

3. A tube of length 45 cm is containing a gas in two sections separated by a mercury column of length 5 cm as shown in figure. The open end of tube is just inside the Hg surface in container find pressure differance of gases in two sections. [Assume atmospheric pressure = 75 cm of Hg column]



4. The closed cylinder shown in figure has a freely moving piston separating chambers 1 and 2. Chamber 1 contains 280 mg of N_2 gas, and chamber 2 contains 200 mg of helium gas. When equilibrium is established, what will be the ratio L_2/L_1 ? (Molecular weights of N_2 and He are 28 and 4).

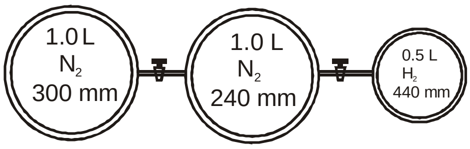


5. A spherical balloon of 21 cm diameter is to be filled up with hydrogen at NTP, from a cylinder containing the gas at 20 atm at 27°C. If the cylinder can hold 2.82 litre of water, calculate the number of balloons that can be filled up.

6. A closed container of volume 0.02 m^3 contains a mixture of neon and argon gases, at a temperature of 27°C and pressure of 1×10^5 Nm^{-2}. The total mass of the mixture is 28 g. If the gram molecular weights of neon and argon are 20 and 40 respectively. Find the masses of the individual gases x and y in the container, assuming them to be ideal. (Universal gas constant R = 8.314 J/mole K) Give your answer as x + y.

7. A column of Hg of 100 mm in length is contained in the middle of a narrow tube 1 m long which is closed at both ends. Both the halves of the tube contained air at a pressure of 760 mm of Hg. By what distance (in mm) will the column of Hg lie displaced if the tube is held vertical. Assume decrease in length of mercury column to be negligible, also take the process at constant temperature. (Isothermal process).

8. Consider the arrangment of bulbs shown below.



If the pressure of the system when all the stopcocks are opened is x (in atm) then find 100 x ?
(760 mm = 1 atm)

9. Two vessels whose volumes are in the ratio 2 : 1 contain nitrogen and oxygen at 2500 mm and 1000 mm pressures respectively when they are connected together what will be the pressure of the resulting mixture (in meters) ?

10. At 20ºC, two balloons of equal volume and porosity are filled to a pressure of 2 atm, one with 14 kg N_2 and other with 1 kg of H_2. The N_2 balloon leaks to a pressure of 1/2 atm in 1 hr. How long will it take for H_2 balloon to reach a pressure of 1/2 atm ?

11. Two flask A & B have capacity of 1 litre and 2 litre respectively. Each of them contain 1 mole of a gas. The temperature of the flask are so adjusted that average speed of molecules in "A" is twice that in "B" & pressure in flask "A" is x times of that in "B". Then value of x is -

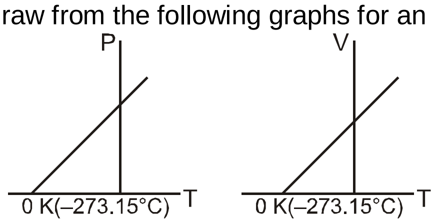
12. 50 ml of gaseous mixture of acetylene and ethylene is taken in a ratio of a : b requires 700 ml of air containing 20% by volume O_2 for complete combustion. Calculate the volume of air required for complete combution of a mixture (50 ml) having ratio b : a. (Report your answer divide by 25).

13. 10 ml of a mixture of CH_4, C_2H_4 and CO_2 was exploded with excess of air. After explosion there was a contraction of 17 ml and after treatment with KOH, there was further reduction of 14ml. Find volume of CO_2 in 20 mL of original mixture (in mL).

PART - III : ONE OR MORE THAN ONE OPTION CORRECT TYPE

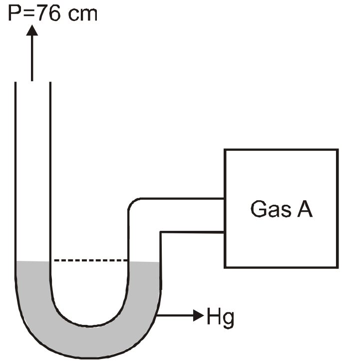
1. A gas cylinder containing cooking gas can withstand a pressure of 14.9 atmosphere. The pressure guaze of cylinder indicates 12 atmosphere _at 27_ºC. Due to sudden fire in the building temperature starts rising. The temperature at which cylinder will explode is :
(A) 372.5 K (B) 99.5 ºC (C) 199 ºC (D) 472.5 k

2. What conculsion would you draw from the following graphs for an ideal gas?



(A) As the temperature is reduced, the volume as well as the pressure increase
(B) As the temperature is reduced, the volume becomes zero and the pressure reaches infinity
(C) As the temperature is reduced, the pressure derease
(D) A point is reached where, theoretically, the volume become zero

3. A 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.

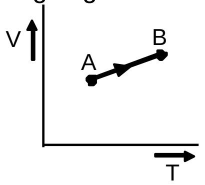


After sparking 'A' dissociates according to following reaction

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

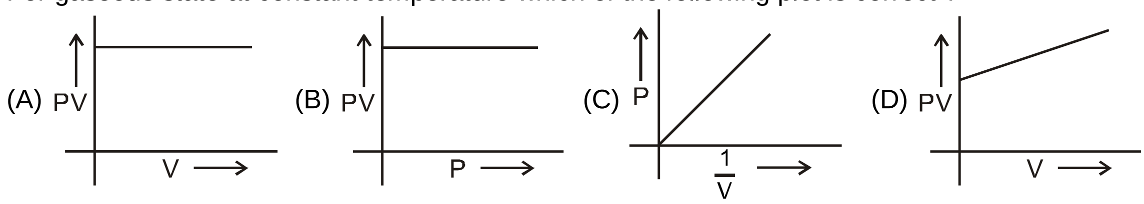
If pressure of Gas "A" decrease to 0.9 atm. Then :
(Assume temperature to be constant and is 300 K)
(A) total pressure increased to 1.3 atm
(B) total pressure increased by 0.3 atm
(C) total pressure increased by 22.3 cm fo Hg
(D) difference in mercury level is 228 mm.

4. Which of the following is/are correct ?
(A) At constant volume, for a definite quantity of an ideal gas graph of PT v/s T^2 will be parabolic
(B) At constant pressure, for a definite quantity of an ideal gas graph of VT v/s T will be parabolic
(C) In going from A to B for definite quantity of an ideal gas pressure increase



(D) At constant volume, for a definite quantity of an ideal gas graph of $\frac{p}{T}$ v/s T^2 will be straight line.

5. For gaseous state at constant temperature which of the following plot is correct ?

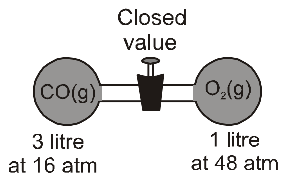


6. In a closed rigid container, 3 mol of gas A and 1 mol of gas B are mixed at constant temperature. If 1mol of another gas C at same temperature is introduced and all gases are considered to be non reacting, then
(A) Partial pressure of gases A and B remain unaffected due to introduction of gas C.
(B) Ratio of total pressure before and after mixing of gas 'C' is $\frac{3}{5}$.
(C) If the total pressure of gas mixture before introducing gas 'C' is 20atm, then the total gas pressure after mixing 'C' will be 25 atm.
(D) If data of option'C' are used, then partial pressure of gas 'C' will be 5 atm.

7. Carbon mono oxide (CO) and oxygen O_2 react according to :

$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$$

Assuming that the reaction takes place and goes to completion, after the valve is opened in the apparatus represented in the accompanying figure. Also assume that the temperature is fixed at 300 K. (Take R = 0.08 atm L/mole K)



(A) Partial Pressure of O_2 = 6 atm. (B) Number of moles of CO_2 formed = 2
(C) Number of moles of O_2 left = 1 (D) Partial Pressure of O_2 = 3 atm.

8. Which of the following statements are correct ?
(A) Helium diffuses at a rate 8.65 times as much as CO does.
(B) Helium escapes at a rate 2.65 times as fast as CO does.
(C) Helium escapes at a rate 4 times as fast as CO_2 does.
(D) Helium escapes at a rate 4 times as fast as SO_2 does.

9. The rate of diffusion of 2 gases 'A' and 'B' are in the ratio 16: 3. If the ratio of their masses present in the mixture is 2 : 3. Then
(A) The ratio of their molar masses is 16 : 1
(B) The ratio of their molar masses is 1 : 4
(C) The ratio of their moles present inside the container is 1 : 24
(D) The ratio of their moles present inside the container is 8 : 3

10. If a gas is allowed to expand at constant tempeature then which of the following does not hold true :
(A) the kinetic energy of the gas molecules decreases
(B) the kinetic energy of the gas molecules increases
(C) the kinetic energy of the gas molecules remains the same
(D) Can not be predicted

11. Precisely 1 mol of helium and 1 mol of neon are placed in a container. Indicate the correct statements about the system.
(A) Molecules of the two gases strike the wall of the container with same frequency.
(B) Molecules of helium strike the wall more frequently.
(C) Molecules of helium have greater average molecular speed.
(D) Helium exerts larger pressure.

12. Indicate the correct statement for equal volumes of N_2(g) and CO_2(g) at 25ºC and 1 atm.
(A) The average translational KE per molecule is the same for N_2 and CO_2
(B) The rms speed remains same for both N_2 and CO_2
(C) The density of N_2 is less than that of CO_2
(D) The total translational KE of both N_2 and CO_2 is the same

13. A hypothetical gaseous element having molecular formula M_x is completely changed to another gaseous allotrope having molecular formula M_y at 310 K. In this act volume of the gas is contracted by 12 ml to a volume of 8 ml. The simplest possible molecular formulae of the two allotropes are
(A) M_2 (B) M_3 (C) M_4 (D) M_5

14. A 100 ml mixture of CO and CO_2 is passed through a tube containing red hot charcoal. The volume now becomes 160 ml. The volumes are measured under the same conditions of temperature and pressure. Amongst the following, select the correct statement(s) :
(A) Mole percent of CO_2 in the mixture is 60. (B) Mole fraction of CO in the mixture is 0.40
(C) The mixture contains 40 ml of CO_2 (D) The mixture contains 40 ml of CO

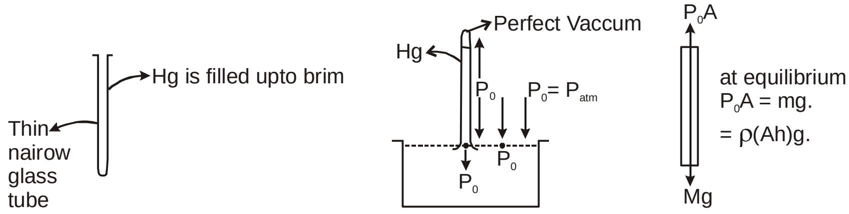
PART - IV : COMPREHENSION

Read the following passage carefully and answer the questions.

Comprehension # 1

MEASUREMENT OF PRESSURE

Barometer: A barometer is an instrument that is used for the measurement of pressure. The construction of the barometer is as follows



Cross sectional view of the capillary column

A thin narrow calibrated capillary tube is filled 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.

Applying force balance, we get,

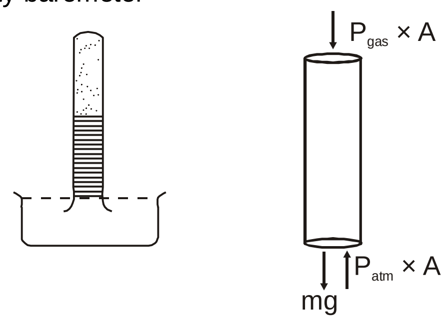
$P_{atm} \times A = m \times g$ ('A' is the cross-sectional area of the capillary tube)

If 'ρ' is the density of the fluid, then $m = \rho \times g \times h$ ('h' is the height to which mercury has risen in the capillary)

Hence, $P_{atm} \times A = (\rho \times g \times h) \times A$ or, $P_{atm} = \rho gh$

Faulty Barometer: An ideal barometer will show a correct reading only if the space above the mercury column is vacuum, but in case if some gas column is trapped in the space above the mercury column, then the barometer is classified as a faulty barometer. The reading of such a barometer will be less than the true pressure.

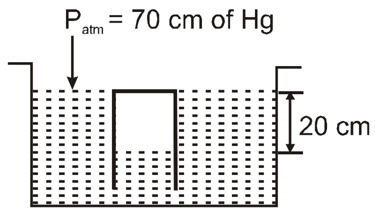
For such a faulty barometer



$P_0A = mg + P_{gas}\,A$

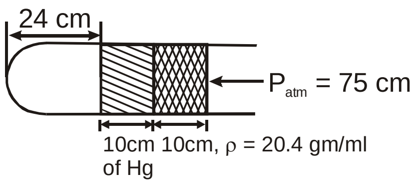
$P_0 = \rho gh + P_{gas}$ or $\rho gh = P_0 - P_{gas}$

1. A tube closed at one end is dipped in mercury as shown in figure-3 such that the closed surface coincides with the mercury level in the container. By how much length of the tube should be extended such that the level of Hg in the tube is 5 cm below the mercury level inside the container. (Assume temperature remains constant)



(A) 18 cm (B) 19 cm
(C) 24 cm (D) 30 cm

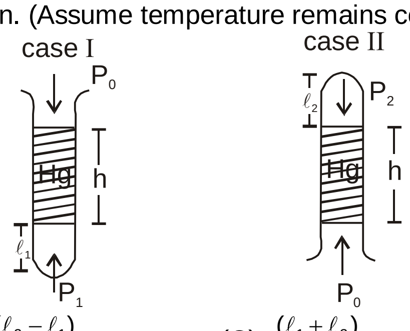
2.



If above tube is placed vertically with the open end upward then the length of the air column will be (assume temperature remains constant)

(A) 20 cm (B) 36 cm (C) 18 cm (D) 15 cm

3. A gas column is trapped between closed end of a tube and a mercury column of length (h) when this tube is placed with its open end upwards the length of gas column is (ℓ_1) the length of gas column becomes (ℓ_2) when open end of tube is held downwards (as shown in fig.). Find atmospheric pressure in terms of height of Hg column. (Assume temperature remains constant)



(A) $\frac{h(\ell_1+\ell_2)}{(\ell_2-\ell_1)}$ (B) $\frac{h(\ell_2-\ell_1)}{(\ell_1+\ell_2)}$ (C) $\frac{(\ell_1+\ell_2)}{h(\ell_2-\ell_1)}$ (D) $(h_1\ell_1 + h_2\ell_2)$

Comprehension # 2

Dalton's Law: Suppose a mixture of two ideal gases, A and B, is contained in a volume V at a temperature T. Then, since each gas is ideal, we can write

$$P_A = n_A \frac{RT}{V}, \qquad P_B = n_B \frac{RT}{V}$$

That is, in the mixture each gas exerts a pressure that is the same as it would exert if it were present alone, and this pressure is proportional to the number of moles of the gas present. The quantities P_A and P_B are called the partial pressures of A and B respectively. According to Dalton's law of partial pressures, the total pressure, P_t, exerted on the walls of the vessel is the sum of the partial pressures of the two gases :

$$P_t = P_A + P_B = (n_A + n_B)\left(\frac{RT}{V}\right).$$

The expression can be generalised so as to apply to a mixture of any number of gases. The result is

$$P_t = \sum_i P_i = \frac{RT}{V}\sum_i n_i, \qquad ...(1)$$

where 'i' is an index that identifies each component in the mixture and the symbol Σ_i stands for the operation of adding all the indexed quantities together. Another useful expression of the law of partial pressures is obtained by writing

$$P_A = n_A \frac{RT}{V}, \qquad P_t = \frac{RT}{V}\sum_i n_i, \qquad \frac{P_A}{P_t} = \frac{n_A}{\sum_i n_i}, \qquad P_A = P_t\left(\frac{n_A}{\sum_i n_i}\right) \quad .....(2)$$

The quantity $\frac{n_A}{\sum_i n_i}$, is called the mole fraction of component A, and equation (2) says that the partial pressure of any component, such as component A, is the total pressure of the mixture multiplied by $\frac{n_A}{\sum_i n_i}$, the fraction of the total moles which are component A.

4. A closed container of volume 30 litre contains a mixture of nitrogen and oxygen gases, at a temperature of 27°C and pressure of 4 atm. The total mass of the mixture is 148 gm. The moles of individual gases in the container are (Take R = 0.08 litre atm/mole K)

(A) n_{N_2} = 2 moles, n_{O_2} = 3 mole (B) n_{N_2} = 3 mole, n_{O_2} = 2 mole
(C) n_{N_2} = 4 mole, n_{O_2} = 1 mole (D) n_{N_2} = 2.5 mole, n_{O_2} = 2.5 mole

5. If the whole mixture (of above problem) is transferred to a 5 litre vessel at same temperature, then choose the correct one :

(A) Total pressure in the container remains same.
(B) Mole fraction of gases will change by $\frac{1}{2}$ unit.
(C) Partial pressure of each gases will be 6 times.
(D) Total pressure in the container becomes half of the initial pressure.

6. If the original mixture (as in Q.No. 4) is allowed to react at this temperature to form NO gas, then the total pressure in the container after the reaction is :

(A) 2 atm (B) 8 atm (C) 4 atm (D) None of these

Comprehension # 3

Answer Q.7, Q.8 and Q.9 by appropriately matching the information given in the three columns of the following table.

In following questions :
M_A & M_B = Molar masses of ideal gases A & B, P = Pressure of gas, A = Area of hole of container
T_A & T_B = Temp of gases A & B in kelvin, n_A & n_B = Moles of gases A & B in container
r_A & r_B = rate of effusion of gas A & B

Column-1		Column-2		Column-3	
(I)	$\frac{M_A}{M_B}=\frac{1}{4}$	(i)	Under similar conditions of P, A, T	(P)	$\frac{r_A}{r_B}=\frac{1}{3}$
(II)	$\frac{M_A}{M_B}=\frac{4}{1}$	(ii)	Under similar conditions of T & P $\frac{A_A}{A_B}=\frac{20}{10}$	(Q)	$\frac{r_A}{r_B}=\frac{4}{3}$
(III)	$\frac{M_A}{M_B}=\frac{4}{9}$	(iii)	Under similar conditions of A & T $\frac{n_A}{n_B}=\frac{2}{3}$	(R)	$\frac{r_A}{r_B}=\frac{2}{1}$
(IV)	$\frac{M_A}{M_B}=\frac{9}{4}$	(iv)	Under similar conditions of P & A $\frac{T_A}{T_B}=\frac{800}{200}$	(S)	$\frac{r_A}{r_B}=\frac{3}{4}$

7. Select correct combination.
(A) I (iv) R (B) I (iii) Q (C) II (ii) Q (D) IV (iii) S

8. Select incorrect combination.
(A) I (i) R (B) iii (iv) S (C) IV (iv) P (D) III (iii) P

9. Select correct combination.
(A) II (iii) P (B) I (ii) Q (C) III (ii) S (D) iv (iii) P

Exercise-3

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

*** Marked Questions may have more than one correct option.**

1. The average velocity of gas molecules is 400 m/sec calculate its r.m.s. velocity at the same temperature. **[JEE-2003(M), 2/60]**

2. For one mole of gas the average kinetic energy is given as E. The U_{rms} of gas is : **[JEE-2004(S), 3/84]**
(A) $\sqrt{\frac{2E}{M}}$ (B) $\sqrt{\frac{3E}{M}}$ (C) $\sqrt{\frac{2E}{3M}}$ (D) $\sqrt{\frac{3E}{2M}}$

3. Ratio of rates of diffusion of He and CH_4 (under identical conditions). **[JEE-2005(S), 3/84]**
(A) $\frac{1}{2}$ (B) 3 (C) $\frac{1}{3}$ (D) 2

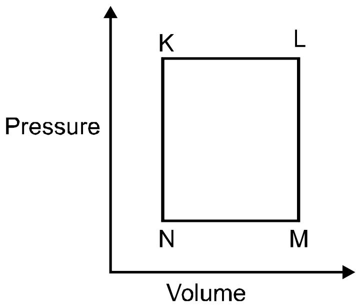
4. At 400 K, the root mean square (rms) speed of a gas **X** (molecular weight = 40) is equal to the most probable speed of gas **Y** at 60 K. The molecular weight of the gas **Y** is. **[JEE-2009, 4/160]**

5.* According to kinetic theory gases **[JEE-2011, 4/180]**
(A) collisions are always elastic
(B) heavier molecules transfer more momentum to the waal of the container
(C) only a small number of molecules have very high velocity
(D) between collisions, the molecules move in straight lines with constant velocities.

6. The atomic masses of He and Ne are 4 and 20 a.m.u., respectively. The value of the de Broglie wavelength of He gas at –73ºC is "M" times that of the de Broglie wavelength of Ne at 727ºC. M is **[JEE(ADVANCED)-2013, 4/120]**

Paragraph for Questions 8 to 9

A fixed mass 'm' of a gas is subjected to transormation of states from K to L to M to N and back to K as shown in the figure

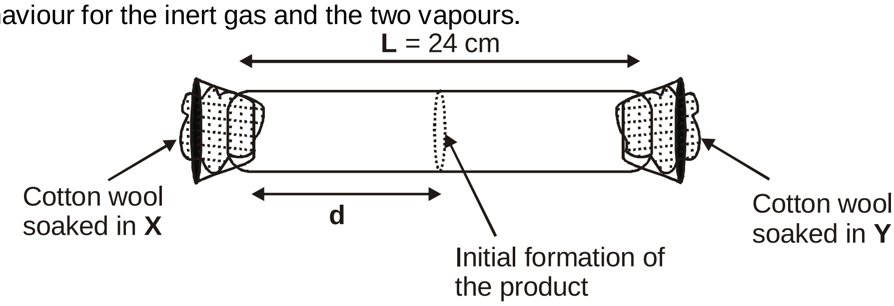


7. The succeeding operations that enable this transformation of states are: **[JEE(Advanced)-2013, 3/120]**
(A) Heating, cooling, heating, cooling (B) Cooling, heating, cooling, heating
(C) Heating, cooling, cooling, heating (D) Cooling, heating, heating, cooling

8. The pair of isochoric processes among the transormation of states is: **[JEE(Advanced)-2013, 3/120]**
(A) K to L and L to M (B) L to M and N to K (C) L to M and M to N (D) M to N and N to K

Paragraph for questions 9 and 10

X and **Y** are two volatile liquids with molar weights of 10 g mol^{-1} and 40 g mol^{-1} respectively. Two cotton plugs, one soaked in **X** and the other soaked in **Y**, are simultaneously placed at the ends of a tube of length **L** = 24 cm, as shown in the figure. The tube is filled with an inert gas at 1 atmosphere pressure and a temperature of 300 K. Vapours of **X** and **Y** react to form a product which is first observed at a distance **d** 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.



9. The value of **d** in cm (shown in the figure), as estimated from Graham's law, is :
[JEE(Advanced)-2014, 3/120]
(A) 8 (B) 12 (C) 16 (D) 20

10. The experimental value of **d** is found to be smaller than the estimate obtained using Graham's law. This is due to **[JEE(Advanced)-2014, 3/120]**
(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.

11. A closed vessel with rigid walls contains 1 mol of $^{238}_{92}U$ and 1 mol of air at 298 K. Considering complete decay of $^{238}_{92}U$ to $^{206}_{82}Pb$, the ratio of the final pressure to the initial pressure of the system at 298 K is
[JEE(Advanced)-2015, 4/168]

12. The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases x times. The value of x is
[JEE(Advanced)-2016, 3/124]

13. 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(Advanced)-2018, 3/120]**

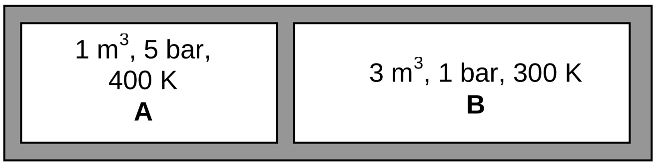


Figure 1

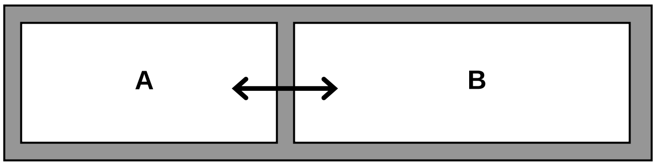


Figure 2

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

JEE(MAIN) OFFLINE PROBLEMS

1. According to kinetic theory of gases in an ideal gas between two successive collisions a gas molecule travels: **[AIEEE 2003, 3/225]**
(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 273 K and 1 atm pressure will be consumed in obtaining 21.6 g of elemental boron (atomic mass = 10.8) from the reduction of boron trichloride by hydrogen? **[AIEEE 2003, 3/225]**
(1) 89.6 L (2) 67.2 L (3) 44.8 L (4) 22.4 L

3. As the temperature is raised from 20ºC to 40ºC, the average kinetic energy of neon atoms changes by a factor : **[AIEEE 2004, 3/225]**
(1) 2 (2) $\sqrt{\frac{313}{293}}$ (3) $\frac{313}{293}$ (4) $\frac{1}{2}$

4. Which one of the following statements regarding helium is **INCORRECT** ? **[AIEEE 2004, 3/225]**
(1) It is used to fill gas balloons instead of hydrogen because it is lighter and non-inflammable
(2) It is used as a cryogenic agent for carrying out experiments at low temperatures
(3) It is used to produce and sustain powerful superconducting magnets
(4) It is used in gas-cooled nuclear reactors

5. Which one of the following statements is not true about the effect of an increase in temperature on the distribution of molecular speeds in a gas ? **[AIEEE 2005, 3/225]**
(1) The area under the distribution curve remains the same as under the lower temperature
(2) The distribution becomes broader
(3) The fraction of the molecules with the most probable speed increases
(4) The most probable speed increases

6. 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 2007, 3/120]**
(1) 1/3 (2) 1/2 (3) 2/3 (4) $\frac{1}{3} \times \frac{273}{298}$

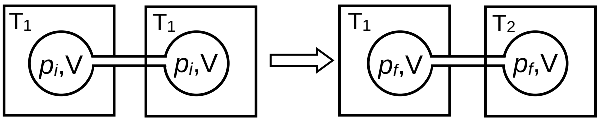
7. When r, P and M represent rate of diffusion, pressure and molecular mass, respectively, then the ratio of the rates of diffusion (r_A/r_B) of two gases A and B, is given as: **[AIEEE 2011, 4/120]**
(1) $(P_A/P_B)(M_B/M_A)^{1/2}$ (2) $(P_A/P_B)^{1/2}(M_B/M_A)$ (3) $(P_A/P_B)(M_A/M_B)^{1/2}$ (4) $(P_A/P_B)^{1/2}(M_A/M_B)$

8. The molecular velocity of any gas is: **[AIEEE 2011, 4/120]**
(1) inversely proportional to absolute temperature.
(2) directly proportional to square of temperature.
(3) directly proportional to square root of temperature.
(4) inversely proportional to the square root of temperature.

9. A gaseous hydrocarbon gives upon combustion 0.72 g of water and 3.08 g. of CO_2. The empirical formula of the hydrocarbon is : **[JEE(Main) 2013, 4/120]**
(1) C_2H_4 (2) C_3H_4 (3) C_6H_5 (4) C_7H_8

10. For gaseous state, if most probable speed is denoted by C*, average speed by and mean square speed by C, then for a large number of molecules the ratios of these speeds are :
[JEE(Main) 2013, 4/120]
(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) $C^* : \bar{c} : C = 1 : 1.225 : 1.128$

11. 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(Main) 2016, 4/120]



(1) $2p_i\left(\frac{T_1}{T_1+T_2}\right)$ (2) $2p_i\left(\frac{T_2}{T_1+T_2}\right)$ (3) $2p_i\left(\frac{T_1T_2}{T_1+T_2}\right)$ (4) $p_i\left(\frac{T_1T_2}{T_1+T_2}\right)$

12. The ratio of mass percent of C and H of an organic compound ($C_XH_YO_Z$) is 6 : 1. If one molecule of the above compound ($C_XH_YO_Z$) contains half as much oxygen as required to burn one molecule of compound C_XH_Y completely to CO_2 and H_2O.The empirical formula of compound $C_XH_YO_Z$ is :
[JEE(Main) 2018, 4/120]
(1) $C_3H_4O_2$ (2) $C_2H_4O_3$ (3) $C_3H_6O_3$ (4) C_2H_4O

JEE(MAIN) ONLINE PROBLEMS

1. The temperature at which oxygen molecules have the same root mean square speed as helium atoms have at 300 K is : (Atomic masses : He = 4 u, O = 16 u) **[JEE(Main) 2014 Online (09-04-14), 4/120]**
(1) 300 K (2) 600 K (3) 1200 K (4) 2400 K

2. 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) 2014 Online (11-04-14), 4/120]
(1) 1.750 L (2) 3.60 L (3) 4.032 L (4) 7.50 L

3. Sulphur dioxide and oxygen were allowed to diffuse through a porpus partition. 20 dm^3 of SO_2 diffuses through the porous partition is 60 seconds. The volume of O_2 in dm^3 which diffuses under the similar condition in 30 seconds will be (atomic mass of sulphur = 32 u) :
[JEE(Main) 2014 Online (19-04-14), 4/120]
(1) 7.09 (2) 14.1 (3) 10.0 (4) 28.2

4. Which of the following is not an assumption of the kinetic theory of gases ?
[JEE(Main) 2015 Online (10-04-15), 4/120]
(1) Gas particles have negligible volume
(2) A gas consists of many identical particels which are in continual motion
(3) At high pressure, gas particles are difficult to compress
(4) Collisions of gas particles are perfectly elastic

5. Initially, the root mean square (rms) velocity of N_2 molecules at certain temperature is u. If this temperature is doubled and all the nitrogen molecules dissociate into nitrogen atoms, then the new *rms* velocity will be : **[JEE(Main) 2016 Online (10-04-16), 4/120]**
(1) 2 u (2) 14 u (3) u / 2 (4) 4 u

6. 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(Main) 2017 Online (09-04-17), 4/120]**
(1) 56 g mol^{-1} (2) 112 g mol^{-1} (3) 224 g mol^{-1} (4) 28 g mol^{-1}

7. Assuming ideal gas behaviour, the ratio of density of ammonia to that of hydrogen chlroide at same temperature and pressure is : (Atomic wt. of Cl 35.5 u) **[JEE(Main) 2018 Online (16-04-18), 4/120]**
(1) 1.46 (2) 1.64 (3) 0.46 (4) 0.64

8. 0.5 moles of gas A and x moles of gas B exert a pressure of 200 Pa in a container of volume 10 m^3 at 1000 K. Given R is the gas constant in JK^{-1} mol^{-1}, x is : **[JEE(Main) 2019 Online (09-01-19), 4/120]**
(1) $\frac{4-R}{2R}$ (2) $\frac{2R}{4+R}$ (3) $\frac{2R}{4-R}$ (4) $\frac{4+R}{2R}$

9. An open vessel at 27°C is heated until two fifth of the air (assumed as an ideal gas) in it has escaped from the vessel. Assuming that the volume of the vessel remains constant, the temperature at which the vessel has been heated is: **[JEE(Main) 2019 Online (12-01-19), 4/120]**
(1) 750 K (2) 750°C (3) 500 ºC (4) 500 K

Answers

EXERCISE - 1

PART - I

A-1. – 111.5°C **A-2.** Final temperature = 360, Increase in temperature is 60 K.

A-3. 6 g **A-4.** 40.3 mL **A-5.** (a) t = – 163.8ºC, (b) P = 1.37 × 10^3 torr

A-6. (a) 477ºC, (b) 2/3, (c) 327ºC **A-7.** 310.4 g escaped.

B-1. P_{N_2} = 418 torr, P_{O_2} = 190 torr, P_{CO_2} = 152 torr, total pressure = 760.

B-2. 8.32 × 10^4 Pa. **B-3.** $\frac{170}{570}$ = 0.30 **B-4.** 1.12 : 1

B-5. 2.201 g/L **B-6.** (a) 1.98% (b) 10.156 litres **C-1.** $\frac{2pT_2}{2T_2 + T_1}$

C-2. P_T = 1.16 atm, 68.18% O_2, 31.82% N_2 **C-3.** 0.66 atm, n_{O_2} = 0.4 (300 K), n_{O_2} = 0.2 (600 K)

D-1. 0.347 **D-2.** 448 g mol^{-1} **D-3.** M = 128 g/mol

D-4. 133 **E-1.** 2.16 × 10^4 cm/sec. **E-2.** 1.73 × 10^4 cm/sec

E-3. 1327ºC **E-4.** T = 22.0 K **F-1.** CO_2 = 0.6 lt, CO = 0.4 lt

F-2. NH_3 **F-3.** 10 ml **F-4.** NO = 44 ml ; N_2O = 16 ml

F-5. 4 : 1 **F-6.** 0.8 g, O_2 = 2.24 Ltr, CH_4.

PART - II

A-1.	(C)	**A-2.**	(C)	**A-3.**	(A)	**A-4.**	(A)	**A-5.**	(C)
A-6.	(A)	**A-7.**	(C)	**A-8.**	(A)	**A-9.**	(C)	**A-10.**	(A)
A-11.	(C)	**A-12.**	(C)	**A-13.**	(C)	**A-14.**	(A)	**A-15.**	(B)
A-16.	(B)	**B-1.**	(D)	**B-2.**	(D)	**B-3.**	(B)	**B-4.**	(A)
C-1.	(C)	**C-2.**	(B)	**C-3.**	(A)	**D-1.**	(D)	**D-2.**	(B)
D-3.	(C)	**D-4.**	(B)	**D-5.**	(A)	**E-1.**	(B)	**E-2.**	(B)
E-3.	(A)	**E-4.**	(A)	**E-5.**	(B)	**E-6.**	(D)	**E-7.**	(B)
E-8.	(C)	**E-9.**	(C)	**E-10.**	(B)	**F-1.**	(D)	**F-2.**	(B)
F-3.	(A)	**F-4.**	(B)	**F-5.**	(B)	**F-6.**	(B)	**F-7.**	(B)
F-8.	(D)								

PART - III

1. (A - s) ; (B - q, s) ; (C - r) ; (D - p, r) **2.** (A - q) ; (B - t) ; (C - s) ; (D - r) ; (E - p)

EXERCISE - 2

PART - I

1.	(C)	**2.**	(A)	**3.**	(C)	**4.**	(D)	**5.**	(B)
6.	(A)	**7.**	(A)	**8.**	(B)	**9.**	(A)	**10.**	(B)
11.	(C)	**12.**	(C)	**13.**	(D)	**14.**	(D)	**15.**	(B)

PART - II

1.	4	**2.**	1	**3.**	5	**4.**	5	**5.**	10
6.	28 (m_{Ar} = 24 + m_{Ne} = 4)			**7.**	30 mm	**8.**	40 atm	**9.**	2 m
10.	16 Minutes	**11.**	8	**12.**	27	**13.**	3		

PART - III

1.	(AB)	**2.**	(CD)	**3.**	(ABD)	**4.**	(BCD)	**5.**	(ABC)
6.	(ACD)	**7.**	(ABC)	**8.**	(BD)	**9.**	(BD)	**10.**	(ABD)
11.	(BC)	**12.**	(ACD)	**13.**	(AD)	**14.**	(ABD)		

PART - IV

1.	(B)	**2.**	(C)	**3.**	(A)	**4.**	(B)	**5.**	(C)
6.	(C)	**7.**_	(B)	**8.**_	(D)	**9.**_	(A)		

EXERCISE - 3

PART - I

1.	434 m/s	**2.**	(A)	**3.**	(D)	**4.**	M_Y = 4.	**5.***	(ABCD)
6.	5	**7.**	(C)	**8.**	(B)	**9.**	(C)	**10.**	(D)
11.	9	**12.**	4	**13.**	2.22				

PART - II

JEE(MAIN) OFFLINE PROBLEMS

1.	(1)	**2.**	(2)	**3.**	(3)	**4.**	(1)	**5.**	(3)
6.	(1)	**7.**	(1)	**8.**	(3)	**9.**	(4)	**10.**	(3)
11.	(2)	**12.**	(2)						

JEE(MAIN) ONLINE PROBLEMS

1.	(4)	**2.**	(1)	**3.**	(2)	**4.**	(3)	**5.**	(1)
6.	(2)	**7.**	(3)	**8.**	(1)	**9.**	(4)		

Additional Problems for Self Practice (APSP)

Marked questions are recommended for Revision.

This Section is not meant for classroom discussion. It is being given to promote self-study and self testing amongst the Resonance students.

PART - I : PRACTICE TEST-1 (IIT-JEE (MAIN Pattern))

Max. Time : 1 Hr. **Max. Marks : 120**

Important Instructions

1. The test is of **1 hour** duration.
2. The Test Booklet consists of **30** questions. The maximum marks are **120.**
3. Each question is allotted **4 (four)** marks for correct response.
4. Candidates will be awarded marks as stated above in Instructions No. 3 for correct response of each question. **¼ (one fourth)** marks will be deducted for indicating incorrect response of each question. No deduction from the total score will be made if no response is indicated for an item in the answer sheet.
5. There is only one correct response for each question. Filling up more than one response in any question will be treated as wrong response and marks for wrong response will be deducted accordingly as per instructions 4 above.

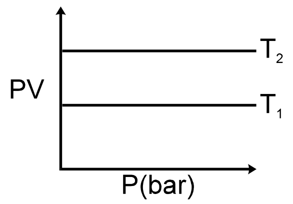
1. 2.5 L of a sample of a gas at 27°C and 1 bar pressure is compressed to a volume of 500 mL keeping the temperature constant, the percentage increase in pressure is
(1) 100 % (2) 400 % (3) 500% (4) 80%

2. For two gases, A and B with molecular weights M_A and M_B, it is observed that at a certain temperature, T, the mean velocity of A is equal to the root mean square velocity of B. Thus the mean velocity of A can be made equal to the mean velocity of B, if
(1) A is at temperature, T_1 and B at T_2, $T_1 > T_2$
(2) A is lowered to a temperature $T_2 < T$ while B is at T
(3) Both A and B are raised to a higher temperature
(4) Both A and B are lowered in temperature.

3. At what temperature, the average speed of gas molecules be double of that at temperature, 27ºC?
(1) 120ºC (2) 108ºC (3) 927ºC (4) 300ºC

4. Two glass bulbs A and B at same temperature are connected by a very small tube having a stop-corck. Bulb A has a volume of 100 cm^3 and contained the gas while bulb B was empty. On opening the stop-corck, the pressure fell down to 20%. The volume of the bulb B is :
(1) 100 cm^3 (2) 200 cm^3 (3) 250 cm^3 (4) 400 cm^3

5. The product of PV is plotted against P at two temperatures T_1 and T_2 and the 'result is shown in figure. What is correct about T_1 and T_2?



(1) $T_1 > T_2$ (2) $T_2 > T_1$ (3) $T_1 = T_2$ (4) $T_1 + T_2 = 1$

6. Match of following (where U_{rms} = root mean square speed, U_{av} = average speed, U_{mp} = most probable speed)

	List I		List II
(a)	U_{rms} / U_{av}	(i)	1.22
(b)	U_{av} / U_{mp}	(ii)	1.13
(c)	U_{rms} / U_{mp}	(iii)	1.08

(1) (a)-(iii), (b)-(ii), (c)-(i) (2) (a)-(i), (b)-(ii), (c)-(iii)
(3) (a)-(iii), (b)-(i), (c)-(ii) (4) (a)-(ii), (b)-(iii), (c)-(i).

7. $N_2 + 3H_2 \longrightarrow 2NH_3$. 1 mol N_2 and 4 mol H_2 are taken in 15 L flask at 27°C. After complete conversion of N_2 into NH_3, 5 L of H_2O is added. Pressure set up in the flask is :

(1) $\frac{3\times0.0821\times300}{15}$ atm (2) $\frac{2\times0.0821\times300}{10}$ atm

(3) $\frac{1\times0.0821\times300}{15}$ atm (4) $\frac{1\times0.0821\times300}{10}$ atm

8. Which of the following is not the correct set of pressure and volume at constant temperature and constant moles of gas ?

	P	V		P	V
(1)	1 atm	200 ml	(2)	760 mm	0.2 L
(3)	0.5 atm	100 L	(4)	2 atm	100 mL

9. 2 litres of moist hydrogen were collected over water at 26ºC at a total pressure of one atmosphere. On analysis, it was found that the quantity of H_2 collected was 0.0788 mole. What is the mole fraction of H_2 in the moist gas.

(1) 0.989 (2) 0.897 (3) 0.953 (4) 0.967

10. When CO_2 under high pressure is released from a fire extinguisher, particles of solid CO_2 are formed, despite the low sublimation temperature (– 77ºC) of CO_2 at 1.0 atm. It is

(1) the gas does work pushing back the atmosphere using KE of molecules and thus lowering the temperature

(2) volume of the gas is decreased rapidly hence, temperature is lowered

(3) both (1) and (2)

(4) None of the above

11. At what temperature will the total KE of 0.3 mol of He be the same as the total KE of 0.40 mol of Ar at 400 K ?

(1) 533 K (2) 400 K (3) 346 K (4) 300 K

12. Potassium hydroxide solutions are used to absorb CO_2. How many litres of CO_2 at 1.00 atm and 22ºC would be absorbed by an aqueous solution containing 15.0 g of KOH ? (Take R = $\frac{1}{12}$ ℓ atm / K/mole)

$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$

(1) 3.24 L (2) 1.62 L (3) 6.48 L (4) 0.324 L

13. The volume of a gas increases by a factor of 2 while the pressure decreases by a factor of 3. Given that the number of moles is unaffected, the factor by which the temperature changes is :

(1) $\frac{3}{2}$ (2) 3 × 2 (3) $\frac{2}{3}$ (4) $\frac{1}{2}$ × 3

14. If V_0 is the volume of a given mass of gas at 273 K at constant pressure, then according to Charle's law, the volume at 10ºC will be :

(1) 10 V_0 (2) $\frac{2}{273}(V_0 + 10)$ (3) $V_0 + \frac{10}{273}$ (4) $\frac{283}{273}V_0$

15. When a gas is compressed at constant temperature :

(1) the speeds of the molecules increase (2) the collisions between the molecules increase

(3) the speeds of the molecules decrease (4) the collisions between the molecules decrease

16. A cylinder is filled with a gaseous mixture containing equal masses of CO and N_2. The partial pressure ratio is :

(1) $P_{N_2} = P_{CO}$ (2) $P_{CO} = 0.875 P_{N_2}$ (3) $P_{CO} = 2 P_{N_2}$ (4) $P_{CO} = \frac{1}{2} P_{N_2}$

17. Helium atom is two times heavier than a hydrogen molecule at 298 K, the average kinetic energy of helium is :

(1) two times that of hydrogen molecule (2) same as that of the hydrogen molecule

(3) four times that of a hydrogen molecule (4) half that of a hydrogen molecule

18. Two flasks A and B have equal volumes. A is maintained at 300 K and B at 600 K, while A contains H_2 gas, B has an equal mass of CO_2 gas. Find the ratio of total K.E. of gases in flask A to that of B.
(1) 1 : 2 (2) 11 : 1 (3) 33 : 2 (4) 55 : 7

19.✍ A quantity of gas is collected in a graduated tube over the mercury. The volume of gas at 18ºC is 50 ml and the level of mercury in the tube is 100 mm above the outside mercury level. The barometer reads 750 torr. Hence, volume at S.T.P. is approximately :
(1) 22 ml (2) 40 ml (3) 20 ml (4) 44 ml

20. If equal weights of oxygen and nitrogen are placed in separate containers of equal volume at the same temperature, which one of the following statements is true? (Mol wt: N_2 = 28, O_2 = 32)
(1) Both flasks contain the same number of molecules.
(2) The pressure in the nitrogen flask is greater than the one in the oxygen flask.
(3) More molecules are present in the oxygen flask.
(4) Molecules in the oxygen flask are moving faster on the average than the ones in the nitrogen flask.

21. Which of the following is NOT a postulate of the kinetic molecular theory of gases?
(1) The molecules possess a volume that is negligibly small compared to the of the container.
(2) The pressure and volume of a gas are inversely related
(3) Gases consist of discrete particles that are in random motion
(4) The average kinetic energy of the molecules is directly proportional to the temperature

22.✍ What is the total pressure exerted by the mixture of 7.0 g of N_2, 2 g of hydrogen and 8.0 g of sulphur dioxide gases in a vessel of 6 L capacity that has been kept in a reservoir at 27°C?
(1) 2.5 bar (2) 4.5 bar (3) 10 atm (4) 5.7 bar

23. At what temperature root mean square speed of N_2 gas is equal to that of propane gas at S.T.P. conditions.
(1) 173.7°C (2) 173.7 K (3) S.T.P. (4) – 40°C

24.✍ 10 L of O_2 gas is reacted with 30 L of CO (g) at STP. The volume of each gas present at the end of the reaction are :
(1) O_2 = 10 L, CO_2 = 20 L (2) CO = 10 L, CO_2 = 20 L
(3) CO = 20 L, CO_2 = 10 L (4) CO = 15 L, CO_2 = 15 L

25. 1 mol of a gaseous aliphahatic compound $C_nH_{3n}O_m$ is completely burnt in an excess of oxygen. The contraction in volume is (assume water get condensed out)
(1) $\left(1+\frac{1}{2}n-\frac{3}{4}m\right)$ (2) $\left(1+\frac{3}{4}n-\frac{1}{4}m\right)$ (3) $\left(1-\frac{1}{2}n-\frac{3}{4}m\right)$ (4) $\left(1+\frac{3}{4}n-\frac{1}{2}m\right)$

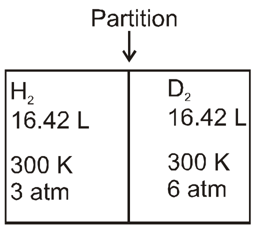
26. One mole of a gas is defined as -
(1) The number of molecules in one litre of gas
(2) The number of molecules in one formula weight of gas
(3) The number of molecules contained in 12 grams of (12 C) isotope
(4) The number of molecules in 22.4 litres of a gas at S.T.P.

27. If two moles of an ideal gas at 546 K occupies a volume of 44.8 litres, the pressure must be -
(1) 2 atm (2) 3 atm (3) 4 atm (4) 1 atm

28. At STP the order of mean square velocity of molecules of H_2, N_2, O_2 and HBr is -
(1) $H_2 > N_2 > O_2 >$ HBr (2) HBr $> O_2 > N_2 > H_2$ (3) HBr $> H_2 > O_2 > N_2$ (4) $N_2 > O_2 > H_2 >$ HBr

29. If all the oxygen atoms present in 4 mole H_2SO_4, 2 mole P_4O_{10} & 2mole NO_2 are collected for the formation of O_2 gas molecules then calculate volume of O_2 gas formed at 2 atm pressure & 273 K temperature.
(1) 224 L (2) 448 L (3) 336 L (4) 112 L

30.✍ If the partition is removed the average molar mass of the sample will be (Assume ideal behaviour).



(1) $\frac{5}{3}$ g/mol (2) $\frac{10}{3}$ g/mol
(3) $\frac{3}{2}$ g/mol (4) 3 g/mol

Practice Test-1 (IIT-JEE (Main Pattern))

OBJECTIVE RESPONSE SHEET (ORS)

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ans.										
Que.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ans.										
Que.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Ans.										

PART - II : NATIONAL STANDARD EXAMINATION IN CHEMISTRY (NSEC) STAGE-I

Ideal Gases

1. The rate of diffusion of a gas of molecular weight M is given by the relation : **[NSEC-2000]**

(A) rate $\propto \sqrt{\text{density of gas}}$
(B) rate $\propto \frac{1}{\sqrt{M}}$
(C) rate $\propto$ M
(D) rate is independent of density of gas.

2. The kinetic energy of one gram mole of any gas depends on : **[NSEC-2000]**

(A) absolute temperature of the gas.
(B) nature of the gas molecules.
(C) pressure of the gas
(D) volume of the gas

3. A flask of gaseous CCl_4 was weighed at measured temperature and pressure. The flask was then flushed and filled with O_2 at same temperature and pressure. The weight of the CCl_4 vapour will be : **[NSEC-2000]**

(A) five times as heavy as O_2
(B) one fifth heavy as compared to O_2
(C) same as that of O_2
(D) twice as heavy as the O_2

4. For an ideal gas, which of the following graphs, will not be a straight line when all the other variables are held constant ? **[NSEC-2000]**

(A) P Vs T (B) V Vs T (C) P Vs 1/V (D) n Vs T

5. A gas cylinder was found unattended in a public place. The investigating team took the cylinder and collected samples from it. The density of the gas was found to be 2.380 g L^{-1} at 15ºC and 736 mm Hg pressure. Hence the molar mass of the gas is : **[NSEC-2003]**

(A) 83 (B) 71 (C) 32 (D) 58

6. Considering air as a 4:1 mixture of nitrogen and oxygen, the mass of air in a hall with dimensions 5 m × 5 m × 5 m at STP is approximately **[NSEC-2003]**

(A) 160 g (B) 160 kg (C) 16 g (D) 1.60 kg.

7. R.M.S. velocity of sulphur trioxide is found to be equal to the most probable velocity of another gas at the same temperature. Hence, the molecular weight of the gas is : **[NSEC-2004]**

(A) 46 (B) 64 (C) 53 (D) 80.

8. What is the total pressure inside a 2L vessel containing 1g of He, 14g of CO and 10g of NO at 27°C ? **[NSEC-2007]**

(A) 0.25 atm (B) 13.2 atm (C) 1.24 atm (D) 21.6 atm

9. The root mean square velocity of SO_2 is equal to that of oxygen at 27°C when the temperature is : **[NSEC-2008]**

(A) 327°C (B) 127°C (C) 227°C (D) 600°C

10. The temperature of a sample of sulfur dioxide is increased from 27°C to 327°C. The average kinetic energy of the gas molecules **[NSEC-2008]**
(A) is doubled
(B) increases by the factor 327/27
(C) is halved
(D) remains same

11. A gas shows positive joule-thomson effect below : **[NSEC-2008]**
(A) Critical temperature
(B) Boyle temperature
(C) Transition temperature
(D) Inversion temperature

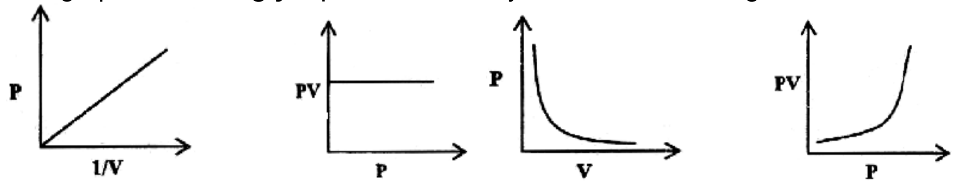
12. A container having volume V contains an ideal gas at 1 atm pressure. It is connected to another evacuated container having volume 0.5 dm^3 through a tube having negligible volume. After some time the first container is found to have pressure 570 mm of Hg. If temperature is constant, V is : **[NSEC-2010]**
(A) 1.0 dm^3
(B) 1.5 dm^3
(C) 2.0 dm^3
(D) 2.5 dm^3

13. A beaker is heated from 27°C to 127°C, the percentage of air originally present in beaker that is expelled is: **[NSEC-2011]**
(A) 50%
(B) 25%
(C) 33%
(D) 40%

14. The vapour density of gas A is four times that of B. If the molecular mass of B is M then molecular mass of A is: **[NSEC-2012]**
(A) M
(B) 4M
(C) M/4
(D) 2M

15. A gas shows positive Joule-Thomson Effect below its **[NSEC-2013]**
(A) Boyle Temperature
(B) Critical Temperature
(C) Inversion Temperature
(D) Transition Temperature

16. The graph that **wrongly** represents the Boyle's law of an ideal gas is **[NSEC-2014]**



(I) (II) (III) (IV)

(A) II
(B) I
(C) IV
(D) III

17. In an experiment, it was found that for a gas at constant temperature, PV = C. The value of C depends on **[NSEC-2015]**
(A) atmospheric pressure
(B) quantity of gas
(C) molecular weight of gas
(D) volume of chamber

18. The quantity that does not change for a sample of a gas in a sealed rigid container when it is cooled from 120°C to 90°C at constant volume is **[NSEC-2015]**
(A) average energy of the molecule
(B) pressure of the gas
(C) density of the gas
(D) average speed of the molecules

19. Equal masses of ethane and hydrogen gas are present in a container at 25ºC. The fraction of the total pressure exerted by ethane gas is : **[NSEC-2016]**
(A) 1/2
(B) 1/16
(C) 15/16
(D) 1/8

20. The volume of nitrogen evolved on complete reaction of 9 g of ethylamine with a mixture of $NaNO_2$ and HCl at 273ºC and 1 atm pressure is : **[NSEC-2016]**
(A) 11.2 dm^3
(B) 5.6 cm^3
(C) 4.48 dm^3
(D) 22.4 cm^3

21. Which of the following will not give a straight line plot for an ideal gas ? **[NSEC-2017]**
(A) V vs T
(B) T vs P
(C) V vs I/P
(D) V vs I/T

22. When a sample of gas kept at 20ºC and 4.0 atm is heated to 40ºC at constant volume **[NSEC-2017]**
(A) average speed of the gas molecules will decrease.
(B) number of collisions between the gas molecules per second will remain the same.
(C) average kinetic energy of the gas will increase.
(D) pressure of the gas will become 8 atm.

23. The pressure inside two gas cylinders of volume 25 m^3 and 50 m^3 are 10 kPa and 20 kPa respectively. The cylinders are kept at the same temperature and separated by a valve. What is the pressure in the combined system when the vale is opened? **[NSEC-2018]**
(A) 30 kPa (B) 15 kPa (C) 16.7 kPa (D) 2.5 kPa

24. Density of CO_2 gas at 0ºC and 2.00 atm pressure can be expressed as **[NSEC-2018]**
(A) 2 g m^{-3} (B) 4 g m^{-3} (C) 4 × 10^3 kg m^{-3} (D) 8 g L^{-1}

Real Gases

25. The critical volume of a gas when expressed in terms of Van der Waals constants 'a' and 'b' takes the form: **[NSEC-2000]**
(A) 3a (B) a/27b^2 (C) 8a/27Rb (D) 3b

26. Real gases approach ideal behaviour at : **[NSEC-2001]**
(A) high temperatures and high pressure (B) high temperatures and low pressures
(C) low temperatures and low pressures (D) critical point

27. A gas will approach ideal behaviour at **[NSEC-2004]**
(A) low temperature and low pressure (B) low temperature and high pressure
(C) high temperature and low pressure (D) high temperature and high pressure.

28. The van der waal`s equation for real gases is $\left(P + a\left(\frac{n}{V}\right)^2\right)$ (V – nb) = nRT.

In the above equation, the terms a $(n/V)^2$ and (–nb) respectively represents the corrections for: **[NSEC-2004]**
(A) intermolecular attractive forces and inelastic collision
(B) intermolecular repulsive force and high temperatures
(C) intermolecular attractive forces and molecular volumes
(D) deviations in the temperature and pressure.

29. In the van der Waals equation of state for a real gas, the term that accounts for intermolecular attraction is **[NSEC-2005]**
(A) (P + a/V^2) (B) (V – b) (C) RT (D) 1/(V – b).

30. A gas shows positive joule-thomson effect below : **[NSEC-2008]**
(A) Critical temperature (B) Boyle temperature
(C) Transition temperature (D) Inversion temperature

31. Under high pressure conitions, van der waal's equation for a real gas reduces to : **[NSEC-2008]**
(A) PV = RT (B) PV + a/V = RT (C) PV – Pb = RT (D) (P + a/V^2) (V – b) = RT

32. In the Vander waal equation of state for a non ideal gas the term that accounts for intermolecular force is **[NSEC-2012]**
(A) (V – b) (B) RT (C) $(P + \frac{a}{v^2})$ (D) 1/RT

33. Real gases behave ideally at **[NSEC-2014]**
(A) low pressure and low temperature (B) high pressure and low temperature
(C) low pressure and high temperature (D) high pressure and high temperature

34. The van der Waals equation for one mole of a real gas can be written as
(P + a/V^2) (V – b) = RT. For the gases H_2, NH_3, and CH_4, the value of 'a' (bar L^{-2} mol^{-2}) are 0.2453, 4.170 and 2.253 respectively.
Which of the following can be inferred from the 'a' values ? **[NSEC-2017]**
(A) NH_3 can be most easily liquified
(B) H_2 can be most easily liquified
(C) value of 'a' for CH_4 is less than that of NH_3 because it has the lower molar mass
(D) intermolecular forces are the strongest in hydrogen

PART - III : PRACTICE TEST-2 (IIT-JEE (ADVANCED Pattern))

Max. Time : 1 Hr. **Max. Marks : 63**

Important Instructions

A. General :

1. The test is of 1 hour duration.
2. The Test Booklet consists of 21 questions. The maximum marks are 63.

B. Question Paper Format :

3. Each part consists of five sections.
4. Section 1 contains 8 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE is correct.
5. Section 2 contains 5 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE OR MORE THAN ONE are correct.
6. Section 3 contains 4 questions. The answer to each of the questions is a single-digit integer, ranging from 0 to 9 (both inclusive).
7. Section 4 contains 1 paragraphs each describing theory, experiment and data etc. 3 questions relate to paragraph. Each question pertaining to a partcular passage should have only one correct answer among the four given choices (A), (B), (C) and (D).
8. Section 5 contains 1 multiple choice questions. Question has two lists (list-1 : P, Q, R and S; List-2 : 1, 2, 3 and 4). The options for the correct match are provided as (A), (B), (C) and (D) out of which ONLY ONE is correct.

C. Marking Scheme :

9. For each question in Section 1, 4 and 5 you will be awarded 3 marks if you darken the bubble corresponding to the correct answer and zero mark if no bubble is darkened. In all other cases, minus one (–1) mark will be awarded.
10. For each question in Section 2, you will be awarded 3 marks. If you darken all the bubble(s) corresponding to the correct answer(s) and zero mark. If no bubbles are darkened. No negative marks will be answered for incorrect answer in this section.
11. For each question in Section 3, you will be awarded 3 marks if you darken only the bubble corresponding to the correct answer and zero mark if no bubble is darkened. No negative marks will be awarded for incorrect answer in this section.

SECTION-1 : (Only One option correct Type)

This section contains 8 multiple choice questions. Each questions has four choices (A), (B), (C) and (D) out of which Only ONE option is correct.

---

1. 10 moles of an ideal gas present in 8.21 litre container at constant temperature. The intercept on y-axis and slope of curve plotted between P/T vs T.

(A) 0.01, 0 (B) 0.1, 1 (C) 0.1, 0 (D) 10, 1

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

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

3. An open flask containing air is heated from 300 K to 500 K. What percentage of air will be escaped to the atmosphere, if pressure is keeping constant?

(A) 80 (B) 40 (C) 60 (D) 20

4. A gaseous mixture of three gases A, B and C has a pressure of 10 atm. The total number of moles of all the gases is 10. If the partial pressure of A and B are 3.0 and 1.0 atm respectively and if C has mol. wt. of 2.0, what is the weight of C in g present in the mixture ?

(A) 6 (B) 8 (C) 12 (D) 3

5. Two vessels connected by a valve of negligible volume. One container (I) has 2.8 of N_2 at temperature T_1 (K). The other container (II) is completely evacuated. The container (I) is heated to T_2 (K) while container (II) is maintained at $T_2/3$ (K). Volume of vessel (I) is half that of vessel (II). If the valve is opened then what is the weight ratio of N_2 in both vessel (W_I/W_{II})?

(A) 1 : 2 (B) 1 : 3 (C) 1 : 6 (D) 3 : 1

6. Correct expression for density of an ideal gas mixture of two gases 1 and 2, where m_1 and m_2 are masses and n_1 and n_2 are moles and M_1 and M_2 are molar masses.
(A) $d = \dfrac{(m_1+m_2)}{(M_1+M_2)}$ (B) $d = \dfrac{(m_1+m_2)}{(n_1+n_2)}\dfrac{P}{RT}$ (C) $d = \dfrac{(n_1+n_2)}{(m_1+m_2)} \times \dfrac{P}{RT}$ (D) None of these

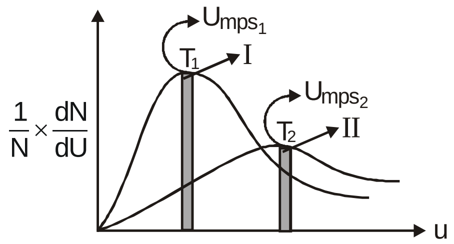
7. A balloon filled with ethyne is pricked with a sharp point and quickly dropped in a tank of H_2 gas under identical conditions. After a while the balloon will :
(A) Shrink (B) Enlarge
(C) Completely collapse (D) Remain unchanged in size

8. 10 ml of gaseous hydrcarbon is exploded with 100 ml O_2. The residual gas on cooling is found to measure 95 ml of which 20 ml is abosrbed by KOH and the reminder by alkaline pyrogallol. The formula of the hydrocarbon is :
(A) CH_4 (B) C_2H_6 (C) C_2H_4 (D) C_2H_2

Section-2 : (One or More than one options correct Type)
This section contains 5 multipole choice questions. Each questions has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

9. The Ne atom has 10 times the mass of H_2. Which of the following statements are true?
(A) Ten moles of H_2 would have the same volume as 1 mole of Ne.
(B) One mole of Ne exerts the same pressure as one mole of H_2 at STP
(C) A H_2 molecule travels 10 times faster than an Ne atom.
(D) At STP, one litre of Ne has 10 times the density of 1 litre of H_2.

10. Following represent the Maxwell distribution curve for an ideal gas at two temperature T_1 and T_2. Which of the following option(s) are true ?



(A) Total area under the two curves is independent of moles of gas
(B) U_{mps} decreases as temperature decreases
(C) $T_1 > T_2$ and hence higher the temperature, sharper the curve
(D) The fraction of molecules having speed = U_{mps} decreases as temperature increases

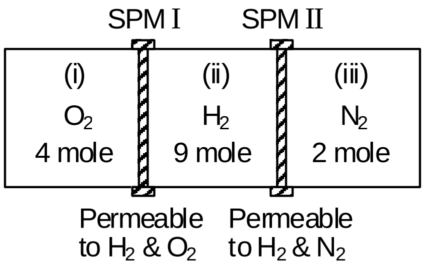
11. If for two gases of molecular weights M_A and M_B at temperature T_A and T_B, respectively, $T_AM_B = T_BM_A$, then which property has the same magnitude for both the gases ?
(A) PV if mass of gases taken are same (B) Pressure
(C) KE per mole (D) V_{rms}

12. Two non reacting gas A & B having mole ratio of 3 : 5 in a container exerts a pressure of 8 atm. If B is removed what would be pressure of 'A' only. If A is removed what would be pressure of 'B' only, temperature remaining constant.
(A) 3 atm (B) 4 atm (C) 5 atm (D) None of these

13. Which of the following does not shows explicitly the relationship between Boyle's law and Charles' law ?
(A) $\dfrac{P_1}{P_2} = \dfrac{T_1}{T_2}$ (B) PV = K (C) $\dfrac{P_2}{P_1} = \dfrac{V_1}{V_2}$ (D) $\dfrac{V_2}{V_1} = \dfrac{P_1}{P_2} \times \dfrac{T_2}{T_1}$

Section-3 : (One Integer Value Correct Type.)
This section contains 6 questions. Each question, when worked out will result in one integer from 0 to 9 (both inclusive)

14. A container is divided into 3 identical parts by fixed semipermeable membrane as shown below.
In compartment (i) 4 moles of O_2 are taken
In compartment (ii) 9 moles of H_2 are taken
In compartment (iii) 2 moles of N_2 are taken
Calculate the ratio of total pressure in the three compartments after a sufficient long time. Assume temperature constant throughout. If ratio is a : b : c (simplest ratio) then express your answer as a + b + c.



15. The density of a gas filled in an electric lamp is 0.75 kg/m^3. When lamp is switched on, the pressure in it increases from 4 Pa to 25 Pa, then what is increase in u_{rms} in m/sec.

16. Gaseous decomposition of A follows Ist order kinetics. Pure A(g) is taken in a sealed flask where decomposition occurs as

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

After 10 sec., a leak was developed in the flask. On analysis of the effused gaseous mixture (Obeying Graham's law) coming out initially, moles of B(g) were found to be double of A. What is rate constant in sec^{-1}.

Given : Molecular weight of A = 16, Molecular weight of B = 4, Molecular weight of C = 8.

[ℓn 3 = 1.1; ℓn 2 = 0.7]

Write your answer by multiplying it with 100.

17. 0.75 mole of solid X_4 and 2 mole of O_2 are heated to completely react in a closed rigid container to form only one gaseous compound (no reactant left behind). Find the ratio of final pressure at 327ºC to the initial pressure at 27ºC in the flask. Fill your answer as x, where ratio is x : 1.

SECTION-4 : Comprehension Type (Only One options correct)

This section contains 1 paragraphs, each describing theory, experiments, data etc. 3 questions relate to the paragraph. Each question has only one correct answer among the four given options (A), (B), (C) and (D)

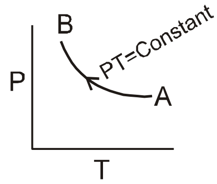
Paragraph for Questions 18 to 20

When a sample of an ideal gas is changed from an initial state to a final state, various curves can be plotted for the process like P–V curve, V–T curve, P–T curve etc.

For example, P–V curve for a fixed amount of an ideal gas at constant temperature is a rectangular hyperbola, V–T curve for a fixed amount of an ideal gas at constant pressure is a straight line and P–T curve for a fixed amount of an ideal gas at constant volume is again a straight line. However, the shapes may vary if the constant parameters are also changed.

Now, answer the following questions :

18. Which of the following statements is correct regarding a fixed amount of ideal gas undergoing the following process :



(A) Root mean square (RMS) speed of gas molecules increases during the process A $\rightarrow$ B.

(B) Density of the gas increases during the process A $\rightarrow$ B.

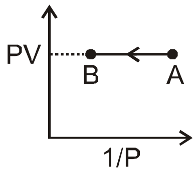
(C) Such a graph is not possible.

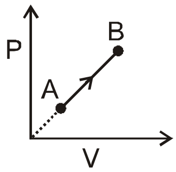
(D) If $P_B = 4P_A$, then $V_A = 4V_B$ (where P_A, V_A, P_B & V_B represent pressure and volume values at states A and B).

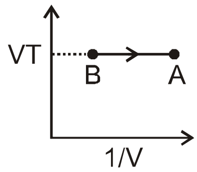
19. Two moles of an ideal gas is changed from its initial state (16 atm, 6L) to final state (4 atm, 15L) in such a way that this change can be represented by a straight line in P–V curve. The maximum temperature attained by the gas during the above change is : (Take R = $\frac{1}{12}$ L atm K^{-1} mol^{-1})

(A) 324 K (B) 648 K (C) 1296 K (D) 972 K

20. Which of the following graphs is not possible for a fixed amount of ideal gas upon moving from initial state A to final state B :

(A) 

(B) 

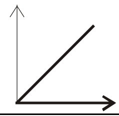
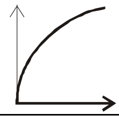
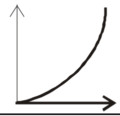
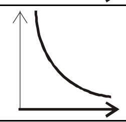
(C) 

(D) None of these

SECTION-5 : Matching List Type (Only One options correct)

This section contains 1 questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D) out of which one is correct.

21. Match each **List-I** with an appropriate pair from **List-II** and select the correct answer using the code given below the lists.

	List-I		**List-II**
P.	$\frac{1}{V^2}$ vs. P for ideal gas at constant T and n.	1.	
Q.	V vs. $\frac{1}{T}$ for ideal gas at constant P and n	2.	
R.	PT vs. T^2 for ideal gas at constant T and n.	3.	
S.	V vs. $\frac{1}{P^2}$ for ideal gas at constant T and n.	4.	

Code :

	P	Q	R	S		P	Q	R	S
(A)	3	4	1	2	(B)	1	2	4	3
(C)	3	1	2	4	(D)	2	3	1	4

Practice Test-2 (IIT-JEE (ADVANCED Pattern))

OBJECTIVE RESPONSE SHEET (ORS)

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ans.										
Que.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ans.										
Que.	**21**									
Ans.										

APSP Answers

PART - I

1.	(2)	**2.**	(2)	**3.**	(3)	**4.**	(4)	**5.**	(2)
6.	(1)	**7.**	(4)	**8.**	(3)	**9.**	(4)	**10.**	(1)
11.	(1)	**12.**	(1)	**13.**	(3)	**14.**	(4)	**15.**	(2)
16.	(1)	**17.**	(2)	**18.**	(2)	**19.**	(2)	**20.**	(2)
21.	(2)	**22.**	(4)	**23.**	(2)	**24.**	(2)	**25.**	(4)
26.	(4)	**27.**	(1)	**28.**	(1)	**29.**	(1)	**30.**	(2)

PART - II

1.	(B)	**2.**	(A)	**3.**	(A)	**4.**	(D)	**5.**	(D)
6.	(B)	**7.**	(B)	**8.**	(B)	**9.**	(A)	**10.**	(A)
11.	(D)	**12.**	(B)	**13.**	(B)	**14.**	(B)	**15.**	(C)
16.	(C)	**17.**	(B)	**18.**	(C)	**19.**	(B)	**20.**	(C)
21.	(D)	**22.**	(C)	**23.**	(C)	**24.**	**(All options are incorrect)**		
25.	(D)	**26.**	(B)	**27.**	(C)	**28.**	(C)	**29.**	(A)
30.	(D)	**31.**	(C)	**32.**	(C)	**33.**	(C)	**34.**	(A)

PART - III

1.	(C)	**2.**	(C)	**3.**	(B)	**4.**	(C)	**5.**	(C)
6.	(B)	**7.**	(B)	**8.**	(D)	**9.**	(BD)	**10.**	(ABD)
11.	(AD)	**12.**	(AC)	**13.**	(ABC)	**14.**	15	**15.**	6
16.	4	**17.**	1	**18.**	(B)	**19.**	(B)	**20.**	(D)
21.	(A)								

APSP Solutions

PART - I

1. Using $P_1V_1 = P_2V_2$; $1 \times 2.5 = 0.5 \times P_2 = 5$ bar.

$\therefore$ % increase in pressure = $\frac{(5-1)\text{bar}}{1\text{bar}} \times 100\% = 400\ \%$.

2. Given, $\sqrt{\frac{8RT}{\pi M_A}} = \sqrt{\frac{3RT}{M_B}}$ $\Rightarrow$ $8M_B = 3\pi\ M_A$

& $\sqrt{\frac{3RT_A}{M_A}} = \sqrt{\frac{3RT_B}{M_B}}$ $\Rightarrow$ $\frac{T_A}{M_A} = \frac{T_B}{M_B}$ $\Rightarrow$ $M_B.T_A = M_A.T_B$

$\Rightarrow$ $\frac{3\pi}{8} M_A.T_A = M_A.T_B$ $\Rightarrow$ $T_B > T_A$ Hence (2)

3. $\sqrt{\frac{8RT}{\pi M}} = 2\sqrt{\frac{8 \times R \times 300}{\pi M}}$ $\Rightarrow$ T = 1200 K = 927ºC

4. 100 P = 0.2 P × 100 + 0.2 P × V

$\frac{1000}{2}$ = 100 + V

V = 400 ml

5. PV $\propto$ T

6. $U_{MPS} = \sqrt{\frac{2RT}{M}}$; $U_{RMS} = \sqrt{\frac{3RT}{M}}$; $U_{av} = \sqrt{\frac{8RT}{\pi M}}$

7.

	N_2	+	$3H_2$	$\longrightarrow$	$2NH_3$
t = 0	1 mole		4 mole		0
$t = t_{final}$	0		1 mole		2 mole

NH_3 will absorb by water and volume will be 15 – 5 = 10 L

$P = \frac{nRT}{V} = \frac{1 \times 0.0821 \times 300}{10}$ atm

8. (1) Total moles = $\frac{1 \times 0.2}{RT}$ (2) Total moles = $\frac{1 \times 0.2}{RT}$

(3) Total moles = $\frac{0.5 \times 100}{RT}$ (4) Total moles = $\frac{2 \times 0.1}{RT}$

9. $n_{Total} = \frac{PV}{RT} = \frac{1 \times 2}{0.0821 \times 299}$ = 0.081 moles

$X_{H_2} = \frac{n_{H_2}}{n_{total}} = \frac{0.0788}{\frac{0.0821}{2} \times 299}$ = 0.967

10. K.E. $\propto$ Temperature

11. $\left[\frac{3}{2}nRT\right]_{He} = \frac{3}{2}nRT$

0.3 T = 0.4 × 400

T = 533 K

12. $V = \frac{15}{56} \times \frac{1}{2} \times \frac{0.0821 \times 295}{1}$ = 3.24 L

13. PV = nRT

$\frac{P}{3} \times 2V = nRT$

$T' = \frac{2}{3}T$

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

$\frac{V_0}{273} = \frac{V_2}{283}$ $\Rightarrow$ $V_2 = \frac{283}{273}V_0$

15. (2) Frequency of collision will increase.

16. $\frac{P_{N_2}}{P_{CO}} = \frac{X_{N_2}}{X_{CO}}$ $\frac{n_{N_2}}{n_{co}} = \frac{x \times 28}{28 \times x} = 1$ $P_{N_2} = P_{co}$

Where x_{N_2}, x_{CO}, is mole fraction of N_2 & CO and x is wt. of N_2 & CO taken.

17. Average K.E. = $\frac{3}{2}$RT and T is constant 298 K

$\therefore$ K.E. is same for all gases at same Temperature.

18. $\frac{n_A T_A}{n_B T_B} = \frac{m}{2} \times \frac{44}{m} \times \frac{300}{600}$

19. Net pressure of gas = P_{gas}

P_{gas} = 650 mm.

$\frac{P_1 V_1}{T_1} = \left(\frac{P_2 V_2}{T_2}\right)_{STP}$

$\frac{650 \times 50}{291} = \frac{760 \times V_2}{273}$

V_2 = 40.11 ml

P_1 = 9 atm $\quad$ P_2 = 6 atm

V_1 = 5 Lt. $\quad$ V_2 = 10 Lt.

20. $n_{N_2} > n_{O_2}$ where 'n' is no of moles of gases.

$\Rightarrow$ $P_{N_2} > P_{O_2}$ because $P_{gas} \alpha$ n.

22. No. of moles of N_2 = $\frac{7}{28} = \frac{1}{4}$

No. of moles of H_2 = 1 Mole

Total moles = $\frac{1}{4} + 1 + \frac{1}{8}$

$= \frac{1}{8}(2 + 8 + 1) = \frac{11}{8}$

No. of moles of SO_2 = $\frac{1}{8}$ moles

$P = \frac{nRT}{V} = \frac{11}{8} \times \frac{0.0821 \times 300}{6} = 5.64 \approx 5.7$ atm.

23. Let Temp (T) where V_{rms} of N_2 = V_{rms} of C_3H_8 at STP

$= \sqrt{\frac{3RT_1}{M_{N2}}} = \sqrt{\frac{3RT_2}{M_{C_3H_8}}} = \sqrt{\frac{3 \times 8.314 \times 273}{44 \times 10^{-3}}}$

$= \sqrt{\frac{3RT_1}{M_{N2}}} = 393.38$

T_1 = 173.72 K

24.

	$2CO$	+	$O_2 \longrightarrow$	$2CO_2$
	30/22.4		10/22.4	
O_2 is limiting reagent	10/22.4		0	20/22.4

$\therefore$ at the end of reaction CO_2 = 20 L

CO = 10 L

25. $C_nH_{3n}O_m + yO_2 \longrightarrow nCO_2(g) + \frac{3n}{2} H_2O\,(l)$

Contraction in volume = Contraction in moles of gas = $1 + \frac{3n}{4} - \frac{m}{2}$

$\Rightarrow \left(2n + \frac{3n}{2} - m\right) \times \frac{1}{2} = y \quad \Rightarrow \quad n + \frac{3n}{4} - \frac{m}{2} = y$

26. No. of molecules in 22.4 L at STP is 6.02×10^{23} = 1 mole of gas.

27. $P = \frac{nRT}{V} = \frac{2 \times 0.0821 \times 546}{44.8} = 2$ atm

28. $V_{rms} \propto \frac{1}{\sqrt{M}}$ 'M' is Molecular wt.

Order of M.wt. = $H_2 < N_2 < O_2 <$ HBr

$\therefore$ Order of V_{rms} = $H_2 > N_2 > O_2 >$ HBr.

29. moles of O_2 in 4 mole (H_2SO_4) = 4 × 2
moles of O_2 in 2 mole (P_4O_{10}) = 10
moles of O_2 in 2 mole (NO_2) = 2
$\therefore$ total moles of O_2 = 20 mole
$\because$ volume of 20 mole at 1 atm = 22.4 × 20 L
$\therefore$ at 2 atm = $\frac{1}{2}$ × 22.4 × 20 = 224 L

30. mole of H_2 = $\frac{3\times16.42}{0.0821\times300}$ = 2 ; mole of D_2 = $\frac{6\times16.42}{0.0821\times300}$ = 4
Average molecular weight = $\frac{2\times2+4\times4}{4+2}$ = $\frac{10}{3}$

PART - III

1. Intercept on y-axis = $\log_{10}\frac{nR}{V} = \log_{10}\frac{10\times0.821}{8.21} = -10$
$\frac{P}{T}$ v/s curve $\frac{P}{T} = \frac{nR}{V}$
Intercept = $\frac{nR}{V} = \frac{10\times0.821}{8.21}$ = 0.1, slope = 0

2. $d_A = 2d_B$; $3M_A = M_B$; PM = dRT

$$\frac{P_A}{P_B}\times\frac{M_A}{M_B}=\frac{d_A}{d_B}\times\frac{RT}{RT}$$

$$\frac{P_A}{P_B}\times\frac{1}{2}=2$$

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

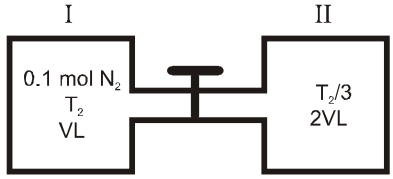
3. $V_1 = V$, $T_1 = 300$ K, $T_2 = 500$ K, V_2 = ?
At constant pressure $V_1T_2 = V_2T_1$
$\therefore$ $V_2 = \frac{P_1T_2}{T_1} = \frac{V\times500}{300} = \frac{5V}{3}$

$\therefore$ Volume of air escaped = final volume – initial volume = $\frac{5V}{3} - V\,\frac{2V}{3}$

$\therefore$ % of air escaped = $\frac{2V/3}{5V/3}$ × 100 = 40%

4. Pressure of Total mixture = 10 atm
$P_A + P_B + P_C = 10$
$3 + 1 + P_C = 10$ $\Rightarrow$ $P_C = 6$ atm
Total moles of mixture = 10
$n_A + n_B + n_C = 10$
$\frac{P_A}{P_B}=\frac{n_A}{n_B}=\frac{3}{1}$ $\Rightarrow$ $\frac{P_B}{P_C}=\frac{n_B}{n_C}=\frac{1}{6}$
Let n_A = K $\Rightarrow$ $n_B = \frac{K}{3}$ $n_C = \frac{1}{6}$ n_B = 2K
$\Rightarrow$ K + $\frac{K}{3}$ + 2K = 10 $\Rightarrow$ $\frac{K}{3}=\frac{n_C}{6}$ $\Rightarrow$ n_C = 2K
$\Rightarrow$ $K\left(\frac{10}{3}\right)$ = 10 K = 3, $\Rightarrow$ n_A = 3
n_B = 1
n_C = 6
weight of 'C' in mixture = 2 × 6 = 12.

5. Let x moe of N_2 present into vessel II and P is final pressure of N_2



$P(2V) = xR(T_2/3)$ and $P(V) = (0.1 - x)RT_2$

$\Rightarrow \quad 2 = \frac{x}{3(0.1 - x)}$

$\Rightarrow \quad x = 0.6/7$ mole,

$\frac{0.6}{7} \times 2.8 \quad \Rightarrow \quad 2.4$ g N_2

II has 2.4 g N_2 and I has 0.4 g of N_2 ;

$\frac{W_I}{W_{II}} = \frac{0.4}{2.4} \Rightarrow 1 : 6$

7. H_2 gas is greater than diffuses into balloon because rate of diffusion of H_2 is greater than the rate of diffusion of ethyne. Hence, it is enlarged.

8. Volume of CO_2 = 20 ml (absorbed gas by KOH)
Volume of air unreacted = 95 – 20 = 75 (gas abosrbed by pyrogallol)
$\therefore$ O_2 reacted = 100 + 75 = 25 ml
$\because$ 10 ml hydrocarbon libarates 20 ml CO_2.
$\therefore$ 2 atoms of 'C' are present in the compound.

$\therefore \quad C_2H_x + yO_2 \longrightarrow 2CO_2 + H_2O$

	C_2H_x	yO_2	$2CO_2$	H_2O
initial	10 ml	25 ml		
final	0	0	20	10 ml

volume of water vapours = (25 – 20) × 2 = 10 ml
$\because$ 10 ml hydrocarbon gives 10 ml water vapours.
$\therefore$ No. of Hydrogen atoms in compounds are 2.
$\therefore$ Compound will be C_2H_2.

10. (A) $\therefore$ area under the curve gives fraction of molecules and total area is constant.
(B) U_{mps} decreases with decrease in temperature.
(C) T_2 is higher temperature
(D) As seen from graph ; $\quad \therefore$ A, B, D

11. When $\frac{T_A}{M_A} = \frac{T_B}{M_B}$ or $T_AM_B = T_BM_A$

$(PV)_A = nRT$ or $\frac{W_A}{M_A}RT_A$ and $(PV)_B = \frac{W_B}{M_B}RT_B$

$\therefore$ When $W_A = W_B$
$(PV)_A = (PV)_B$

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

$\therefore \quad U_A = \sqrt{\frac{3RT_A}{M_A}} \quad ; \quad U_B = \sqrt{\frac{3RT_B}{M_B}}$

$\therefore \quad U_A = U_B \quad \left(\frac{T_A}{M_A} = \frac{T_B}{M_B}\right)$

12. $P_T = X_AP^\circ_A + X_BP^\circ_B$

$8 = \frac{3}{8}P_A + \frac{5}{8}P_B$

$\frac{P_A}{P_B} = \frac{3}{5} \quad \therefore \; P_A = 3$ atm ; $P_B = 5$ atm

14. After a very long time

$\Rightarrow$ P_{H_2} will be same in all the compartments

$\Rightarrow$ P_{O_2} will be same in (i) & (ii) compartment

$\Rightarrow$ P_{N_2} will be same in (ii) & (iii) comportment

Compartment	(i)	(ii)	(iii)
	O_2 = 2 mole	H_2 = 3 mole	H_2 = 3 mole
	H_2 = 3 mole	O_2 = 2 mole	N_2 = 1 mole
		N_2 = 1 mole	

Ratio of Pressure = Ratio of moles = 5 : 6 : 4 ($\because$ V & T is same)

a + b + c = 5 + 6 + 4 = 15

15. $u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3P}{d}}$ d = $\frac{PM}{RT}$

$\Delta u_{rms} = \sqrt{\frac{3}{d}}(\sqrt{P_2} - \sqrt{P_1})$ = 2 × 3 = 6 m/sec.

16. $\underset{1-\alpha}{A(g)} \longrightarrow \underset{2\alpha}{2B(g)} + \underset{\alpha}{C(g)}$

$\frac{r_B}{r_A} = \frac{2}{1} = \frac{2\alpha}{1-\alpha} \times \sqrt{\frac{16}{4}}$ $\Rightarrow \alpha = \frac{1}{3}$

$K = \frac{1}{10}\, ln\, \frac{3}{2} = \frac{0.4}{10}$ = 0.04 sec^{-1}

17. Mole atoms of X = 0.75 × 4 = 3

Mole atoms of O = 2 × 2 = 4

Hence the product is X_3O_4 (g)

Initial moles of gaseous reactants, n_1 = 2 (oxygen only)

Final moles of gaseous product, n_2 = 1 (X_3O_4)

Hence, $\frac{P_2}{P_1} = \frac{n_2T_2}{n_1T_1} = \frac{1\times600}{2\times300}$ = 1 or $P_2 : P_1$: 1 : 1

18. (A) Temperature decreases during process A to B, so RMS speed decreases (V_{RMS})

(B) $d_{gas} = \frac{PM}{RT}$. Upon moving from A to B, P increases and temperature decreases. So, density of gas increases.

(C) This graph is possible if during the process : $P \propto \frac{1}{V^{1/2}}$.

$\because$ PT = Constant $\therefore$ $P\left(\frac{PV}{nR}\right)$ = Constant $\therefore$ P^2V = Constant or $PV^{1/2}$ = Constant

(D) If $P_B = 4P_A$, then $V_A = 16V_B$ (according to P^2V = Constant for process)

19. Equation of straight line :

$(y - y_1) = \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x - x_1)$

$(P - 16) = \left(\frac{4-16}{15-6}\right)(V - 6)$

3P + 4V = 72

$T_{max} = \frac{(PV)_{max}}{nR}$

For $(PV)_{max}$, $3P = \frac{72}{2}$ and $4V = \frac{72}{2}$

P = 12, V = 9

$T_{max} = \frac{12\times9}{1\times(1/12)}$ = 648K.

20. (A) This graph is possible if temperature of gas is kept constant and pressure is increased from A to B.
(B) This graph is possible if temperature of gas is increased continuously during the process A to B.
(C) This graph is possible if during the process : $P \propto \frac{1}{V^2}$

$\because$ VT = constant $\therefore$ $V\left(\frac{PV}{nR}\right)$ = Constant or PV^2 = constant.

21. $y = \frac{1}{V^2}$ or $\sqrt{y} = \frac{1}{V}$

$P = x$ and $P = \frac{\text{constant}}{V}$

(A) $x = (k)\sqrt{y} \Rightarrow y = k^1x^2$

(B) $V = kT$; $y = V$ & $\frac{1}{T} = x \therefore y = \frac{k}{x}$

(C) $P = kT$; $PT = kT^2$ or $y = kx$

(D) $v = \frac{c}{p} \Rightarrow y = c\sqrt{x}$; $y^2 = cx$