CHAPTER : 04.

STATES OF MATTER. I

GASES.

INTRODUCTION:-

MATTER :-

Any thing, which occupy some space is known as MATTER.

STATES OF MATTER :-

There are Four states of matter

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i. Solid.
ii. Liquid.
iii. Gas. (State of matter having neither constant vol. nor constant shape).
iv. Plasma (A Partially ionized gas at very high temperature.)

GAS:-

The word "gas" is derived from "Chaos", means "random". This is because the gaseous particles have "Chaotic (Random) motion".

Molecules of gas travels in a straight line untill they collide with each other or with the walls of container. This movement of molecules of gas is called "BROWNIAN MOVEMENT" (Robert Brown 1827)

PROPERTIES :-

Gases have following Properties :-

1. Indefinite Volume :-

Gases have **indefinite** volume, because in gases, distance b/w the molecules is very large.

2. Indefinite Shape :-

Gases have **indefinite** shape, because they adapt the shape of container just like Liquid.

3. Low Density :-

Gases have low **density** as compared to solids and liquids, Therefore, gases **bubbled** through Liquids.

4- Rate Of Diffusion OR Effusion:-

Gases have **high** rate of diffusion or effusion as compared to liquids and solids.

5. Compressability:-

when **pressure** is applied on gas molecules, volume of gas **decreases.** This property is called Compressability.

6- Thermal Expansion:-

when gas is **heated**, volume of the gas **increases.** This property is called Thermal Expansion.

7- Joule-Thomson Effect:-

when a compressed gas **suddenly expands**, its **Temperature falls down.** This effect is called Joule-Thomson Effect.

8- Pressure Of A Gas:-

Gas molecules collide with each other and also collide with the walls of container. They exert a force on the wall. This force acting on per unit area is called Pressure of a Gas. Pressure of a Gas is **directly** Proportional to no. of Collision (ٹکراؤ).

$$P = \frac{F}{A}$$

9- Inter-Molecular Forces:-

In gases, intermolecular forces are **negligible** (نہ ہونے کے برابر).

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KINETIC MOLECULAR THEORY OF GASES:-

The behaviour of gas as well as properties of gases can be theoretically explained by Kinetic molecular theory of gases. (Abbrevation: KMT OF GASES).

It can only explains the **Physical behaviour** of molecules, not **Chemical.**

i. This theory was put forward by **Daniel Bernoulli**, a swiss mathematician.

ii. **Clausius** derived **Kinetic Equation** on the basis of K.M.T of gases, in 1857.

iii. This theory was **extended** by **James Maxwell** (1859).

iv. **Distribution** of energies among the gas molecules was study by **Boltzmann** in 1870.

v. **Vander waal** derived **"vander waal's Equation"** on the basis of K.M.T of gases.

POSTULATES OF K.M.T OF GASES:-

This theory is based on following Postulates.

1. MOLECULE:-

Gases consists of **small particles**, which are called molecules. Molecules of noble gases are **mono-atomic**.

e.g; He, Ne, Ar, -----.

2. Collision:-

Gas molecules collide with each other and also collide with walls of container. During collision, their direction changes. This collision is perfectly **elastic** (Elastic means energy and momentum are fixed).

3. PRESSURE OF GAS:-

Gas molecules collide with each other and also collide with walls of container. They exert a **force** **on per-unit area**, this is called Pressure of a gas.

Pressure of a gas $\propto$ no. of collision.

$$P = \frac{F}{A}.$$

4. INTER-MOLECULAR SPACES:-

In gases, distance b/w molecules is **very large** (FOR CONCEPT Only normally 300 times of a diameter of one molecule). The empty Spaces b/w gas molecules are called inter-molecular spaces.

5. INTER-MOLECULAR FORCES :-

There is no force of attraction among the gas molecules.

6. ACTUAL VOLUME :-

Actual volume of the gas is negligible as compared to total volume of gas.

7. EFFECT OF GRAVITY :-

There is no effect of gravity on gas molecule.

8. KINETIC ENERGY & ABSOLUTE TEMPERATURE :-

Kinetic Energy is directly proportional to Absolute Temperature. If there are two gases at same temperature and pressure, their K.E is same.

↗★ QUESTION :-

Point out the faulty Postulates/Assumptions of K.M.T of Gases?

Ans: The following are the faulty postulates of K.M.T of gas:-

1. Inter-molecular Forces :-

There is no force of attraction among the gas molecules.

2. ACTUAL VOLUME :-

Actual volume of a gas is negligible as compared to total volume of a gas.

These postulates are true under normal condition, but under high pressure and low temperature, these are not true.

Q- what is Kinetic Equation?

Ans. Kinetic Equation:-

R.J Clausius derived Kinetic equation on the basis of K.M.T of gases, to explain the pressure of a gas.

According to Clausius:-

"Gas molecules collide with each other, they also collide with the walls of the container. They exert a force on the wall. This force acting per unit area is called pressure of a gas."

Mathematically:

$$PV = \frac{1}{3} mN\bar{C}^2$$

where;

P = Pressure of a gas.
V = Volume of a gas.
m = Mass of one molecule of a gas.
N = No. of molecules.
$\bar{c}^2$ = Mean Square velocity.

Q. what is "Mean Square Velocity"?

Ans. Velocity of each gas molecule is different, therefore, mean square velocity is used. It is defined as;

"Average Square of all the velocities is called mean square velocity."

e.g; n_1 is the no. of mol. having velocity = C_1
n_2 " " " " " " = C_2
n_3 " " " " " " = C_3

so;

$$\bar{C}^2 = \frac{C_1^2 + C_2^2 + C_3^2 - - - -}{n_1 + n_2 + n_3 - - -}$$

ROOT MEAN SQUARE VELOCITY:-

It is the square root of mean square velocity is called "root mean square velocity".
It is denoted by $C_{r.m.s}$.

Mathematically;

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

★ MOTION OF MOLECULES:-

According to K.M.T of gases, the gaseous molecules are always in a state of haphazard motion. As a result, due to their motion, they will have certain K.E. The increase or decrease of temp. will increase or decrease their motion.
In gases, the molecular motion is of three types:

i. **Translational Motion:-**
Motion in which molecules move in straight direction untill to collision.
K.E due to this type of motion is called "Translational K.E."

ii. **Vibrational Motion:-**
Motion due to oscillation of molecules is called Vibrational motion. It is also called "to and fro motion."

iii. **Rotational Motion:-**
Motion due to net angular momentum about their axis of gravity is called rotational motion.

Note:-
The vibrational motions in poly-atomic molecules (CO_2, NH_3 etc.) are quite complicated.

ABSOLUTE TEMPERATURE SCALE ON THE BASIS OF CHARLE'S LAW:-

According to Charle's law, when temp. is increased or decreased by 1°C, volume of the gas changes 1/273 or 2cm³ of its original volume.

Mathematically;

$$V_T = V_o\left(1 + \frac{T}{273}\right)$$

where; V_T = volume at temp. T
V_o = " " " 0°C
T = Temp. in °C.

when Temp. is decreased to -273.15°C, volume of a gas becomes theoretically zero, but practically, it is not possible, because gases are changed into liquid or solid before this temp.

Lord Kelvin (1824–1907) succeeded in measuring the gas with the help of a new scale, called "Absolute Kelvin Temp. scale" or 'Kelvin Temp. scale'. According to this scale, -273.15°C is the starting point of the scale.

Mathematically;

$$K = °C + 273.$$
$$°C = K - 273.$$

Example 4.1:-

Convert the following Celsius Temp. to Kelvin Temp.

Solution:

a- -132°C :-
$K = °C + 273$
$= -132 + 273$
$K = 141\ TK.$

b- 96°C :-
$K = °C + 273.$
$= 96 + 273.$
$K = 369\ TK.$

c- 0°C :-

$K = {}^\circ C + 273$

$= 0 + 273$

$K = 273$ TK.

d- -12°C :-

$K = {}^\circ C + 273$

$= -12 + 273$

$K = 261$ TK.

e- 148°C :-

$K = {}^\circ C + 273.$

$= 148 + 273$

$K = 421$ TK.

Example 4.2:-

Convert The following Temp. from K To °C.

Solution:-

a- 340 TK :-

$T^\circ C = K - 273$

$= 340 - 273$

$T^\circ C = 67\,^\circ C.$

b- 200 TK :-

$T^\circ C = K - 273.$

$= 200 - 273.$

$T^\circ C = 73\,^\circ C.$

c- 10 TK :-

$T^\circ C = 10 - 273$

$= -263\,^\circ C.$

d- 405 TK :-

$T^\circ C = 405 - 273$

$= 132\,^\circ C.$

✓ Relationship b/w Temperature and Average K.E of Particles in gas:-

The Temp. of a gas depends upon K.E of The molecules. The increase of Temp. increases The average K.E of The molecules and vice versa.

v.Imp** Q- Derive a relationship b/w average K.E and Absolute Temp.

According To Kinetic Equation:

$$PV = \frac{1}{3} mN\bar{c}^2 \longrightarrow ①$$

$$K.E = \frac{1}{2} m\bar{c}^2.$$

$$PV = \frac{2}{2} \times \frac{1}{3} m N \bar{c}^2 . \quad (\because \text{ Xing \& dividing by '2'}$$

$$= \frac{2N}{3}\left(\frac{1}{2} m c^2\right).$$

$$PV = \frac{2}{3} N . K.E.$$

For one mole; $N = N_A$.

$$PV = \frac{2}{3} N_A . K.E \longrightarrow ②.$$

According to ideal gas equation;

$$PV = nRT.$$

For one mole; $n = 1$.

$$PV = RT.$$

eq. ② becomes.

$$\frac{2}{3} . N_A . K.E = RT.$$

$$K.E = \frac{3RT}{2N_A}$$

$$K.E = K.T \qquad \text{where; } \frac{3R}{2N_A} = K.$$

$$\boxed{K.E \propto T}.$$

CONCLUSION:-

The Kelvin temp. of a gas is actually the measure of average translational kinetic energy of its mol. In gases and liquids, the temp. explains the average translational energy of mol. In solids, where molecules can't move freely, temperature becomes a measure of vibrational K.E.

Example 4.3:-

what is the total K.E of translation in ergs of two moles of perfect gas at 27°C in calories?

Solution:-

No. of moles = 02.

Temp. = 27°C + 273 = 300K.

$R = 8.314 \times 10^7$ ergs K^{-1} mol^{-1}.

We know that;

$$K.E = \frac{3}{2} nRT$$

$$= \frac{3 \times 2 \times 8.314 \times 10^7 \times 300}{2}.$$

$$\boxed{K.E = 7483.5 \times 10^7 \text{ ergs } dm^{-3}.}$$

PRESSURE OF A GAS:-

According to KMT of gases, gas molecules collide with each other. They also collide with the walls of a container. They exert a force on the wall. This force acting per unit area is called Pressure of a gas.

UNITS OF PRESSURE OF A GAS:-

SI unit of Pressure is Pascal (Pa), in System international, unit of force is Newton (N), and unit of area is metre square (m^2). Thus One Pascal is one $N m^{-2}$.

1 atm = 101325 Pa = 101325 $N m^{-2}$.

1 atm = 14.7 Psi (Pound per square inch).

1 atm = 101.325 KPa.

1 atm = 760 Torr = 760 mm of Hg.

1 J = 1 Nm = 10^7 ergs. = $Kgm^2 s^{-2}$.

1 Cal. = 4.187 J.

Example 4.4:-

Convert 10 Pascles into.

i- Kilo Pascals.

ii- Atmosphere.

Solution:-

i- One K Pa = 1000 Pa.

or 1000 Pa = One Kilo Pascles

$$10 \text{ Pa} = \frac{1}{100} \times 10 = 0.01 \text{ Kilo Pascal.}$$

ii- One atm. = 101325 Pa.

$$10 \text{ Pa} = \frac{1}{101325} \times 10 = 0.000098 \text{ atm.}$$

EFFECT OF CHANGE IN PRESSURE ON THE VOLUME OF A GAS:-

OR

BOYLE'S LAW:-

· In the middle of the 17th centuary, Robert Boyle (1627–1691) and his assistant Robert Hooke (1635–1702) made many investigations about the relationship b/w Pressure and volume of a gas. Robert Boyle, in 1662, gave a law, which is named after him. as "Boyle's law."

According to Boyle's law;

"Volume of given mass of a gas is inversly Proportional to external Pressure, when Temp. and number of moles are Kept Constant."

Mathematically;

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

$$V = K \cdot \frac{1}{P} \Rightarrow \boxed{PV = K}.$$

According to Boyle's law, Product of Pressure and volume is always constant, at constant temp. and no. of moles.

For gas 1,

$$P_1V_1 = K \longrightarrow ①$$

For gas 2,

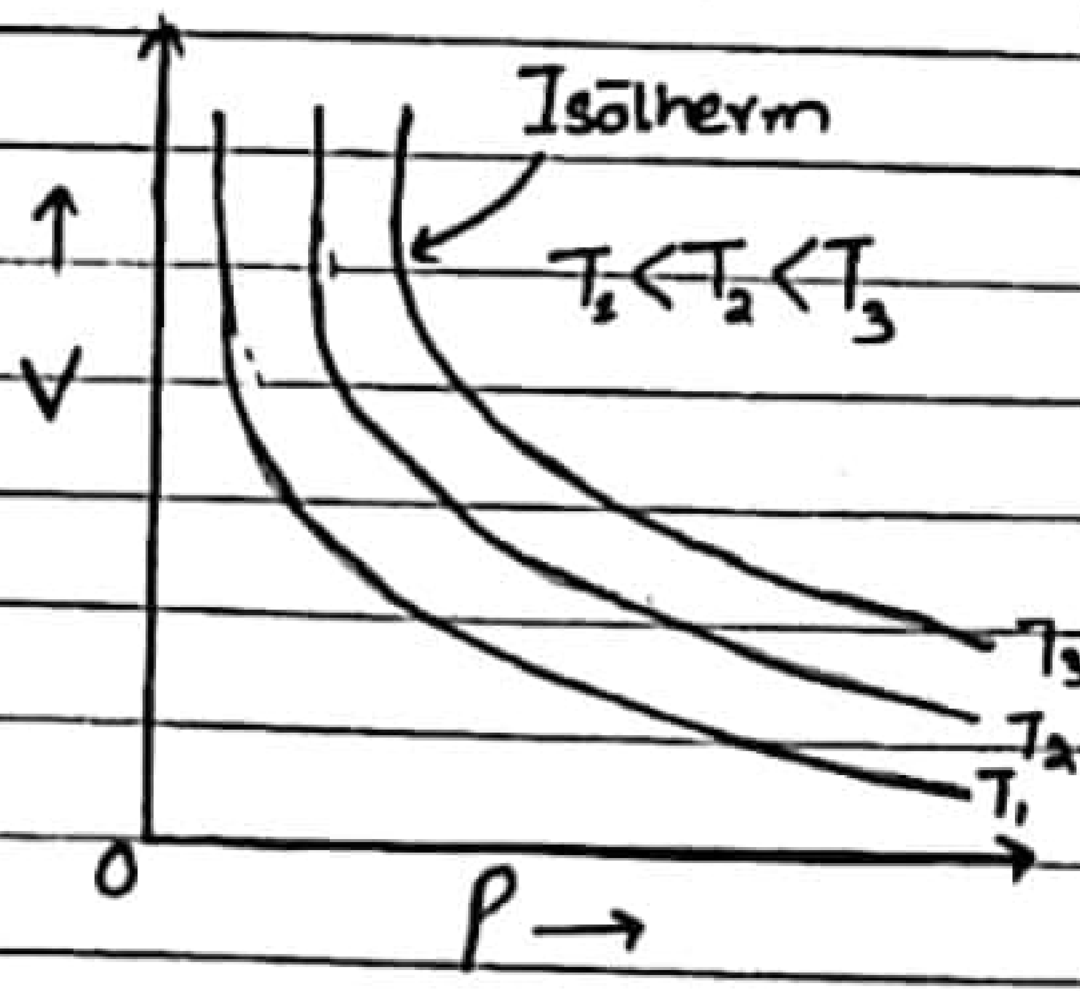
$$P_2V_2 = K \longrightarrow ②$$

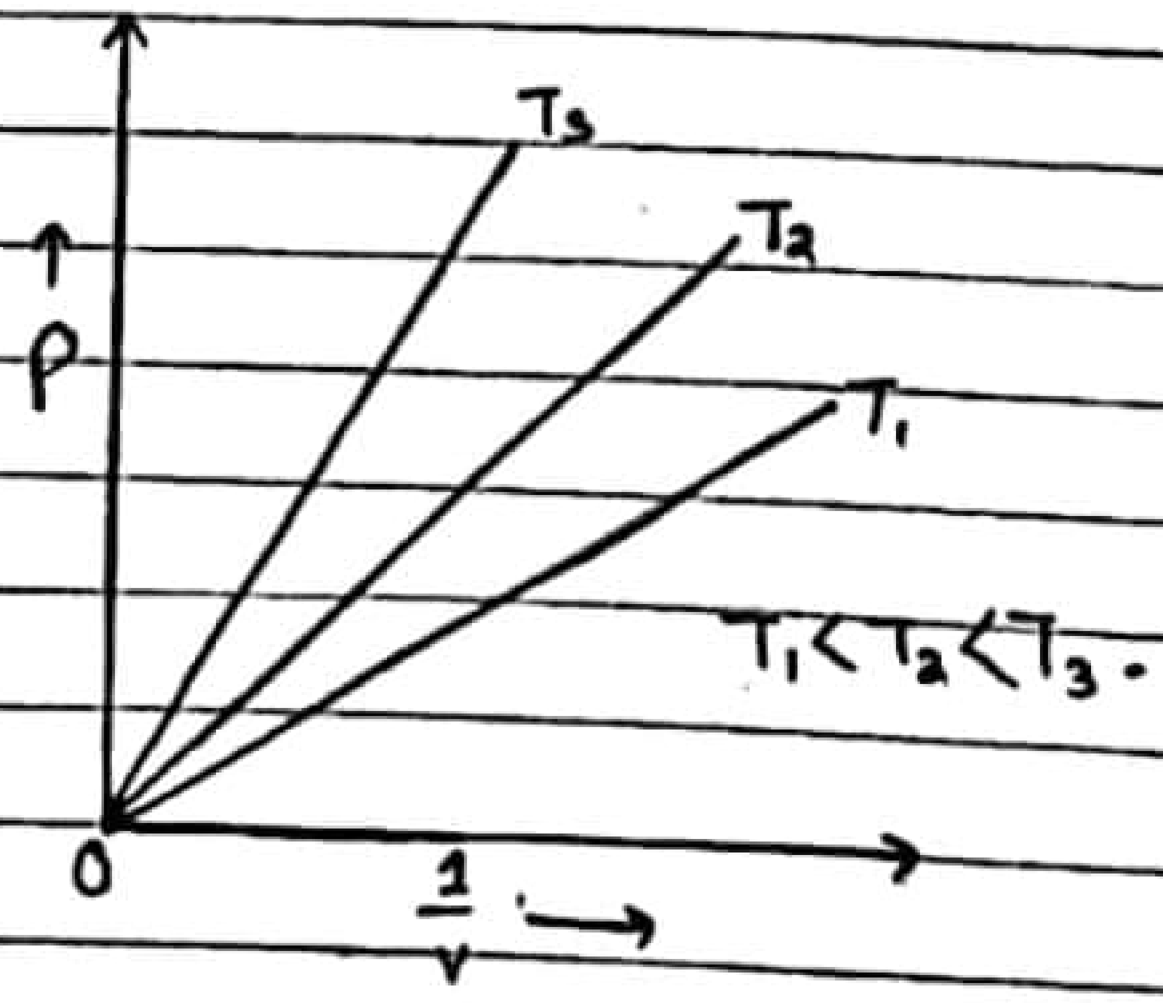
Comparing ① and ②;

$$\boxed{P_1V_1 = P_2V_2}$$

GRAPHICAL EXPLANATION :-

When the graph is plotted b/w Pressure and volume, we get a family of curves. Each curve is a hyperbola with different values of K. Each curve is known as Isotherm (Constant Temp. Plot). As the Temp. is increased, isotherm goes away from both the axis. This is because, at high temp, volume of the gas increases.





Example 4.4:-

An ideal gas occupies a volume of 0.300 dm^3 at a Pressure of 1.80×10^5 Pa. what is the volume of the gas maintained at the same temp. if the Pressure is reduced to 1.15×10^5 Pa?

Solution:-

$V_1 = 0.300\ dm^3$,

$V_2 = ?$

$P_1 = 1.80 \times 10^5\ Pa$.

$P_2 = 1.15 \times 10^5\ Pa$.

According to Boyle's law;

$$P_1V_1 = P_2V_2.$$

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

$$= \frac{0.300 \times 1.80 \times 10^5}{1.15 \times 10^5}$$

$$\boxed{V_2 = 0.469\ dm^3}.$$

Example 4.5:-

At sea level, where the Pressure was 775 Torr, the gas in a ballon occupied 2 m^3. what volume, will the ballon expand when it has risen to an altitude where the Pressure is: (a) 100 Torr (b) 10 Torr. (at Const. Temp.)

Solution:

(a)- $P_1 = 755$ Torr , $P_2 = 100$ Torr

$V_1 = 2\ m^3$, $V_2 = ?$

$$P_1V_1 = P_2V_2$$

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

$$V_2 = \frac{755 \times 2}{100} \Rightarrow \boxed{V_2 = 15.10\ m^3.}$$

(b)- $P_1 = 755$ Torr , $P_2 = 10$ Torr

$V_1 = 2 m^3$, $V_2 = ?$

$$P_1V_1 = P_2V_2.$$

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

$$V_2 = \frac{755 \times 2}{10} \Rightarrow \boxed{V_2 = 151 m^3.}$$

EFFECT OF CHANGE IN TEMPERATURE ON THE VOLUME OF GAS:-

OR

CHARLE'S LAW:-

The Thermal expansion of gases was studied by Jacques Charles (1746-1823). He derived a relationship b/w vol. of a gas and Temp. in 1787. This relationship is known as charle's law.

According to this law;

> "Volume of given mass of a gas is directly proportional to absolute Temp. when Pressure and no. of moles are kept Constant."

Critical Form Of Law:-

Volume of gas at 0°C $= V_0$

" " " " 1°C $= V_0 + V_0\left(\frac{1}{273}\right)$

" " " " 2°C $= V_0 + V_0\left(\frac{2}{273}\right)$

" " " " T°C $= V_0 + V_0\left(\frac{T}{273}\right)$

$$V_t = V_0\left(1 + \frac{T}{273}\right)$$

$$= V_0\left(\frac{273 + T}{273}\right)$$

$$V_T = V_0 \cdot \frac{T}{273}$$

$$V_T = \frac{V_0}{273} \cdot T$$

$$V_t = K \cdot T \qquad \therefore \frac{V_0}{273} = K.$$

$$\boxed{\frac{V}{T} = K}$$

For gas ①;

$$\frac{V_1}{T_1} = K \longrightarrow ①$$

For gas ②;

$$\frac{V_2}{T_2} = K \longrightarrow ②$$

Comparing ① and ②;

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

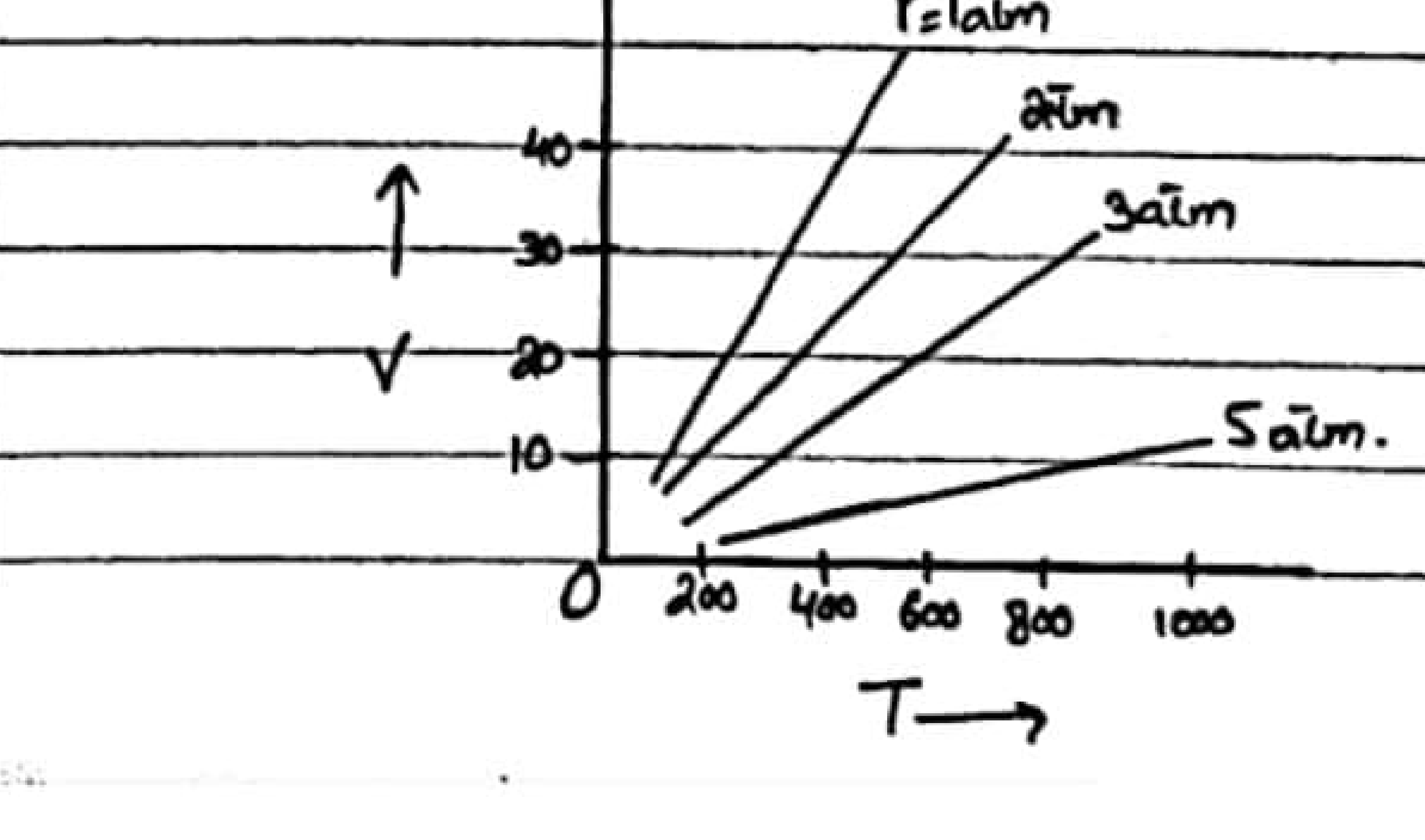
initial volume and Temp(Absolute)

→ Final Volume.

→ Absolute Temp. (in Kelvin Scale)

GRAPHICAL EXPLANATION:-

The equation of Charle's law gives a straight line proved by plotting a graph b/w volume and Temp. Different straight lines are obtained at different pressures, which are constant. Each constant pressure line is called "Isobar."



ABSOLUTE ZERO:-

Defination:-

"Temperature at which, volume of any mass of a gas becomes theoretically zero, is called Absolute zero."

It is an application of Charle's Law. According to Charle's law, when temp. is increased or decreased by 1°C, volume of the gas changes 1/273 of its original volume.

Mathematically;

$$V_t = V_0\left(1 + \frac{t}{273}\right)$$

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

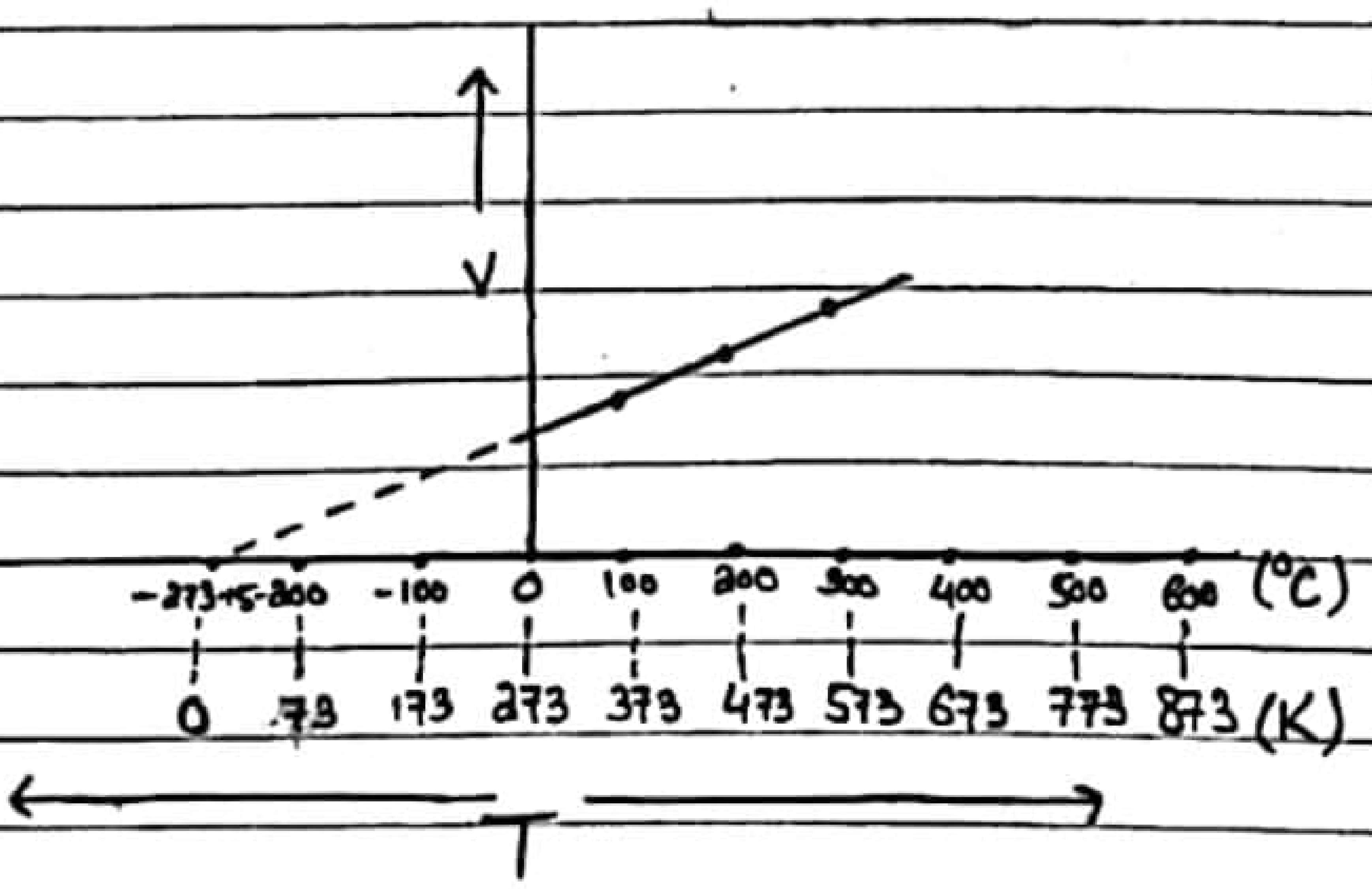
at $-273.15°C$,

$$V_t = V_0 - \frac{\cancel{273}\, V_0}{\cancel{273}}$$

$$V_t = V_0 - V_0$$

$$\boxed{V_t = 0}$$

GRAPH:-



Significance Of Absolute Zero:-

i- A Gas can not exist at Absolute zero, because, before this Temp., gas changes into liquid or solid

ii- At Absolute zero ($-273.15°C$), molecular motion of gas molecules becomes "ceased" and volume is minimum.

iii- It may be initialized to get Kelvin Temperature.

iv- Zero Kelvin is called Absolute zero, which is the lowest possible Temp.

EXAMPLE 4.6

If $50 cm^3$ of a gas in a syringe at 15°C is heated to 50°C and the piston of syringe is allowed to move outwards against constant atm. pressure, calculate the new vol. of the hot gas.

Solution:-

$V_1 = 50 cm^3$, $V_2 = ?$

$T_1 = 15°C + 273 = 288K$ $T_2 = 50°C + 273 = 323 K$.

By Charle's law

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

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

$$= \frac{50}{288} \times 323$$

$$V_2 = 56 \text{ cm}^3.$$

Example 4.7:-

At 17°C, a sample of H_2 gas occupies $125 cm^3$. what would be the vol. at 100°C? (Pressure remains Constant).

Solution:-

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

$$V_2 = \frac{V_1}{T_1} \times T_2 , \quad V_2 = \frac{125}{290K} \times 373K , \quad \boxed{V_2 = 161 \text{ cm}^3.}$$

AVOGADRO'S LAW:-

This law was proposed by an Italian Physicist Amedeo Avogadro (1776-1856) in 1811.

According to this law:-

"Equal Volume of all the gases at same Temp. and pressure contains equal no. of molecules."

OR

"Volume of given mass of a gas is directly proportional to no. of moles at constant Temp. and Pressure."

Mathematically:

$$V \propto n \quad (\text{at Const. } T \text{ and } P.)$$

$$V = Kn$$

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

For gas ①

$$\frac{V_1}{n_1} = K \longrightarrow ①$$

For gas ②

$$\frac{V_2}{n_2} = K \longrightarrow ②$$

Comp. ① and ②

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

EXAMPLES:-

1 mole of H_2 = 2.016g = 22.414 dm^3 = 6.02×10^{23} mol.

" " " CH_4 = 16g = 22.414 dm^3 = 6.02×10^{23} mol.

" " " CO_2 = 44g = 22.414 dm^3 = 6.02×10^{23} mol.

" " " Cl_2 = 71g = 22.414 dm^3 = 6.02×10^{23} mol.

Significance of Avogadro's Law:-

This law is used to find no. of molecules mass of a molecule and volume.

No. of molecules:-

$22.414\ dm^3$ of H_2 has molecules $= 6.02\times10^{23}$

$1\ dm^3$ " " " " $= \frac{6.02\times10^{23}}{22.414} = 2.68\times10^{22}$ mol.

Mass of molecule:-

$22.414\ dm^3$ of H_2 has mass $= 2.016\ g$

$1\ dm^3$ " " " $= \frac{2.016}{22.414}\ g = 0.09 g.$

Volume:-

$2.016\ g$ of H_2 has volume $= 22.414\ dm^3$

$1\ g$ of " " " $= \frac{22.414}{2.016}$

$0.09g$ " " " " $= \frac{22.414\times0.09}{2.016}$

$= 1.000625\ dm^3.$

Q- What is "Ideal" OR "General" Gas Equation.

ideal gas equation is a combination of three laws.

i- Boyle's law ii- Charle's Law iii- Avogadro's law.

According to Boyle's law;

$$V \propto \frac{1}{P} \rightarrow ① \text{ (when } T \ \& \ n \text{ are const.)}$$

According to Charle's law;

$$V \propto T \text{ (when } P \ \& \ n \text{ are const.)} \rightarrow ②$$

According to Avogadro's law;

$$V \propto n \text{ (when } T \ \& \ P \text{ are const.)} \rightarrow ③$$

Comparing ①, ② and ③;

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

$$V = \frac{RTn}{P} \Rightarrow \boxed{PV = nRT}$$

For one mole; $n = 1$

$$\boxed{PV = RT}$$

$$\boxed{R = \frac{PV}{T}}$$

For gas ①;

$$\frac{P_1V_1}{T_1} = R \rightarrow ③$$

For gas ②;

$$\frac{P_2V_2}{T_2} = R \rightarrow ④$$

Comparing ③ and ④;

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

Standard Temperature and Pressure (S.T.P):-

Ideal gas equation enables us to calculate the effect of a change in temp. and pressure on the vol. of gas. Gas volumes are usually compared at 0°C (273 K) and 1 atm. These conditions are referred to as standard temp. and pressure (S.T.P).

Significance of Ideal gas Equation:-

ideal gas equation helps us to determine (i) Molecular mass of a gas (ii) Density of a gas.

1. Molecular Mass (M):-

According to ideal gas eq.

$$PV = nRT$$

where; $n = \frac{W}{M}$ ∴ W = mass of gas.
M = Mol. mass of gas.

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

$$\boxed{M = \frac{WRT}{PV}}$$

It means, when W, T, P & V are known, M can be calculated (R is constant).

2. **DENSITY OF GAS (d) :-**

According to ideal gas equation;

$$PV = nRT.$$

$$\therefore \quad n = \frac{W}{M}.$$

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

$$PV = dRT \qquad \therefore d = \frac{W}{M}$$

$$\boxed{d = \frac{PV}{RT}}$$

It means that, if P, V and T are known, d can be calculated (R is constant).

NUMERICAL VALUE OF "R" :-

According to ideal gas eq.

$$PV = nRT$$

$$R = \frac{PV}{nT}$$

One mole of a gas at S.T.P occupy vol. = 22.414 dm^3.

$$n = 1$$

$$T = 0°C = 273\ K$$

$$P = 1\ atm$$

$$R = \frac{PV}{nT} = \frac{1\ atm \times 22.414\ dm^3}{1\ mole \times 273\ K}.$$

$$R = 0.0821\ atm\,dm^3\,mol^{-1}\,K^{-1} \longrightarrow ①$$

we know that, 1 atm = 760 torr.

$$R = 0.0821 \times 760\ torr\ dm^3\ mol^{-1}\ K^{-1}.$$

$$R = 62.4\ torr\ dm^3\ mol^{-1}\ K^{-1} \longrightarrow ②$$

$$1\ torr = 1\ mm\ of\ Hg.$$

$$R = 62.4\ mm\ of\ Hg\ dm^3\ K^{-1}\ mol^{-1} \longrightarrow ③$$

2. Density of Gas (d) :-

According to ideal gas equation;

$$PV = nRT.$$

$$\therefore \quad n = \frac{W}{M}.$$

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

$$PV = dRT \qquad \therefore \; d = \frac{W}{M}$$

$$\boxed{d = \frac{PV}{RT}}$$

It means that, if P, V and T are known, d can be calculated (R is constant).

NUMERICAL VALUE OF "R" :-

According to ideal gas eq.

$$PV = nRT$$

$$R = \frac{PV}{nT}$$

One mole of a gas at S.T.P occupy vol. = 22.414 dm^3.

$$n = 1$$

$$T = 0°C = 273\,K$$

$$P = 1\,atm$$

$$R = \frac{PV}{nT} = \frac{1\,atm \times 22.414\,dm^3}{1\,mole \times 273\,K}.$$

$$R = 0.0821\; atm\,dm^3\,mol^{-1}\,K^{-1} \longrightarrow ①$$

we know that, 1 atm = 760 torr.

$$R = 0.0821 \times 760 \; torr\,dm^3\,mol^{-1}\,K^{-1}.$$

$$R = 62.4 \; torr\,dm^3\,mol^{-1}\,K^{-1} \longrightarrow ②$$

1 torr = 1 mm of Hg.

$$R = 62.4 \; mm\ of\ Hg\ dm^3\,K^{-1}\,mol^{-1} \longrightarrow ③$$

$1\,dm^3 = 1000\,cm^3.$

$R = 62.4 \times 1000$ torr $cm^3\,K^{-1}\,mol^{-1}$

$R = 62400$ torr $cm^3\,K^{-1}\,mol^{-1} \longrightarrow$ ④

SI-unit of R:-

$$R = \frac{PV}{nT}.$$

$n = 1$

$V = 0.022414\,m^3$

$P = 1\,atm = 101325\,Nm^{-2}.$

$T = 273\,K.$

$$R = \frac{101325\,N\cancel{m^{-2}} \times 0.022414\,\cancel{m^3}}{1\,mol. \times 273\,K}$$

SI-unit ⇒ $\boxed{R = 8.314\,Nm\,mol^{-1}\,K^{-1}} \longrightarrow$ ⑤

$1\,Nm = 1\,J$

$R = 8.314\,J\,mol^{-1}\,K^{-1}. \longrightarrow$ ⑥

$1\,J = 10^7$ ergs.

$R = 8.314 \times 10^7$ ergs $K^{-1}\,mol^{-1} \longrightarrow$ ⑦

1 Calori = $4.184\,J.$

$$R = \frac{8.314}{4.184}\ cal.\ K^{-1}\,mol^{-1}.$$

$R = 1.987$ cal. $K^{-1}\,mol^{-1} \longrightarrow$ ⑧.

DEVIATION FROM IDEAL GAS BEHAVIOUR:-

↗	IDEAL GAS	NON-IDEAL OR REAL GAS.
i.	Gas, which obeys gas laws and ideal gas equation under all conditions of Temp. and Pressure. There is no gas which is perfectally ideal.	i. Gas, which do not obey gas laws and ideal gas equation under all conditions of Temp. & pressure. All gases exisits in nature are non-ideal or real.
ii.	There is no force of attraction b/w mol. of ideal gas.	ii. There is force of attraction b/w mol. of real gas.
iii.	Ideal gas can't be converted To liquid.	iii. Real gas can be converted To liquid.
iv.	Compressability factor of ideal gas always "unity". $\frac{PV}{RT} = 1$	iv. Compressability factor of real gas doesn't equal To one. $\frac{PV}{RT} \neq 1$
v.	Ideal gas do not obey Joule-Thomson Effect.	v. Real gas obeys Joule-Thomson Effect.
vi.	High Temp. and low pressure makes The gases ideal.	vi. Low Temp. and high pressure makes The gases non-ideal.

Q. Why Real gases deviate from Gas laws.

Ans. Real gases do not obey gas laws due To Two wrong assumptions of KMT of gases.

i. There is no force of attraction among gas mol.

ii. Actual volume of gas molecule is negligible as Compared To Total vol. of gas.

↗ These assumptions are True under normal conditions but not True under low Temp. and high Pressure.

↗ **Deviation under low Temperature:-**

At high Temp., the K.E of the gaseous molecules is very high. As a result, the attractive forces b/w the gas mol. is negligible. But at low Temp., the K.E of gas mol. decreases. The intermolecular forces b/w gas mol. become significant. It means that intermolecular forces b/w gas mol. increase.

Examples:-

SO_2 gas liquifies at -10°C while H_2 at -252.7°C. Therefore attractive forces b/w SO_2 mol. can't be considered negligible at room Temp. For this reason, SO_2 gas shows non-ideal behaviour at room Temp. as compared to H_2 gas.

↗ **Deviation under high Pressure:-**

At low pressure, actual vol. of gas mol. is very small as compared to total vol. of container. However, this vol. does not remains negligible at high pressure.

Example:-

When pressure is one atm, individual vol. of one mole of gas mol. say 32 cm^3 is negligible as compared to Total vol. of gas 22400 cm^3. But if pressure on it increased to 100 atm, the vol. of gas is reduced to 224 cm^3. Under this pressure, individual vol. of gas mol. (32 cm^3) is not negligible as compared to vol. at 100 atm (244 cm^3).

GRAPHICAL EXPLANATION:-

For one mole of a gas, if graph is plotted b/w PV/RT and Pressure, then for an ideal gas, it must give a straight line (Temp. remains 0°C). But actually it is seen that the gases do not gives a straight line. They deviate from their original behaviour as shown in graph.

According to ideal gas eq.

$$PV = nRT$$

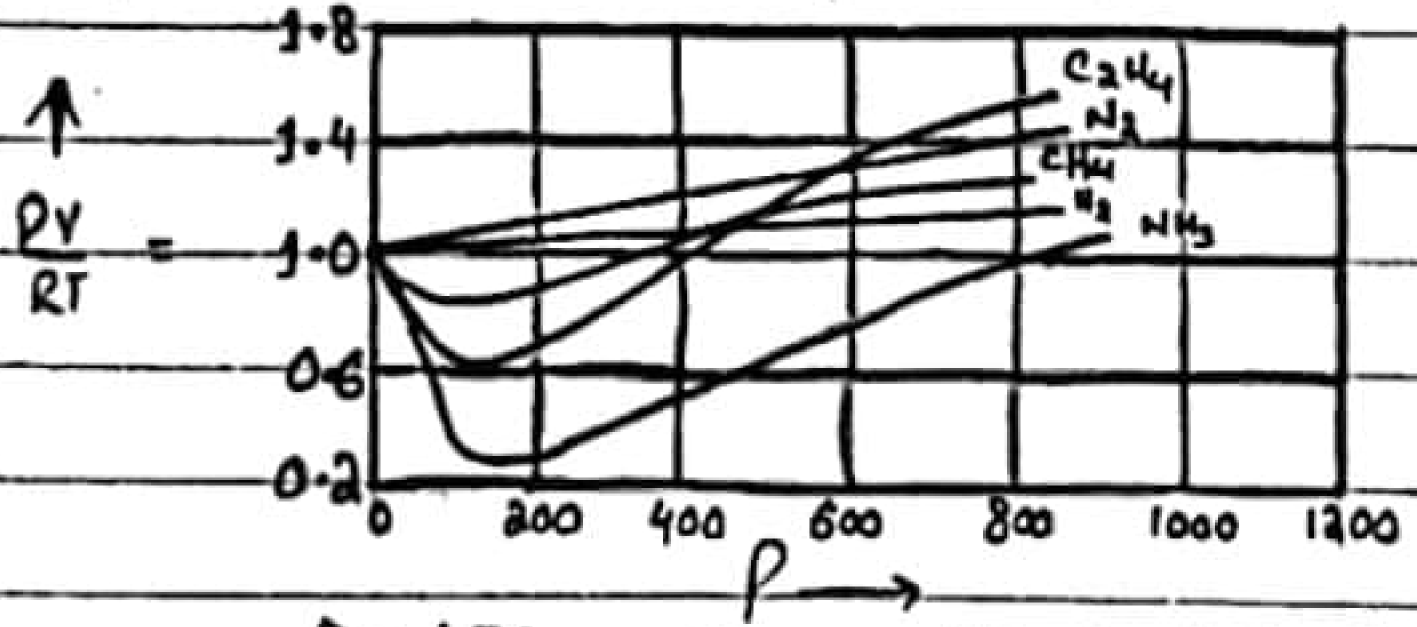
$$\frac{PV}{RT} = n$$

for one mole, $n = 1$

$$\frac{PV}{RT} = 1$$

where; $\frac{PV}{RT}$ = Compressability factor.

For ideal gas, $\frac{PV}{RT}$ always equal to one.



Deviation From ideal behaviour.

imp.*

VAN DER WAAL'S EQUATION (For Real Gases):-

Real gases don't obey ideal gas eq. under all Conditions of Temp. and pressure. Therefore, vander waal modified ideal gas eq. by vol. correction and pressure correction.

VOLUME CORRECTION:-

In gas molecules, distance b/w them is very large. Therefore, actual vol. of gas is negligible as compared to total vol. of gas. But vander waal pointed out that in compressed gas, actual vol. of a gas can't be neglected.

Let "b" is excluded vol. for one mole of a gas, then vol. available to gas mol. is

$$V_{free} = V_{vessel} - V_{molecule}$$

where; $V_{molecule} = b$

$$V_{free} = V_{vessel} - b \rightarrow ①$$

where; V_{vessel} = vol. of container.

V_{free} = vol. available to gas under high pressure.

b = excluded volume.

Value of 'b' depends upon size of molecule. larger the molecule, larger will be the value of "b" and vice versa.

"b" is related with actual vol. for one mole of gas:

$$b = 4V_m.$$

where; V_m = Actual Vol.

UNIT OF "b":-

It is measured in dm^3/mol. Its SI unit is m^3/mol.

PRESSURE CORRECTION:-

Under normal condition, there is no force of attraction among the gas mol. but under high pressure, gas mol. comes closer and inter-molecular forces becomes strong.

Let "A" is interior molecule. It is being attracted from all sides. There is no un-balanced force acting on it, but at a point of collision it is being attracted in backward direction and P' is the decrease in pressure due to force of attraction b/w molecules "A" and "B", then pressure of gas is given by;

$$P = P_i - P'$$

$$P_i = P + P'$$

$$\Rightarrow \quad P' \propto C_A \cdot C_B$$

$$P' \propto \frac{n}{V} \cdot \frac{n}{V} \qquad \therefore C = \frac{n}{V}.$$

$$P' \propto \frac{n^2}{V^2}$$

$$P' = \frac{an^2}{V^2}$$

$$P_i = P + \frac{an^2}{V^2} \longrightarrow ②.$$

From ① (Volume correction) and ②;

$$PV = nRT$$

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

For one mole; $n = 1$

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

where; a = vander waal constant.

→ value of "a" depends upon intermolecular forces b/w the gas molecules.

UNIT OF "a":-

$$P' = \frac{n^2 a}{v^2}$$

$$a = \frac{P'v^2}{n^2} = \frac{atm\,(dm^3)^2}{(mol)^2}$$

$$\boxed{a = atm.dm^6.mol^{-2}.}$$

SI - unit of "a":-

$$a = \frac{Nm^{-2} \times (m^3)^2}{(mol)^2}$$

$$\boxed{a = Nm^4\,mol^{-2}.}$$

DALTON'S LAW OF PARTIAL PRESSURE:-

This law was proposed by an English Chemist John Dalton.

According to this law;

"Total Pressure exerted by mixture of gases is equal to sum of partial pressure of all the individual gases, provided (بشرطیکہ) gases can't react chemically with each other."

Mathematically;

$$P_T = P_A + P_B + P_C.$$

Particular Example:-

Air is a mixture of non-reacting gases:

Percentage of each gas is given by:

$N_2 = 78.08\ \%$

$O_2 = 20\ \%$

$Ar = 0.93\ \%$

$CO_2 = 0.03\ \%$

where some gases are present in trace amount like, He, Ne, Kr and Co etc.

Q. Derive relationship Pressure and no. of moles of gas.

According to ideal gas eq.

$$PV = nRT$$

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

For gas 'A'

$P_A = \frac{n_A RT}{V} \longrightarrow$ ①

For gas "B"

$P_B = \frac{n_B RT}{V} \longrightarrow$ ②

For gas "C"

$P_C = \frac{n_C RT}{V} \longrightarrow$ ③

Total Pressure of gases "A", "B" and "C".

$P_T = \frac{n_T RT}{V} \longrightarrow$ ④

÷ ① and ④

$$\frac{P_A}{P_T} = \frac{n_A \cancel{RT/V}}{n_T \cancel{RT/V}}$$

$$\frac{P_A}{P_T} = \frac{n_A}{n_T}$$

$$P_A = \frac{n_A \times P_T}{n_T}$$

where; $\frac{P_T}{n_T}$ = Constant

P_A = Constant . n_A

$\boxed{P_A \propto n_A.}$

Similarly;

↗ $P_B \propto n_B$

↗ $P_C \propto n_C$.

Q. Derive relationship b/w Pressure and mole fraction (X).

According to ideal gas eq.

$$PV = nRT.$$

$$P = \frac{nRT}{V}.$$

For gas 'A'

$$P_A = \frac{n_A RT}{V} \longrightarrow ①$$

For gas "B"

$$P_B = \frac{n_B RT}{V} \longrightarrow ②$$

For gas 'C'

$$P_C = \frac{n_C RT}{V} \longrightarrow ③$$

Total Pressure of gases 'A', 'B' and "C";

$$P_T = \frac{n_T RT}{V} \longrightarrow ④$$

÷ing ① and ④;

$$\frac{P_A}{P_T} = \frac{n_A \cancel{RT/V}}{n_T \cancel{RT/V}}$$

$$\frac{P_A}{P_T} = \frac{n_A}{n_T}$$

$$P_A = \frac{n_A}{n_T} \times P_T$$

$$\boxed{P_A = X_A \times P_T}. \qquad \therefore \frac{n_A}{n_T} = X_A$$

OR

$$\boxed{P_i = X_i \times P_T}.$$

Applications Of DALTON'S LAW:-

i. **Collection of Gases Over Water:-**

Most of the gases are collected over water. Water is changed into vapours, so, Total pressure is given by;

$$P_T = P_{dry\ gas} + P_{water\ vapours}$$

$P_{water\ vapours}$ = Aqueous Tension.

$$\boxed{P_T = P_{dry\ gas} + \text{Aqueous Tension}}$$

$$P_{dry\ gas} = P_T - \text{Aqueous Tension.}$$

ii. **Respiration at High Altitude:-**

Partial Pressure of oxygen in air is 159 Torr. and partial pressure of O_2 in lungs is 116 Torr. At this pressure difference, respiration becomes comfortable. But at high altitude, Partial Pressure of O_2 in air becomes 150 Torr.

iii. **Respiration by deep sea divers:-**

Deep sea divers breathe air under pressure. At a depth of 40 meters, the pressure increased 5 times than the normal Pressure. There-fore, regular air can't be used in diver's tank because partial Pressure of O_2 would be 795 mm of Hg $(159 \times 5 = 795)$ in that case. Therefore, deep sea divers use a mixture of 96 % of He and 04 % of O_2 in respiration tank, the scuba.

A scuba contains compressed air to breath. As diver returns to surface, it becomes hazardous for him if not handled properly. As the diver comes up, the pressure of surrounding water drops. Consequently, the compressed air in lungs expands. Surfacing must be done very slowly, so that the compressed air may

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Q. How deep sea divers respire on return from sea?

Ans. The %age of N_2 in air is about 80%. If N_2 is present in diver's tank, the solubility of N_2 in blood can increase with increase in pressure in very deep sea. And blood of a diver may be saturated with N_2 during a dive. If the diver returns to surface quickly, he will face life threating condition called "**bends**". Deep sea divers must either use different solutions of gases such as He in O_2 or spend many hours in a decompression chamber after a dive. The %age in decompression chamber is slowly lowered over many hours. N_2 gas comes out of the blood and disposed off safely for normal breathing.

↗ Diffusion:-

Spontaneous mixing of gas mol. as a result of collision to form homogeneous mixture with the molecule of another gas is called diffusion.

e.g; i- Fragrance of rose.

ii- intermixing of NH_3 & HCl to gives dense white fumes of NH_4Cl.

iii- Smell of Perfume.

↗ Effusion:-

Escape of gas molecules through a small narrow hole, without collision, from high pressure region to low pressure region, is called effusion.

e.g; Leakage of gas through a pipe.

GRAHAM'S LAW OF DIFFUSION AND EFFUSION:-

The confirmation of Kinetic theory of Gases was proved by the work of an English Chemist, Thomas Graham (1805–1869) in 1831.

He proposed a law in 1831, which is stated as follows:

"Rate of diffusion or effusion of a gas is inversly proportional to square root of its density or molecular mass at constant temperature and Pressure."

Mathematically;

$$r \propto \frac{1}{\sqrt{d}} \quad \text{OR} \quad r \propto \frac{1}{\sqrt{M}}$$

$$r = K \cdot \frac{1}{\sqrt{d}}$$

$$\boxed{r\sqrt{d} = K}$$

For gas ①

$$r_1\sqrt{d_1} = K \rightarrow ①$$

For gas ②

$$r_2\sqrt{d_2} = K \rightarrow ②$$

Comp. ① and ②

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

$$\boxed{\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}} \quad \text{or} \quad \boxed{\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}}$$

LIQUEFACTION OF GASES:-

Conversion of gases into liquid under high pressure and low temperature is called Liquefaction of gases.

Linde's Method (1895):-

Principle:-

This method is based on Joule-Thomson effect.

"When compressed gas suddenly expands, its Temp. falls down. This is called Joule Thomson effect."

Parts of Apparatus:-

1- Compressor
2- Coil (C)
3- Copper Spiral Tube (S)
4- Control valve (V)
5- Exponsion Chamber (L).

WORKING STEPS:-

i- Air is compressed to 200 atm approximately.

ii- Most of the water in the air condenses and is removed.

iii- The heat generated as a result of compression is removed by passing the gas through coil "C".

iv- The dry gas is then passed through a copper Spiral coil 'S'.

v- It is then expanded to almost atmospheric pressure through a controlled valve 'V'.

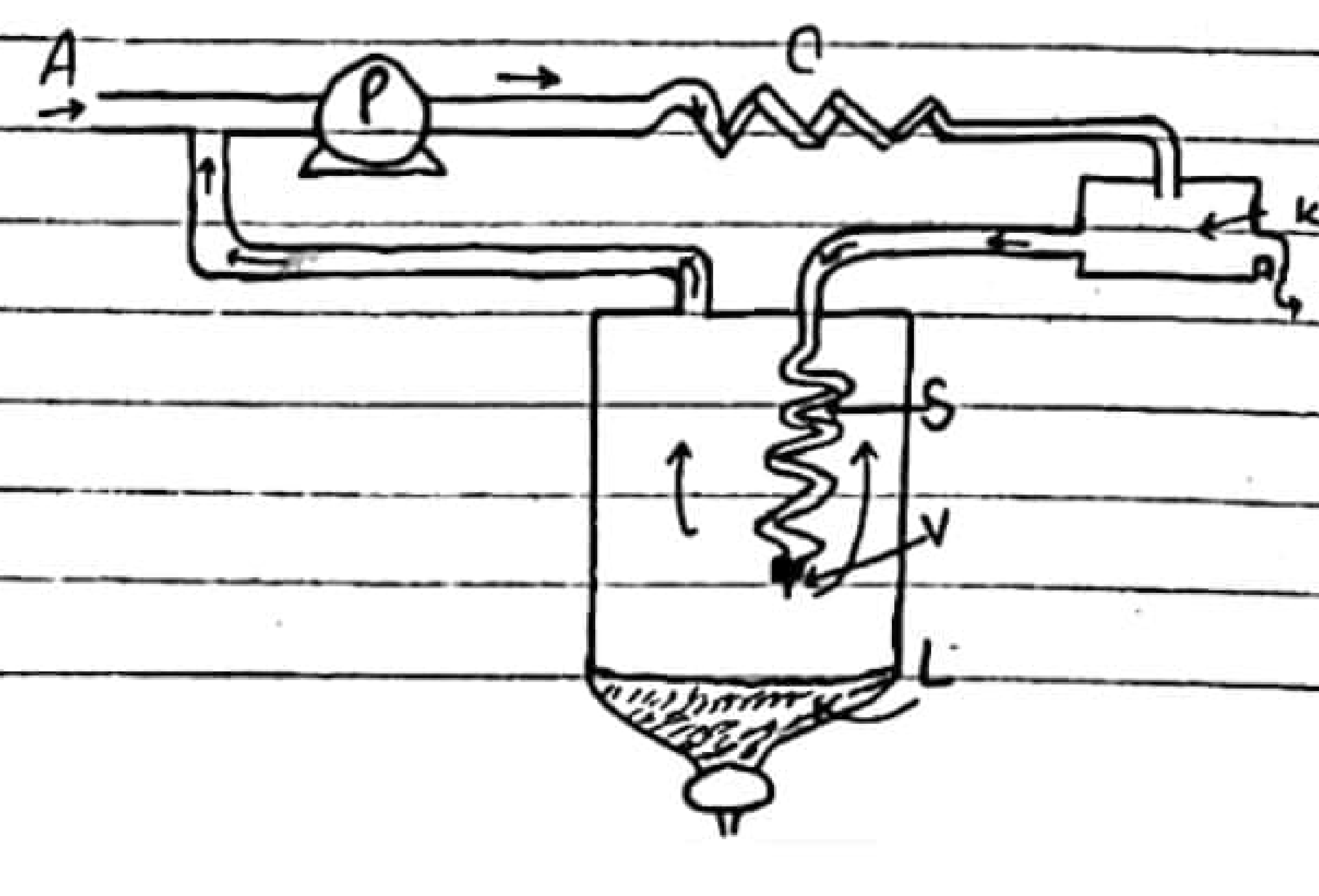
vi- The issuing gas, cooled now due to Joule-Thomson's effect is passed over the copper spiral and cool further the incoming compressed gas.

vii- The cycle is repeated Several times.

viii- The Temp. of the expanding gas finally drops and the remaining air is liquefied.

ix- The liquid air collects in the chamber 'L' can be drawn off.

x- Any un-condensed air is re-circulated.



USES OF LINDE'S METHOD:-

i. Construction Of Appliances:-

The construction of appliances such as refrigerators, heat pumps and air-conditioners all work on Joule-Thomson's effect.

e.g; In a refrigerator, a Compressor, Compresses a gas such as freon.

Thus, an increase in temp. takes place. The hot freon gas moves to a condenser on the outside of the refrigerator. Air at room temp. cools the gas down and as a result condenses into liquid. The liquid, Freon, now at room temp. is then passed through a small hole in restriction valve into the low pressure tubes which are inside the refrigerator. There, the Freon liquid vapourizes rapidly. The heat of vaporization needed to do this is drawn from the K.E of the Freon mol. becoming very cold. This cold gas absorbs heat from the refrigerator and its contents, thereby cooling. Then the Freon gas is then fed into the compressor and the cycle starts over again.

ii. Self-Cooling Pop Can:-

It is a small container holding liquid CO_2 is built right into the can. when the can is opened, the liquid CO_2 vapourizes and escapes out of the top of the can. The heat absorbed by the vapourizing CO_2 can lower the temp. of the pop by about 16°C in a few seconds. Thus the temp. is lowered considerably.

Applications of K.M.T :-

i- Velocity of Molecules:-

The equation for the root mean square velocity deduced from Kinetic equation is;

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

where; M = Molecular mass of a gas.
T = Absolute Temp. (in Kelvin).

This eqs. gives a quantitative relationship b/w the absolute Temp. and the velocities of gas molecules. Higher the Temp. of a gas, greater would be the velocities of molecules.

ii- Graham's Law of Diffusion Of Gases:-

According to postulates of K.M.T, the K.E of the particles is proportional to the Absolute Temp.

Mathematically;

$$E_K = \frac{1}{2} mv^2.$$

$$v^2 = \frac{2E_K}{m}$$

$$v = \sqrt{\frac{2E_K}{m}} \qquad \therefore \text{ Taking sq. root on b.s.}$$

$$v = \sqrt{\frac{1}{m}} . \sqrt{2E_K}$$

$$v = K . \sqrt{\frac{1}{m}} \qquad \therefore \sqrt{2E_K} = K \text{ (Constant)}.$$

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

Thus; the K.M.T predicts that the average speed depends upon the molecular mass. Further, the average speed of the particles is inversly proportional to the square root of their molecular mass.

FOURTH STATE OF MATTER — THE PLASMA:-

Plasma is the fourth state of matter. It was first identified by William Crooks in 1879. He obtained it by heating molecular gas changing into atomic form and then to ionic form at higher temp.

Molecular gas → Atomic gas → Ions.

At a higher temp. of $10^4 - 10^5$ Kelvins, ēs are removed from atoms to form ions. Plasma is composed of a mixture of un-ionized gas, free ēs and +vely charged particles. Most of the universe contains matter in the plasma state (about 99%). All shining stars are made up of Plasma. On earth, it does not exist in free state.

PROPERTIE OF PLASMA:-

i- Plasma consists of neutral particles, +ve ions and -ve ēs.

ii- Plasma may also be called as free electrons in a metal.

iii- Plasma is strongly influenced by both magnetic and electric force.

iv- Plasma shows a characteristic glow depending upon the gas present in the discharge tube. e.g; oxygen gives a red glow, hydrogen gives green and nitrogen gives purple or pink glow.

EXERCISE-

Q1. MCQ's :-

i- (a)
ii- (b)
iii- (a)
iv- (a)
v- (b)
vi- (c)
vii- (a)
viii- (b)
ix- (d)
x- (d)
xi- (b)
xii- (b)
xiii- (b)
xiv- (d)
xv- (b)
xvi- (d)
xvii- (d)
xviii- (e)
xix- (a)
xx- (c)

Q2- Write Brief Answers-

i- See the topic "Absolute Zero."

ii- See the topic "Properties of Plasma."

iii- See to topic "Units of R."

iv- See The Topic 'Motions of Molecules."

v- See The Topic 'Units of Pressure."

vi- See The Topic "Charle's Law".

vii- See "Avogadro's Law".

viii- See "Deviation from ideal gas behaviour".

ix- See "Dalton's Law".

x- See "Ideal OR General Gas Equation".

xi.

Ans. when air strikes with ice on wind-screen, rate of evaporation of ice increases. so, ice can be evaporated when car is moving, even without the heater on.

xii-

Ans- when salt is placed on ice, rate of evaporation increases and rate of freezing decreases, so ice is melt, when salt is placed on it.

xiii-

Ans. when jar of coffee opened, people in all parts of room soon notice the smell. This is due to diffusion Process. Gas particles moves in all possible directions and reached to every part of room.

xiv.

Ans. when a bubble of methane gas rises from bottom, its size is small because pressure of water on it is high.

when it move upward, its size increases because pressure of water vapour decreases.

xv.

Ans. Rate of diffusion is inversly proportional To density, so gases have low density and Their rate of diffusion is higher Than liquids.

xvi.

a. when block of butter placed in fridge, Temp. of fridge from inside is low, due to which K.E of molecules of butter becomes low and inter-molecular forces b/w them becomes strong. when we take it out from fridge, Temp. rises, which increases The K.E of molecules, so, mol. move away from one another and inter-molecular forces b/w Them become weak.

b. It is due To diffusion process because molecules of gas moves in all possible directions and smell of reo is spread in home.

c. AT day Time, Temp. increases, so K.E of mol. of gas increases and They stay away from one another. But at night Time, Temp. decreases, which decrease The K.E of gas inside football and mol. of gas comes closer, so, The size of football decreases at night Time.

d. Windy day is a good drying day, because when wind strikes with wet clothes, rate of evaporation increases. That's why windy day is a good drying day.

xviii. One reason for This is effusion. Another reason is That, at day Time, Temp. increases, so K.E of mol. increases and They move away from one another. AT night Time, Temp. decreases and K.E of mol. also decreases, so size of ballon becomes smaller.

Q3- See "Kinetic Molecular Theory of Gases."

Q4- See "Relation b/w Temp. and Average K.E."

Q5- a- See "Standard Temp. and Pressure."

b- Given:-

Temperature = 25°C = 298 K

Pressure = 300 mm of Hg. = 0.394 atm

Molar mass of SO_2 = 32+32 = 64 $g\,mol^{-1}$.

General Gas Constant 'R' = 0.0821 atm $dm^3\,K^{-1}\,mol^{-1}$.

Solution:-

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

$$= \frac{0.394 \times 64}{0.0821 \times 298}\ g\,dm^{-3}.$$

$$\boxed{d = 1.03\ g\,dm^{-3}.}$$

Q6. a. see

b- "Kinetic Molecular Theory."

Q7. a- See "Units of Pressure."

b- See "Boyle's Law."

c- See "Graphical Representation of Boyle's Law."

d- Given:- $V_1 = 1\,dm^3$ $V_2 = 100\,cm^3 = 0.1\,dm^3$

$T_1 = 25°C = 298\,K$ $T_2 = 25°C = 298\,K$

$P_1 = 1\,atm$ $P_2 = ?$

Solution:-

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \quad P_2 = \frac{V_1P_1}{T_1} \times \frac{T_2}{V_2}$$

$$P_2 = \frac{1 \times 1}{298} \times \frac{298}{0.1}$$

$$\boxed{P_2 = 10\ atm.}$$

Q8. a- See "Graphical Explanation of Charles's Law."

b- Given:-

$V_1 = 1\ dm^3$

$T_1 = 25°C = 298\ K$

$V_2 = 100\ cm^3 = 0.1\ dm^3$

$T_2 = ?$

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

$= \frac{0.1 \times 298}{1}$, $\boxed{T_2 = 29.8\ K.}$

Q9. a- See "Absolute zero".

b- See "Significance of Absolute zero".

c- See "Mathematical form of Absolute zero."

d-

Q10. a- See "Significance of Avogadro's Law"

b-

Q11. a- See "Ideal Gas Equation."

b- See "Significance of ideal Gas Eq."

c- Given:-

$d = 1.92\ g\,dm^{-3}$.

$P = 150\ KPa = 1.48\ atm$

$T = 298\ K$.

$R = 0.0821\ atm\ dm^3\ K^{-1}\ mol^{-1}$.

$d = \frac{MP}{RT}$, $M = \frac{dRT}{P}$

$M = \frac{1.92 \times 0.0821 \times 298}{1.48}$, $\boxed{M = 31.73\ g\ mol^{-1}.}$

Q12. a- See "Different units of R."

b- Given:-

$P = 161.325\ KPa = 1.59\ atm.$

$T = 298.15\ K$

$d = 1.59\ g\ dm^{-3}.$

$M = ?$

Solution:-

$$M = \frac{dRT}{P}$$

$$= \frac{1.59 \times 0.0821 \times 298.15}{1.59}$$

$$\boxed{M = 24.47\ g\ mol^{-1}.}$$

Q13- a- See

b- "Deviations From ideal gas behaviour."

Q14- See "Vander waal's Equation."

Q15- a- i- See

ii- "Dalton's Law of Partial

iii- Pressure."

Q16- a- Given:-

$n = 3$

$V = 10\ dm^3$

$P = 15\ atm$

$a = 2.253\ atm\ dm^6\ mol^{-2}.$

$b = 0.0428\ dm^3\ mol^{-1}.$

$T = ?$

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

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

$$T = \frac{\left(15 + \frac{2.253(3)^2}{(10)^2}\right)\left[10 - 3(0.0428)\right]}{3 \times 0.0821}$$

$$T = \frac{(15.20)(9.8716)}{0.2463}$$

$T = 609.20$ K

$T = 609.20 - 273$ °C

$\boxed{T = 336\ °C.}$

b- Given:-

$V_1 = 6\ dm^3$

$P_1 = 720\ mm\ Hg = 0.94\ atm.$

$T_1 = 25°C = 298\ K$

$V_2 = ?$ (at S.T.P, mean $P = 1\ atm$, $T = 25°C = 298K$)

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

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} = \frac{0.94 \times 6}{298} \times \frac{298}{1}$$

$\boxed{V_2 = 5.64\ dm^3.}$

Q17. a- See "Graham's Law of Diffusion."

b- Given:-

$t_{N_2} = 35s$, $t_x = 50s$

$M_x = ?$, $M_{N_2} = 28$

Solution:-

$$\frac{r_{N_2}}{r_x} = \sqrt{\frac{M_x}{M_{N_2}}}$$

Putting values:-

$$\frac{0.02857}{0.02} = \sqrt{\frac{M_x}{28}}$$

$\Rightarrow 2.0406 = \frac{M_x}{28}$

$\Rightarrow M_x = 57.13\ g/mol$

$$T = \frac{\left(15 + \frac{2.253(3)^2}{(10^{-})^2}\right)\left[10 - 3(0.0428)\right]}{3 \times 0.0821}$$

$$T = \frac{(15.20)(9.8716)}{0.2463}$$

$$T = 609.20 \text{ K}$$

$$T = 609.20 - 273 \ {}^\circ C$$

$$\boxed{T = 336\ {}^\circ C.}$$

b- Given:-

$V_1 = 6\ dm^3$

$P_1 = 720\ mm\ Hg = 0.94\ atm.$

$T_1 = 25^\circ C = 298\ K$

$V_2 = ?$ (at S.T.P, mean $P = 1\ atm$, $T = 25^\circ C = 298K$)

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

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2} = \frac{0.94 \times 6}{298} \times \frac{298}{1}$$

$$\boxed{V_2 = 5.64\ dm^3.}$$

Q17. a- See "Graham's Law of Diffusion."

b- Given:-

$t_{N_2} = 35s$, $t_x = 50s$

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Putting values:-

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$$\Rightarrow M_x = 57.13\ g/mol$$