

WHAT ARE DIFFERENT STATES OF MATTER?

ANS: MATTER EXIST IN FOUR PHYSICAL STATES. THESE ARE :-

(i) GAS (ii) LIQUID (iii) SOLID (iv) PLASMA STATE.

SIMPLEST STATE: SIMPLEST STATE OF MATTER IS GASEOUS STATE

MOST ABUNDANT AROUND US: SOLID STATE

MOST ABUNDANT IN UNIVERSE: PLASMA STATE.

LEAST ABUNDANT STATE: LIQUID STATE.

REASON: LIQUID STATE CAN EXIST BETWEEN A NARROW RANGE OF TEMP. AND PRESSURE I.E F.P AND B.P. BELOW F.P LIQUID CHANGES INTO SOLID AND ABOVE THIS TEMP. LIQUID CHANGES INTO GASEOUS STATE.

PROPERTIES OF GASES.

1. SHAPE AND VOLUME: GASES DONOT HAVE ANY DEFINITE SH. OR VOLUME. THEY FILL ALL AVAILABLE SPACE AND ACQUIRE THE SHAPE OF CONTAINER.

2. LOW DENSITIES: GASES HAVE VERY LOW DENSITIES AS COMPARED TO LIQUIDS AND SOLIDS. HENCE GASES BUBBLE THROUGH LIQUIDS AND TEND TO RISE UP.

3. DIFFUSION AND EFFUSION: DUE RAPID MOVEMENT, LARGE EMPTY SPACES AND NEGLIGIBLE FORCES OF ATTRACTION. GASES DIFFUSE AND EFFUSE. THIS PROPERTY IS PRESENT IN LIQUIDS ALSO. IT IS NEGLIGIBLE IN SOLIDS.

4. COMPRESSIBILITY: DECREASE IN VOLUME BY INCREASE OF PRESSURE IS CALLED COMPRESSIBILITY. SINCE THERE ARE LARGE EMPTY SPACES BETWEEN GAS MOLECULES, THEREFORE GASES ARE HIGHLY COMPRESSIBLE.

5. EXPANSION OF GASES: THE INCREASE IN VOLUME BY INCREASE OF TEMP. OR INCREASE IN AVAILABLE SPACE IS CALLED EXPANSION. GASES SHOW GREAT EXPANSION. LIQUIDS AND SOLIDS HAS V. LITTLE INCREASE IN VOLUME ON HEATING.

6. JOULE THOMSON EFFECT: WHEN HIGHLY COMPRESSED GAS IS ALLOWED TO EXPAND SUDDENLY COOLING TAKES PLACE. IT IS CALLED JOULE THOMSON EFFECT.

PRESSURE: Gases exert pressure on the walls of container. Gas molecules are constantly moving in random directions. They collide on the walls of container. The pressure of gas is due to collisions of gas molecules on walls of container.

INTERMOLECULAR FORCES: There are very weak intermolecular forces in gases.

PROPERTIES OF LIQUIDS:

1. SHAPE AND VOLUME: Liquids have no definite shape but they have definite volume. They adopt the shape of container. On the other hand solids have definite shape.

2. MOTION OF LIQUID MOLECULES: Liquid molecules are constantly moving. The evaporation and diffusion of liquid molecules is due to motion of molecules.

3. DENSITIES: The densities of liquids are much greater than that of gases but close to those of solids.

4. INTERMOLECULAR SPACES: Just like solids, liquids have negligible intermolecular spaces.

5. INTERMOLECULAR FORCES: The intermolecular forces are intermediate between gases and solids. The m.p., b.p. of gases, liquids and solids depend upon strength of intermolecular forces.

6. KINETIC ENERGY: Liquid molecules possess K.E. due to their motion. Liquids can be converted into solids by decreasing K.E.

7. COLLISIONS: Molecules of liquids collide with one another and exchange energies. Solid molecules cannot do so.

PROPERTIES OF SOLIDS:-

1. NON COMPRESSIBLE: particles present in solids are very close to each other. They are tightly packed. Thus solids are non compressible. They cannot diffuse.

2. INTERMOLECULAR FORCES: There are strong attractive forces in solids. Thus solids have definite shape and volume.

3. VIBRATIONAL MOTION: Solid particles possess only vibrational motion.

UNIT OF PRESSURE

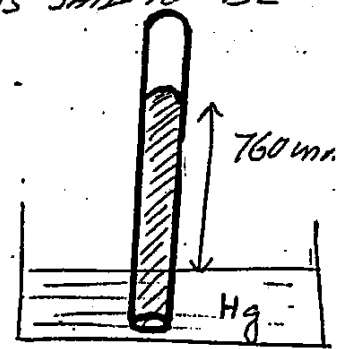
PRESSURE IS DEFINED AS, "FORCE PER UNIT AREA". $P = \frac{F}{A}$

UNIT OF PRESSURE IS "PASCAL". WHEN 1 NEWTON FORCE ACTS UPON AN AREA OF 1m^2 , PRESSURE IS SAID TO BE 1 PASCAL.

$$1 \text{ PASCAL} = \frac{1 \text{ N}}{1 \text{ m}^2}$$

STANDARD PRESSURE = 1 ATMOSPHERE

ONE ATMOSPHERIC PRESSURE IS PRESSURE WHICH CAN KEEP Hg STANDING AT A HEIGHT OF 760 MM. SOME OTHER UNITS OF PRESSURE ARE GIVEN



$$1 \text{ ATM} = 760 \text{ mm (Hg)} = 760 \text{ Torr} = \frac{101325 \text{ N}}{\text{m}^2} = 101325 \text{ Pa} = 1.01325 \text{ kPa} = 1 \text{ Bar} = 76 \text{ cm}$$

UNIT OF VOLUME

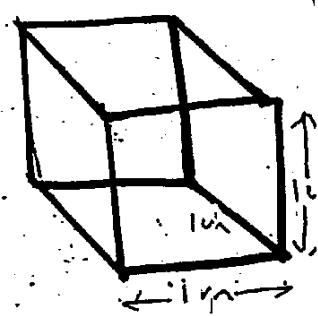
IN S-I SYSTEM UNIT OF VOLUME IS CUBIC METER (m^3)

1 CUBIC METER IS VOLUME OCCUPIED BY A CUBE WHOSE EACH LENGTH IS 1 METER

$$V = L \times B \times H$$

$$V = 1 \text{ m} \times 1 \text{ m} \times 1 \text{ m}$$

$$V = 1 \text{ m}^3$$



COMMONLY USED UNIT OF VOLUME IS "dm³" OR LITRE.
 $1 \text{ LITRE} = 1 \text{ dm}^3 = 1000 \text{ cm}^3 = 1000 \text{ mL} = 1000 \text{ C.C.}$

SCALES OF TEMPERATURE

INTERCONVERSION OF °C & KELVIN

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

$$t^{\circ}\text{C} = \text{K} - 273$$

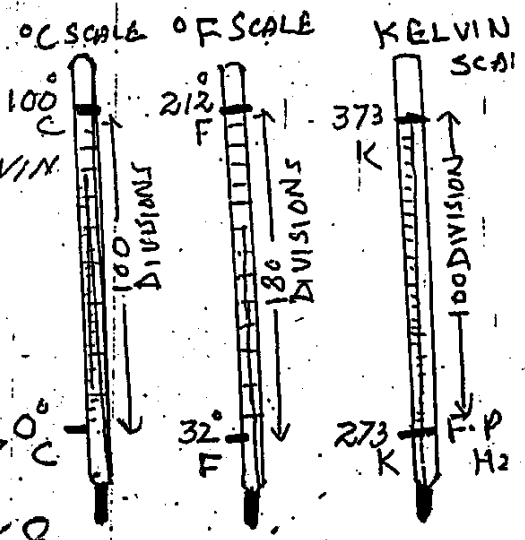
$$\frac{9}{5} t^{\circ}\text{C} + 32 = F^{\circ}$$

$$t^{\circ}\text{C} = \frac{5}{9} (F^{\circ} - 32)$$

F.P. OF H₂O

⇒ 0° C

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GAS LAWS

1. BOYLE'S LAW:- It is defined as, "The volume of a given mass of a gas is inversely proportional to pressure applied to the gas at constant temperature. Mathematically it could be written as:- ~~the~~

$$V \propto \frac{1}{P} \quad (\text{AT CONSTANT TEMP. AND MASS})$$

$$V = k \frac{1}{P} \quad k \text{ is called PROPORTIONALITY CONSTANT}$$

→ The value "k" is different for different amount of the same gas. It is also different at different temp.

$$P \times V = k \quad \text{--- (1) (when T and 'n' are constant)}$$

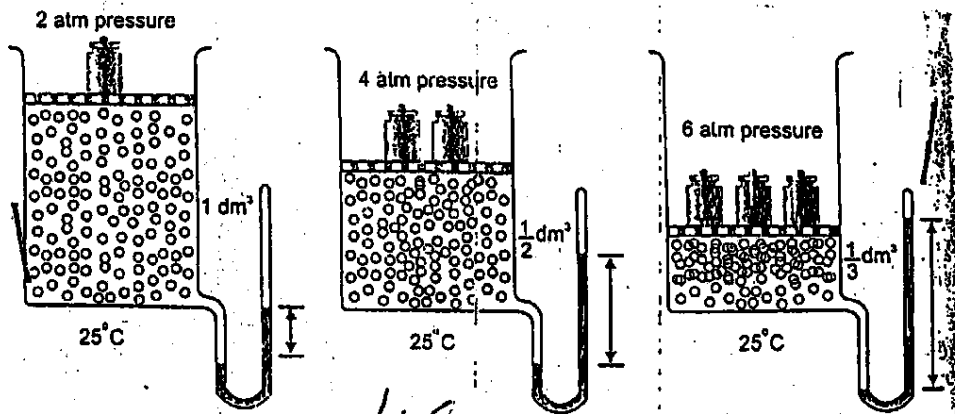
From Equation 1, Boyle's Law could be defined as "The product of pressure and volume always remains constant at constant temp. & constant quantity of gas. Thus eq (1) can be written as

$$P_1 \times V_1 = k \quad \text{AND} \quad P_2 \times V_2 = k$$

" $P_1 V_1$ " and initial values of pressure and volume and " $P_2 V_2$ " and final values of pressure & volume.

EXPERIMENTAL VERIFICATION:-

Let us consider definite mass of gas present in a cylinder fitted with a movable piston. The cylinder is also fitted with a manometer to read pressure of gas directly. Let initial volume is 1 dm^3 when initial pressure is 2 atm (due to 1 wt. of on piston). When volume of gas is reduced to one half ($\frac{1}{2} \text{ dm}^3$) by adding two wt on piston, pressure becomes four Atmospheres. When volume is reduced to one third ($\frac{1}{3} \text{ dm}^3$) by adding three equal wts. the pressure becomes 6 Atm.



It is found that

$$P_1 \times V_1 = k = 2 \times 1 = 2 \text{ atm dm}^3 = k$$

$$P_2 \times V_2 = k = 4 \times \frac{1}{2} = 2 \text{ atm dm}^3 = k$$

$$P_3 \times V_3 = k = 6 \times \frac{1}{3} = 2 \text{ atm dm}^3 = k$$

Thus it is concluded that product of pressure and volume always remains constant at constant "T" and.

GRAPHICAL EXPLANATION OF BOYLE'S LAW.

Let us consider definite mass of a gas enclosed in a cylinder fitted with a movable piston. The volume of gas decreases by increasing pressure at constant temp. (say 0°C). If a graph is plotted between pressure along X-axis (ORDINATE) and volume along Y-axis (Abscissa) a curve is obtained. It is called ISOTHERM.

Now if temperature of same mass of gas is increased to 25°C the volume of gas is increased.

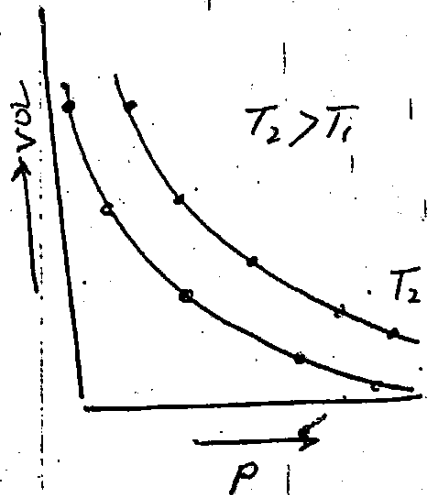
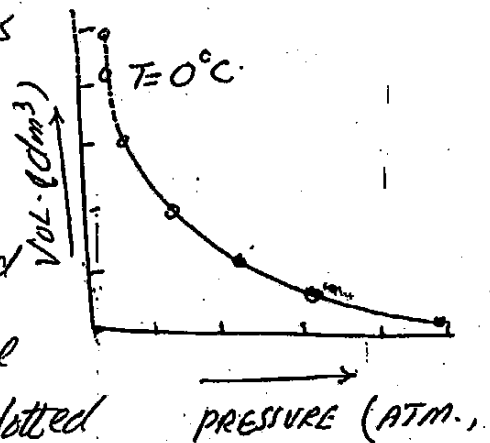
The pressure of gas is increased

by keeping temp. 25° constant. The volume decreases. The graph is plotted between pressure and volume. A new isotherm is obtained which is away from both axes.

If another isotherm is drawn at further higher temperature, it also goes away from axes.

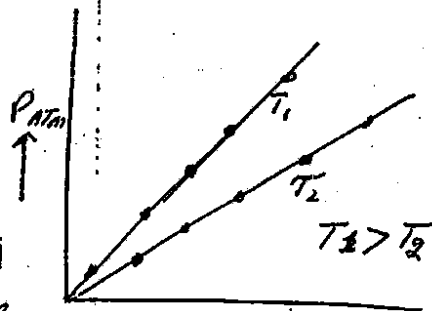
GRAPH BETWEEN PRESSURE AND INVERSE OF VOLUME $\frac{1}{V}$

If a graph is plotted between inv. of volume ($\frac{1}{V}$) along X-axis and pressure along Y-axis a straight line



is obtained. This shows that pressure and inverse of volume are directly proportional to each other. This straight line will

meet at the origin which means that when pressure is very close to zero then volume is so high that inv. of volume is close to zero.

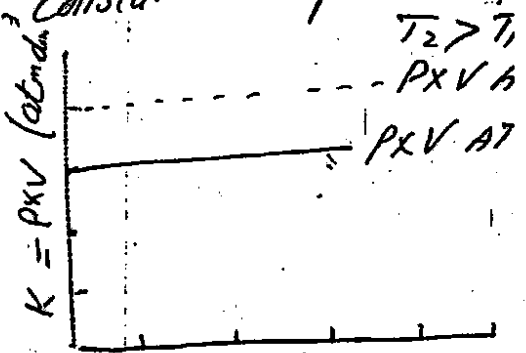


By increasing temperature of the same gas from T_1 to T_2 and keeping it constant at T_2 we can vary pressure and volume. The graph of this data will give another straight line. This straight line will be closer to x-axis at low temp.

GRAPH BETWEEN PRESSURE AND PV of a gas

is plotted between "P" along x-axis and "PV" along y-axis a straight line parallel to x-axis is obtained which indicates that product of pressure and volume always remains constant at constant temperature.

At some higher temp. volume increases if pressure is kept constant. Thus value of PV at high temp. is higher but constant.



The gas whose PV remains constant is called an ideal gas. But for real gases PV does not remain constant. Boyle's law is applicable to an ideal gas.

brings about liquefaction is called CRITICAL TEMP. For example CO_2 cannot be converted into liquid by appl. of pressure if its temp. is above 31°C . However if temp. is below 31°C , increase in pressure will change CO_2 into liquid. Thus 31°C is critical temp. of CO_2 .

In other words critical temp. is the highest temp. at which a substance can exist as a liquid. Beyond which liquid form is not possible.

CRITICAL PRESSURE P_c The pressure required to convert a gas into liquid at critical temp. T_c is called CRITICAL PRESSURE P_c .

FACTORS AFFECTING CRITICAL TEMPERATURE

The value of critical temp. of gas depends upon

- (1) SIZE OF MOLECULE
- (2) SHAPE OF MOLECULE

(3) INTER MOLECULAR FORCES.

Non polar gases with low polarizability have low critical temp. while polar gases like H_2O , NH_3 have high critical temp. i.e. they have better ability to change into liquid.

IMPORTANCE The knowledge of critical temp. and critical pressure provide us information about conditions under which a gas can change into liquid. For exor.

O_2 has critical temp. 154.4K (-118.75°C). It must be cooled below this temperature to convert into liquid by application of pressure. Ammonia is

a polar gas with critical temp. 405.6K (132.44°C). It indicates that NH_3 can be easily liquefied by application of pressure near room temperature.

Please See Table 3.2 (Page 78)

According to eq (5) kelvin temp. is directly proportional to average translational kinetic energy of molecules.

This change in temp. means change in translational K.E.

FLOW OF HEAT When heat flows from one body to another, the molecules of hotter body, give some of their kinetic energy to molecules of colder body by collisions. This process goes on until translational K.E. of all molecules becomes equal and temp. also becomes equal.

TEMPERATURE OF SOLIDS In gases and liquids temperature is measure of average K.E. of molecule. In solids molecules cannot have translational K.E.

temperature is measure of vibrational K.E.

ABSOLUTE ZERO According to kinetic interpretation of temperature, absolute zero is that temperature at which the molecular motion will stop. The absolute zero is unattainable. The temp. as low as

10^{-5} K. has been attained.

LIQUEFACTION OF GASES:

GENERAL PRINCIPLE :- The gases can be converted into liquids by two methods (i) By application of pressure (ii) By decreasing temperature.

At high pressure molecules get closer to each other and develop some forces of attraction among themselves. At low temp. the K.E. of molecules is decreased and attractive forces become dominant.

CRITICAL TEMPERATURE The temperature beyond which no gas can be liquefied by application of pressure and below which continuous increase in pressure

Taking sq. root of both sides

$$\sqrt{\frac{3PV}{M}} = \sqrt{\bar{c}^2}$$

$$\sqrt{\frac{3P}{M/V}} = \sqrt{\bar{c}^2}$$

$$\sqrt{\frac{3P}{d}} = \bar{c}$$

At constant pressure $\sqrt{\frac{1}{d}} \propto \bar{c}$ which is Graham's law
 (\bar{c} = rate of diffusion)

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

KINETIC INTERPRETATION OF TEMPERATURE.

According to kinetic equation pressure of gas is due to collision of gas molecules on walls of container. The kinetic equation could be written as $PV = \frac{1}{3} mN\bar{c}^2$.

The kinetic energy is due to translational motion of molecules. It is given by following expression $E_k = \frac{1}{2} mN\bar{c}^2$.

E_k is average translational K.E. of gas molecule. Multiplying and kinetic eq by (2) we get

$$PV = \left(\frac{1}{3} mN\bar{c}^2\right) \times \frac{2}{2}$$

$$PV = \left(\frac{1}{2} m\bar{c}^2\right) \frac{2}{3} N \quad \text{--- (3)}$$

Putting value of $\frac{1}{2} m\bar{c}^2$ in eq 3 from eq 2.

$$PV = E_k \frac{2}{3} N$$

$$\frac{3PV}{2N} = E_k \quad \text{--- (4)}$$

For 1 mole of gas $N = N_A$ (1 mole of contains Avogadro's no. of molecule)

$$\frac{3}{2} \frac{PV}{N_A} = E_k$$

$$\frac{3}{2} RT = E_k$$

(54) $\left\{ \begin{array}{l} PV = RT \\ \text{for 1 mole of gas} \end{array} \right.$

Equation 7 is mathematical form of Charles' law.

AVOGADRO'S LAW:

According to this law equal volume of different gases under same conditions of temp and pres contain equal no. of molecules.

Let us consider two gases 1 and 2 at same pressure and volume. The number of molecules are N_1 and N_2 respectively.

The kinetic equation for these two gases could be written as

$$PV = \frac{1}{3} m_1 N_1 \bar{c}_1^2 \quad \text{--- (1)}$$

$$PV = \frac{1}{3} m_2 N_2 \bar{c}_2^2 \quad \text{--- (2)}$$

Since L.H.S of these two equations is equal. Thus R.H.S. are also equal

$$\frac{1}{3} m_1 N_1 \bar{c}_1^2 = \frac{1}{3} m_2 N_2 \bar{c}_2^2$$

$$m_1 N_1 \bar{c}_1^2 = m_2 N_2 \bar{c}_2^2 \quad \text{--- (3)}$$

At same temp. mean average K.E. of molecule will be the same

$$\frac{1}{2} m_1 \bar{c}_1^2 = \frac{1}{2} m_2 \bar{c}_2^2 \quad \text{--- (4)}$$

Dividing eq. (3) by eq. (4) we get

$$\frac{m_1 N_1 \bar{c}_1^2}{m_1 \bar{c}_1^2} = \frac{m_2 N_2 \bar{c}_2^2}{m_2 \bar{c}_2^2}$$

$$\boxed{N_1 = N_2} \quad \text{--- (5)}$$

Thus equal volume of all gases at same condition of temp and pressure will have equal number of molecules. This is Avogadro's Law.

GRAHMS LAW OF DIFFUSION: According to Graham's law $r \propto \frac{1}{\sqrt{d}}$ at constant temperature and pressure. Kinetic equation for volume of gas could be written as

$$PV = \frac{1}{3} m N \bar{c}^2$$

For 1 mole of gas containing Avogadro's number of molecules

$$P.V = \frac{1}{3} m N_A \bar{c}^2$$

$$P.V = \frac{1}{3} M \bar{c}^2$$

$$3PV = M \bar{c}^2$$

($m N_A$ = Molecules wt of compound)

CHARLE'S LAW

It is a quantitative relationship between temperature and volume of a gas. It states that, "The volume of a given mass of a gas is directly proportional to absolute temperature at constant pressure. Mathematically it could be written as follows

$$V \propto T \text{ (at Constant P and Mass)}$$

$$V = kT \text{ (k is constant of proportionality)}$$

$$\frac{V}{T} = k \quad \text{--- (1)}$$

If temperature T is changed from T_1 to T_2 , volume changes from V_1 to V_2 .

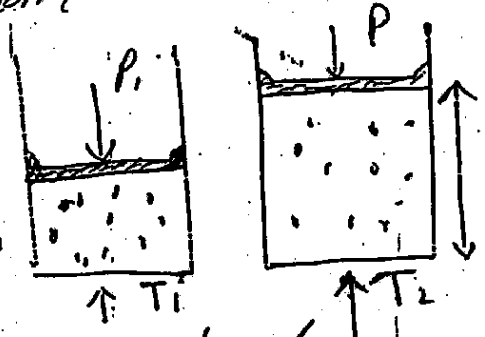
$$\frac{V_1}{T_1} = k \qquad \frac{V_2}{T_2} = k$$

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

Equation (1) can be defined as "Ratio of volume and temp. always remains constant at const pressure".

EXPERIMENTAL VERIFICATION

Let us consider definite mass of a gas enclosed in a cylinder fitted with a movable piston. The volume of gas is V_1 and Temp. is T_1 . When gas is heated, both volume and temp. increase. Say volume becomes V_2 and Temp. becomes T_2 . It has been found



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

... Charles' Law

GENERAL GAS EQUATION:

It is an equation obtained by combination of Boyle's law, Charles' Law and Avogadro's law.

According to Boyle's Law $V \propto \frac{1}{P}$ AT CONSTANT "T" & "n"

According to Charles' Law $V \propto T$ AT CONST. "P", "n".

According to Avogadro's law $V \propto n$ AT CONST. T, P.

If none of the variables is kept constant then we can combine above three laws as follows.

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

$$V = \text{CONSTANT} \frac{nT}{P}$$

$$V = R \frac{nT}{P}$$

$$PV = nRT \quad \text{--- (1)}$$

Equation (1) is called Ideal Gas Equation or General Equation. This equation can be reduced to Boyle's, Charles' Law or Avogadro's Law if some variables are kept constant.

If "n" & T are constant then eq (1) is reduced to Boyle's law. $PV = k$ ($nRT = \text{constant } k$)

If n & P is kept constant eq (1) is reduced to Charles' law, $PV = nRT \Rightarrow V = \frac{nRT}{P}$

If T, P is kept constant, we get Avogadro's law. $V = kT$

$$PV = nRT \text{ or } V = n \frac{RT}{P}$$

$$V = k n \quad \left(\frac{RT}{P} = k \right)$$

FOR ONE MOLE OF GAS GENERAL GAS EQ. CAN BE REDUCED TO $PV = RT \Rightarrow \frac{PV}{T} = R$

Equation (2) can be written as

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

Hence
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{--- (3)}$$

CALCULATION OF VALUE OF "R" IN DIFFERENT U.

The value of "R" is independent of nature of gas. It depends upon units of Pressure, volume & Temp.

CALCULATION Let us consider 1 mole of gas at S.T.

According to Avogadro's law it has volume 22.414 dm³

$$PV = nRT$$

$P = 1 \text{ atm}$

$T = 273.15 \text{ K}$

$n = 1 \text{ mole}$

$V = 22.414 \text{ dm}^3$

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

$$\frac{1 \text{ atm} \times 22.414 \text{ dm}^3}{1 \text{ mole} \times 273.15 \text{ K}} = R$$

$$0.0821 \text{ dm}^3 \text{ atm mole}^{-1} \text{ K}^{-1} = R$$

PHYSICAL MEANING It means if we have 1 mole ^{ideal} gas at 273.15K and 1 atm pressure, 0.0821 dm³ atm energy is required to raise temp of gas by 1K

The value of "R" is same for all gases. It means Avogadro's No. of molecules (1 mole) of all gases demand same amount of energy.

VALUE OF "R" IN SI SYSTEM

$n = 1 \text{ MOLE}$

$P = 101325 \text{ N/m}^2$

$T = 273.15 \text{ K}$

$V = 0.022414 \text{ m}^3$

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

$$R = \frac{101325 \frac{\text{N}}{\text{m}^2} \times 0.022414}{1 \text{ mole} \times 273.15 \text{ K}}$$

$$R = \frac{8.3143 \text{ Nm}}{\text{mole K}}$$

$$R = 8.3143 \text{ J mole}^{-1} \text{ K}^{-1}$$

SINCE $1 \text{ cal} = 4.18 \text{ J}$ So value of R can be changed into Cal. Also

$$R = \frac{8.3143}{4.18} = 1.987 \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$\Rightarrow \text{IF PRESSURE} = 760 \text{ mm(Hg)}$$

$$T = 273.15 \text{ K}$$

$$V = 22414 \text{ cm}^3$$

$$R = \frac{PV}{nT} \Rightarrow R = \frac{760 \text{ mm} \times 22414 \text{ cm}^3}{1 \text{ mole} \times 273 \text{ K}}$$

$$R = 62400 \text{ cm}^3 \text{ Torr mol}^{-1} \text{ K}^{-1}$$

$$= 62.400 \text{ cm}^3 \text{ mm(Hg) mol}^{-1} \text{ K}^{-1} \quad (1 \text{ mm(Hg)} = 1 \text{ Torr})$$

$$= 62.4 \text{ dm}^3 \text{ mm(Hg) mol}^{-1} \text{ K}^{-1}$$

→ CALCULATION OF DENSITY OF GAS

GENERAL Gas Equation can be used to determine density of gas as follows.

$$PV = nRT$$

since $n = \frac{\text{mass}}{\text{Molecular mass}}$

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

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

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

Since $\frac{\text{mass}}{\text{Vol}} = \text{density}$

$$PM = dRT$$

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

This equation shows that density of gas is directly proportional to molecular wt of gas and

to Pressure and Inversely proportional to Temp.

This equation can also be used to calculate MW of a gas.

(See Example No. 3, 4, 5)

Q:- WRITE A NOTE ON ABSOLUTE ZERO. 10
 The hypothetical temperature at which volume of a gas is reduced to zero is called Absolute Zero. It is equal to -273.15°C . The scale of temp at which -273.15°C is taken as zero is called Absolute Zero Scale or Kelvin Scale.

In order to understand absolute zero let us consider quantitative definition of Charles' law. According to Charles' law, "Volume of a given mass of a gas increases or decreases $\frac{1}{273}$ times its volume at 0°C by every degree rise or fall of temperature."

Let us consider a gas at 0°C . Its volume is V° . Then according to Charles' Law its

$$\text{Volume at } 1^{\circ}\text{C} = V^{\circ} + \frac{1}{273} \times V^{\circ}$$

$$\text{Volume at } -1^{\circ}\text{C} = V^{\circ} - \frac{1}{273} \times V^{\circ}$$

$$\text{Volume at } -2^{\circ}\text{C} = V^{\circ} - \frac{2}{273} \times V^{\circ}$$

$$\text{Volume at } -100^{\circ}\text{C} = V^{\circ} - \frac{100}{273} \times V^{\circ}$$

$$\text{Volume of gas at } -273^{\circ}\text{C} = V^{\circ} - \frac{273}{273} V^{\circ}$$

$$= V^{\circ} - V^{\circ} = \text{ZERO}$$

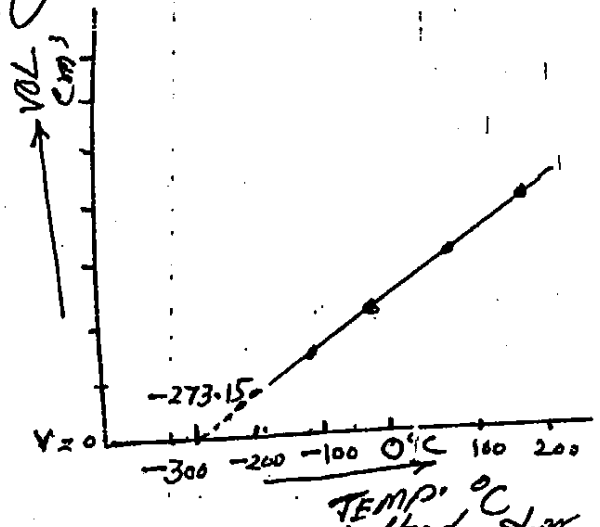
Thus according to quantitative definition of Charles' law volume of a gas is reduced to zero at -273.15°C . This temp. is called Absolute Zero.

GRAPHICAL EXPLANATION: One mole of a gas at 0°C and 1 atm pressure has volume of 22.4 dm^3 . If we plot a graph between temp. (in $^{\circ}\text{C}$) along X-axis and Volume along Y-axis, we get a straight line. This straight line cuts X-axis at -273.15°C .

This is possible only if we extrapolate graph upto -273.15
 This is lowest possible temp. which can be achieved
 if gas the substance remains in gaseous state.

Actually all gases change into
 liquids or solids before
 reaching this temp.

Charles' law is obeyed when
 temperature is taken on
 Kelvin scale.



If graph between "T" and volume are plotted for
 different amounts of gases, different straight lines are
 obtained. The slopes of line is greater for larger
 quantity of gas. However when these lines are ext
 rated, they meet at a single point (-273.15°C) or C
 It is apparent that this temp. will be attained when
 volume of gas becomes zero. But for real gas zero
 volume is not possible. Thus temp. -273.15°C cannot
 be attained for real gas. Thus we can say that
 -273.15°C must be the coldest temperature.

Q: WHY KELVIN SCALE HAS BEEN DEVELOPED?
 Charles' law is not obeyed when temperature is me
 used on $^{\circ}\text{C}$ scale.

In order to understand the need
 of Kelvin scale let us consider a definite mass of
 at 0° having a volume of 546cm^3 . Now according
 to Charles' law vol of gas at $1^{\circ}\text{C} = V^{\circ} + \frac{1}{273} \times V^{\circ}$

$$= 546 + \frac{1}{273} \times 546$$

$$= 548\text{cm}^3$$

$$\therefore \text{at } 10^{\circ}\text{C} = 546 + \frac{10}{273} \times 546 = 566\text{cm}^3$$

$$\text{Volume of gas at } 100^{\circ}\text{C} = 546 + \frac{100}{273} \times 546$$

$$= 746 \text{ cm}^3$$

Say $T_1 = 10^{\circ}\text{C}$

$$V_1 = 566$$

$$T_2 = 100^{\circ}\text{C}$$

$$V_2 = 746 \text{ cm}^3$$

According to Charles' law

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

But in this case $\frac{566}{10} \neq \frac{746}{100}$

The two ratios are not equal. Hence Charles' law is not obeyed if temp. is taken on $^{\circ}\text{C}$. For this reason a new scale has been developed at which -273.15°C is taken as zero. This is called Kelvin scale.

If same ratio is considered at Kelvin scale the ratio remains constant.

$$T_1 = 10 + 273 = 283 \text{ K}$$

$$V_1 = 566 \text{ cm}^3$$

$$T_2 = 100 + 273 = 373 \text{ K}$$

$$V_2 = 746 \text{ cm}^3$$

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

$$\frac{566}{283} = \frac{746}{373} = K.$$

Hence temperature is always taken on Kelvin scale.

DALTON'S LAW OF PARTIAL PRESSURES.

This law can be defined as, "The total pressure of a mixture of gases is equal to sum of partial pressures of individual components."

$$P_T = P_1 + P_2 + P_3 \quad \text{--- (1)}$$

P_T = "is" total pressure of mixture of gases and
 P_1, P_2, P_3 are partial pressures of gases 1, 2, 3.

Let us consider four cylinders of same volume.
Three gases H_2, CH_4 , and O_2 are separately enclosed in each of them at same temp. The respective pressures are 500 torr, 400 torr and 100 torr.
These gases are transferred to fourth cylinder at same temp. According to Dalton's law

$$P_T = P_{H_2} + P_{CH_4} + P_{O_2} = 1000 \text{ Torr}$$

$$P_T = 500 + 400 + 100 = 1000 \text{ Torr}$$

These three are non reacting gases. The molecules are moving independently. They have equal chance of collision on walls of container. Each gas exerts its own pressure in mixture. The total pressure is the result of total number of collisions per unit area per unit time.

Let us apply general gas equation to individual gases in the mixture

$$P_{H_2} V = n_{H_2} RT \quad \text{OR} \quad P_{H_2} = \frac{n_{H_2} RT}{V} \quad \Rightarrow \quad P_{H_2} \propto n_{H_2}$$

$$P_{CH_4} V = n_{CH_4} RT \quad \Rightarrow \quad P_{CH_4} = \frac{n_{CH_4} RT}{V} \quad \Rightarrow \quad P_{CH_4} \propto n_{CH_4}$$

$$P_{O_2} V = n_{O_2} RT \quad \Rightarrow \quad P_{O_2} = \frac{n_{O_2} RT}{V} \quad \Rightarrow \quad P_{O_2} \propto n_{O_2}$$

The "T" and "V" are same volume each gas in mixture. Thus the value $\frac{RT}{V}$ is constant. Partial pressure of

gas is directly proportional to number of moles of gas

$$P_t = P_{H_2} + P_{CH_4} + P_{O_2} \quad \text{--- (2)}$$

$$P_t = n_{H_2} \frac{RT}{V} + n_{CH_4} \frac{RT}{V} + n_{O_2} \frac{RT}{V} \quad \text{--- (3)}$$

$$P_t = (n_{H_2} + n_{CH_4} + n_{O_2}) \frac{RT}{V}$$

$$P_t = n_t \frac{RT}{V}$$

$$P_t V = n_t RT \quad \text{--- (4)}$$

CALCULATION OF PARTIAL PRESSURE OF EACH GAS

The partial pressure of each gas can be calculated if we know moles of each gas and total no. of moles in the mixture.

Let us consider two gases "A" and "B" in a cylinder. Their numbers of moles are n_A and n_B respectively. Then writing general gas eq. for each gas

$$P_A V = n_A RT \quad \text{--- (5)} \quad P_B V = n_B RT \quad \text{--- (6)}$$

For mixture $P_t V = n_t RT \quad \text{--- (7)}$

Dividing eq. (5) and (6) by eq. (7) we get

$$\frac{P_A V}{P_t V} = \frac{n_A RT}{n_t RT} \quad \text{--- (8)} \quad \frac{P_B V}{P_t V} = \frac{n_B RT}{n_t RT}$$

$$\frac{P_A}{P_t} = \frac{n_A}{n_t} \quad \text{--- (10)} \quad \frac{P_B}{P_t} = \frac{n_B}{n_t} \quad \text{--- (11)}$$

$$P_A = \frac{n_A}{n_t} P_t \quad \text{--- (12)} \quad P_B = \frac{n_B}{n_t} P_t \quad \text{--- (13)}$$

$$P_A = X_A P_t \quad \text{--- (14)} \quad P_B = X_B P_t \quad \text{--- (15)}$$

" X_A " and " X_B " are called mole fractions of gas "A" and "B" respectively.

APPLICATIONS OF DALTON'S LAW

1. COLLECTION OF GASES OVER WATER

Gases which are insoluble in water are collected over water in lab. Whenever a gas is collected over water, some vapours are also included in gas. This is called wet gas. The total pressure is $P_T = P_{\text{gas}} + P_{\text{vapours}}$. In order to get pressure of dry gas, pressure of vapours must be subtracted from total pressure.

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

Pressure of vapours is called aqueous tension.

2. RESPIRATION PROCESS

The respiratory pressure depends upon difference in partial pressures of gases. The partial pressure of O_2 is greater in inhaled Air. The partial pressure of O_2 is lesser in blood supplied to the lungs (159 g/cm^3). Thus oxygen diffuses from Air to blood. The partial pressure of CO_2 is greater in blood and lesser in Air. Thus CO_2 diffuses out.

3. BREATHING AT HIGH ALTITUDES

At high altitudes partial pressure of oxygen is decreased (below 159 g/cm^3). Thus pilots feel uncomfortable breathing in their unpressurized cabins.

4. DEEP SEA DIVING

Deep sea divers take 4% O_2 mixed with an inert gas 'He' in their tank and adjust pressure of O_2 according to requirements.

EXPLAIN THE

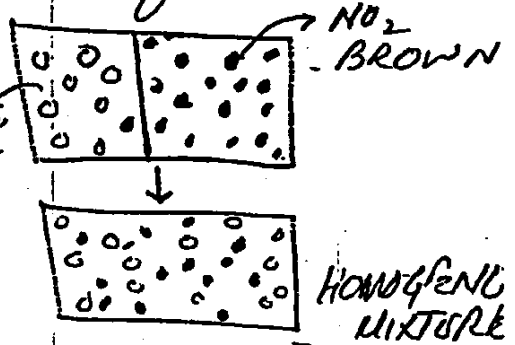
DIFFUSION OF GASES

The intermixing of gases in all proportions to form a homogeneous mixture is called diffusion. The diffusion is due to constant motion of gas molecules in random directions and their collision with one another and also with walls of container.

Examples: Spreading of fragrance of rose or scent

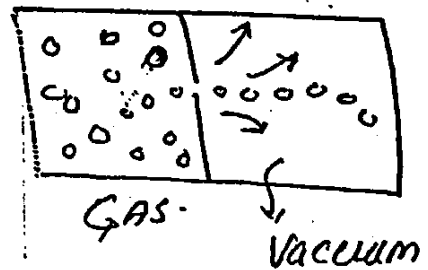
When two gases diffuse, they try to make their partial pressures same every where.

Suppose NO_2 a brown gas and O_2 a colourless gas are separated from each other by a partition when partition is removed, both diffuse into each other due to collision and random motion. A stage is reached when gases generate a homogeneous mixture. The pressure becomes uniform every where.



EFFUSION :- The escape of gas molecules from aperture of very small size one by one without collision is called effusion. This spreading is not due to collision but their tendency to escape one by one.

Molecules constantly collide with walls of container. When a molecule approaches the wall in front of opening it enters the other portion of vessel. This is called effusion.



GRAHMS LAW OF DIFFUSION AND EFFUSION

It states that "the rate of diffusion or effusion of a gas is inversely proportional to square root of its density at constant temperature and pressure."

According to Graham's law Rate of diffusion $\propto \frac{1}{\sqrt{d}}$ (at const. T, P)

$$\text{Rate of diffusion} = \frac{k}{\sqrt{d}}$$

$$\text{Rate of diffusion} \times \sqrt{d} = k$$

$$\text{Rate} \times \sqrt{d} = k$$

k is constant for all gases at same temp. and press.
Let us consider two gases "1" and "2" their respective rates of diffusion and densities are r_1, r_2, d_1, d_2

Then according to Graham's law

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

and

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

$$r_1 = k \frac{1}{\sqrt{d_1}}$$

$$r_2 = k \frac{1}{\sqrt{d_2}}$$

$$r_2 \times \sqrt{d_2} = k$$

$$r_1 \times \sqrt{d_1} = k$$

Then by dividing above two equations

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

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

Since densities are proportional to molecular masses
So Graham's law can also be written as

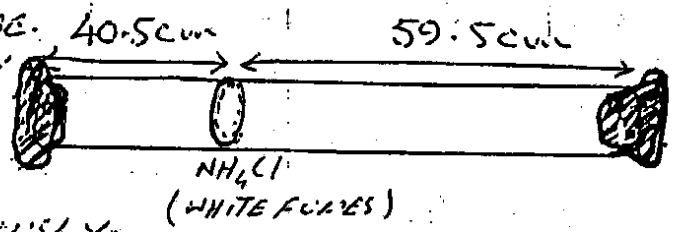
$$\frac{r_1}{r_2} = \frac{\sqrt{M_2}}{\sqrt{M_1}} \quad (\text{at constant } T, P)$$

G7

VERIFICATION OF GRAHAM'S LAW.

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TAKE A 100CM LONG GLASS TUBE. 40.5cm
PUT A COTTON PLUG SOAKED IN
NH₃ AT ONE END AND A
COTTON PLUG SOAKED IN HCl
AT OTHER END SIMULTANEOUSLY.
BOTH GASES ESCAPE FROM RESPECTIVE ENDS AND TRAVEL
TO CENTRE. WHERE THESE GASES REACT, A RING OF
WHITE DENSE FUMES OF NH₄Cl ARE FORMED.
THIS NH₄Cl FORMED IS 59.5cm AWAY FROM NH₃ PLUG
AND 40.5cm AWAY FROM HCl PLUG.
IT SHOWS THAT VELOCITY OF NH₃ IS GREATER
THAN HCl. THE RATES OF DIFFUSION DEPEND UPON
VELOCITY. SO NH₃ IS EXPECTED TO HAVE HIGHER RATE
OF DIFFUSION THAN HCl.



$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = \frac{\text{DISTANCE COVERED BY NH}_3}{\text{DISTANCE COVERED BY HCl}}$$

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = \frac{59.5}{40.5}$$

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = 1.47$$

THE EXPERIMENT SHOWS THAT
RATE OF DIFFUSION OF NH₃
SHOULD BE 1.47 TIMES GREATER
THAN HCl.

CALCULATION FROM GRAHAM'S LAW:

ACCORDING TO GRAHAM'S LAW RATES OF DIFFUSION OR
EFFUSION OF GASES ARE INV. PROP. TO SQ. ROOTS OF THEIR
DENSITIES OR MOLECULAR WTS. AT SAME TEMP & PRESS.

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = \sqrt{\frac{\text{MWT OF HCl}}{\text{MWT OF NH}_3}}$$

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = \sqrt{\frac{36.5}{17}}$$

$$\frac{r_{\text{NH}_3}}{r_{\text{HCl}}} = 1.47$$

THE RATIO OF RATES OF D
CALCULATED FROM GRAHAM'S
LAW IS THE SAME AS DETER
MINED EXPERIMENTALLY.
HENCE GRAHAM'S LAW IS
VERIFIED.

KINETIC THEORY OF GASES:

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- In order to explain behaviour of gases quantitatively
- Bernoulli put forward kinetic molecular theory of gases.
 - Clausius derived kinetic equation from this theory and deduced all gas laws from it. The theory was further explained by Maxwell. He gave law of distribution of molecular velocities. According to this law there are groups of molecules having definite velocity range.
 - Boltzmann studied distribution of energies among gas molecules. Fundamental postulates of K.T.G. are given below.

Q. POSTULATES OF K.T.G. & DERIVATION OF GAS LAWS ON THE BASIS OF K.T.G.

The main postulates of K.T.G. are given below.

- (1) All gases consist of very small particles called atoms or molecules. (atoms for monoatomic gases only e.g. He, Ne)
- (2) The actual size of gas molecule is negligible as compared to total volume of gas. So most of space in a gas container is empty.
- (3) There are no forces of attraction or repulsion between gas molecules. Thus each molecule moves independently.
- (4) The gas molecules are constantly moving in straight line. Their direction changes when they collide with another molecule or with walls of container.
- (5) Due to their motion gas molecules possess K.E. The temperature of gas is measure of average kinetic energy of gas molecules. The average speed and average kinetic energy is directly proportional to temp. on Kelvin scale.
- (6) At same temperature different gases have same average K.E.
- (7) Gas molecules are constantly moving in random directions. Their direction changes only when they collide with another molecule or walls of container. Pressure of gas is due to collisions of molecules on walls of container.
- (8) Force of gravity has no influence on gas molecules.
- (9) The collision of molecules is ELASTIC i.e. they do not lose any kinetic energy on collision. The collision without any gain or loss of energy is called Elastic Collision. C.G.

9mp.

WHAT IS KINETIC EQUATION? DERIVE GAS LAWS FROM K.T.G USING KINETIC EQUATION;

By using kinetic theory of gases R.J. Clausius deduced an expression for the pressure of an ideal gas.

According to K.T.G gas molecules are constantly moving they collide with one another and also with walls of container. Due to these collisions they exert some force on walls of container. This force per unit area exerted by gas molecules is called pressure. The kinetic eq. derived by Clausius is $PV = \frac{1}{3} mN\bar{c}^2$ — (1)

P = Pressure, V = volume, m = mass of one molecule
 N = number of molecules, \bar{c}^2 = mean sq. velocity.

All gas molecules do not have same velocities. If there are " n_1 " molecules with velocity " c_1 " and " n_2 " molecules with velocity " c_2 " then

$$\bar{c}^2 = \frac{N_1 c_1^2 + N_2 c_2^2 + N_3 c_3^2 + \dots}{N_1 + N_2 + N_3 + \dots}$$

\bar{c}^2 is called average of sq. of velocities i.e. mean sq. velocity

The sq. root of mean sq. velocity is called C_{rms} .

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

This equation is quantitative relationship between absolute temperature and velocities of gas molecules. According to this equation higher the temperature of gas, greater is the velocity of molecules.

EXPLANATION OF GAS LAWS FROM KINETIC Eq.

BOYLE'S LAW: According to Boyle's law volume of a given mass of gas is inversely proportional to pressure at constant temperature. $V \propto \frac{1}{P}$ at const. T

$$V = k \times \frac{1}{P} \text{ or } P \times V = k \quad \text{--- (1)}$$

According to K.T.G the kinetic energy of molecule is directly proportional to absolute temperature.

$$\frac{1}{2} m n \bar{C}^2 \propto T$$

$$\frac{1}{2} m n \bar{C}^2 = kT \quad \text{--- (2)}$$

According to kinetic equation multiplying and dividing by 2

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

$$PV = \left(\frac{1}{3} m n \bar{C}^2\right) \times \frac{2}{2}$$

$$PV = \left(\frac{1}{2} m n \bar{C}^2\right) \frac{2}{3}$$

Since $\frac{1}{2} m n \bar{C}^2 = kT$

$$PV = kT \frac{2}{3} \quad \text{--- (3)}$$

from eq (2) At constant "T" R.H.S of eq (3) is constant. $PV = \text{Constant}$

Thus product of pressure and volume remains constant at constant temperature. This is Boyle's Law.

CHARLES LAW:

a given mass of gas is directly proportional to absolute Temp. at constant pressure.

$$V \propto T$$

$$V = kT \quad \text{--- (5) "k" is constant}$$

$$\frac{V}{T} = k \quad \text{--- (6)}$$

Eq. (6) can be defined as "Rate of volume and Temp. always remains constant at constant pressure."

From eq. (3)

$$PV = kT \frac{2}{3}$$

$$V = kT \frac{2}{3P}$$

$$V = \frac{2}{3P} kT$$

At constant pressure $\frac{2}{3P} k = k'$ or $V \propto T$

$$V = k' \frac{T}{1} \quad \text{--- (7)}$$

METHODS OF LIQUEFICATION OF GASES.

JOULE THOMSON EFFECT:

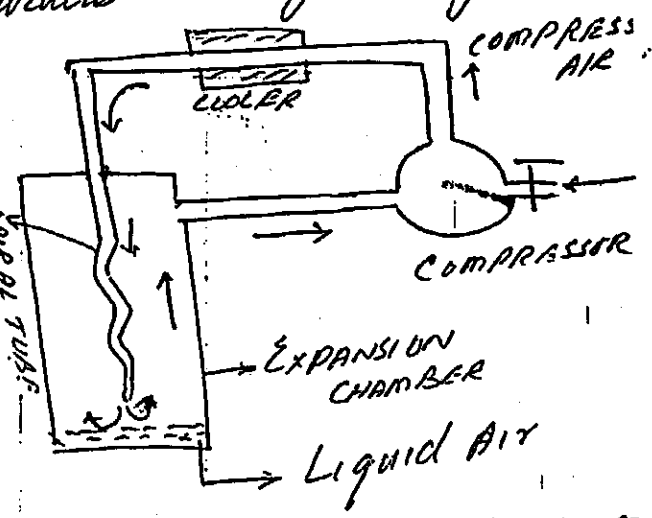
PRINCIPLE: When a highly compressed gas is allowed to expand into a region of low pressure cooling takes place.

When a gas is compressed, molecules get closer to each other and develop some forces of attraction among themselves. When gas is allowed to expand suddenly, the molecule move apart from each other. They have to break intermolecular force. The energy required for this purpose is absorbed from the gas itself. Thus gas is cooled.

LINDS' METHOD OF LIQUEFACTION OF GASES:

PRINCIPLE: It is based upon Joule Thomson effect. i.e. When a highly compressed gas is allowed to expand cooling takes place. The apparatus used for this purpose is shown below.

The air is compressed to about 200 atm. Then it is passed through cooler to remove heat of compression. It is then allowed to pass through a spiral pipe having a jet at the end.



The air is allowed to expand from 200 atm to 1 atm. Cooling takes place due to expansion. The cooled air goes upward and cools incoming compressed air. Then it is returned to compression pump. The process is repeated over and over again. The liquid air is collected at the bottom of chamber.

All gases except H_2 and He can be liquefied by this procedure.

METHODS OF LIQUEFICATION OF GASES.

JOULE THOMSON EFFECT:

PRINCIPLE: When a highly compressed gas is allowed to expand into a region of low pressure, cooling takes place.

When a gas is compressed, molecules get closer to each other and develop some forces of attraction among themselves. When gas is allowed to expand suddenly, the molecules move apart from each other. They have to break intermolecular force. The energy required for this purpose is absorbed from the gas itself. Thus gas is cooled.

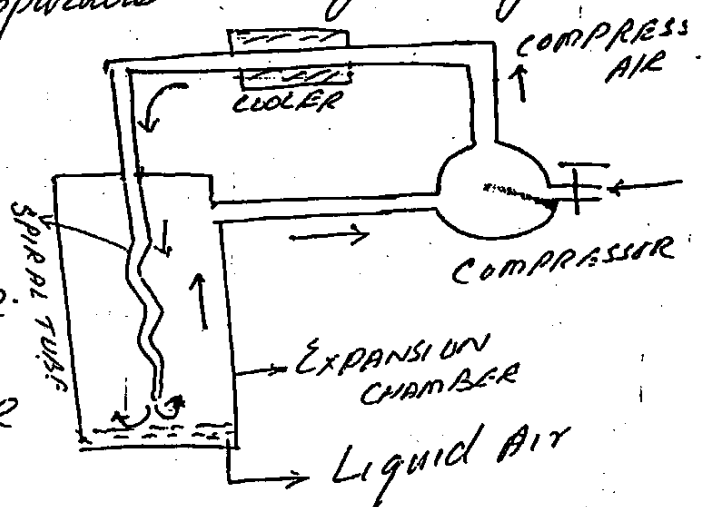
LIND'S METHOD OF LIQUEFACTION OF GASES:

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→ All gases except H_2 and He can be liquefied by this procedure.

CAUSES OF DEVIATION:

The real gases deviate from ideal behaviour due to two faulty assumptions in kinetic theory of gases.

- 1. The actual size of gas molecule is negligible as compared to total volume occupied by gas.
- 2. There are no forces of attraction or repulsion between gas molecules and each gas molecule behaves independently.

The deviations from ideality depend upon following factors.

- (i) Nature of gas (ii) Temperature (iii) Pressure.

The deviations are much more pronounced at low temp. and high pressure. The first assumption is responsible for deviation at high pressure and second postulate is responsible for deviation at low temperature.

DEVIATION AT HIGH PRESSURE:

At high pressure the gas molecules come closer to each other. The empty spaces between molecules decrease. Thus actual volume occupied by gas molecule is not negligible at this state, as compared to total volume of gas. Further when gas molecules come closer to each other they have some forces of attraction for each other.

DEVIATION AT LOW TEMPERATURE:

When temperature is very high, kinetic energy of molecules is very large. The forces of attraction between them are negligible.

However at low temperature kinetic energy becomes very low. The intermolecular forces remain no more negligible. Thus collision between molecules are not elastic at low temp. Therefore gases show marked deviations at low temperature.

Non polar gases and monoatomic gases which have very low B.P. (-252.7°C for H_2) behave almost ideal at room temperature because room temperature (25°C) is sufficiently high temperature for these gases. On the other hand polar gases like SO_2 , H_2S with relatively high B.P. show more deviations at room temperature. Because polar gases do have some intermolecular forces (dipole-dipole interactions) at room temperature.

DERIVE VANDER WAALS EQUATION.

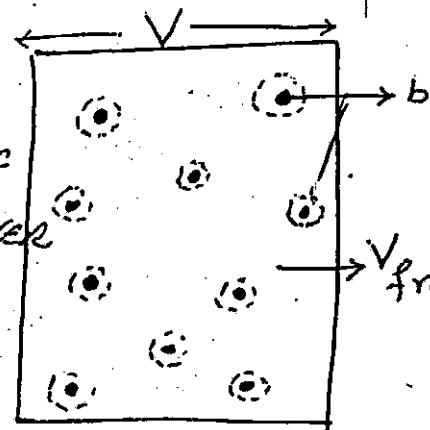
REAL GASES DEVIATE FROM GENERAL GAS EQUATION $PV = nRT$. VANDER WAALS POINTED OUT THAT TWO CORRECTIONS MUST BE MADE TO ADOPT GENERAL GAS EQUATION TO REAL GASES. ONE OF THESE CORRECTIONS IS VOLUME CORRECTION AND OTHER ONE IS PRESSURE CORRECTION. THE EQUATION THIS OBTAINED AFTER THESE TWO CORRECTIONS IS CALLED VANDER WAALS EQUATION.

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

ALL GASES OBEY THIS EQUATION.

DERIVATION:-

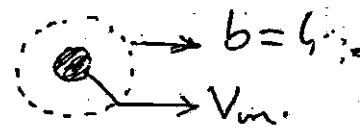
VANDER WAALS SUGGESTED THAT VOLUME OF GAS IS NOT EQUAL TO VOLUME OF CONTAINER. IT IS ACTUALLY THE VOLUME AVAILABLE TO GAS MOLECULES TO MOVE IS ACTUALLY VOLUME OF CONTAINER MINUS VOLUME OCCUPIED BY GAS MOLECULES THEMSELVES.



$$(b = 4V_m)$$

$$V_{free} = V - nb \quad \text{--- (3)}$$

"b" IS CALLED EXCLUDED VOLUME
 $b = 4V_m$



"V_m" IS ACTUAL VOLUME OF MOLE OF GAS MOLECULE. EXCLUDED VOLUME IS FOUR TIMES THE ACTUAL VOLUME OF MOLE OF GAS MOLECULES. FOR MOLE OF GAS $V_{free} = V - b$

UNIT OF b

"b" IS ALSO CALLED INCOMPRESSIBLE VOLUME OR EXCLUDED VOL. ITS UNIT IS $\frac{dm^3}{mole}$ OR $m^3/mole$. IN SI SYSTEM UNIT OF b = $m^3/mole$.

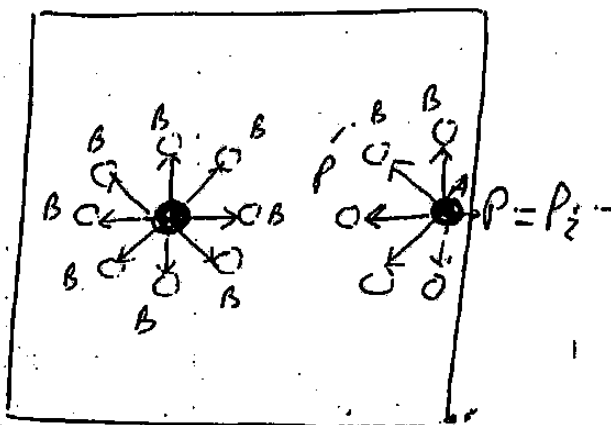
IT DEPENDS UPON SIZE OF MOLECULE. THE LEAST VALUE IS THAT OF $H_2 = 0.0266 m^3/mole$.

IT MEANS 1 MOLE OF H_2 WILL OCCUPY A VOLUME OF $0.0266 m^3$ AT A DISTANCE OF CLOSEST APPROACH IN GAS STATE. IT IS ALSO CALLED EFFECTIVE VOLUME OF MOLE GAS

PRESSURE CORRECTION

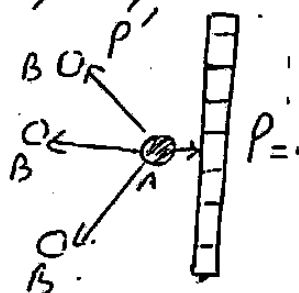
THE PRESSURE EXERTED BY REAL GAS MOLECULE ON WALLS OF CONTAINER IS ALWAYS LESS THAN IDEAL PRESSURE

$$P = P_2 - P' \quad \text{--- (5)}$$



REASON: WHEN A GAS MOLECULE IS PRESENT IN BODY OF CONTAINER (IN CENTRE), IT IS ATTRACTED BY MOLECULES IN ALL DIRECTIONS. THERE IS NO NET FORCE ON MOLECULE. BUT WHEN A MOLECULE IS JUST GOING TO STRIKE ON WALLS OF CONTAINER TO EXERT PRESSURE, IT IS SLIGHTLY PULLED BACK BY NEIGHBOURING MOLECULE. THE PRESSURE ON WALLS OF CONTAINER IS SLIGHTLY LESS THAN TRUE KINETIC PRESSURE P_2

$$P = P_2 - P'$$



P' IS THE PRESSURE CONSIDERED TO OVERCOME FORCES OF ATTRACTION OF NEIGHBOURING MOLECULES.

TRUE KINETIC PRESSURE (IDEAL PRESSURE P_2 WHICH GAS MOLECULES MAY HAVE EXERTED IN ABSENCE OF FORCE OF ATTRACTION OF NEIGHBOURING MOLECULES) CANNOT BE CALCULATED AS FOLLOWS

$$P + P' = P_2 \quad \text{--- (6)}$$

THE VALUE OF P' FOR "n" MOLES OF GAS IS

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

FOR 1 MOLE

OF GAS IT IS EQUAL TO $P' = \frac{ca}{V^2}$

a IS CALLED CO-EFFICIENT OF ATTRACTION OR ATTRACTION PER UNIT VOLUME. IT DEPENDS UPON STRENGTH OF INTERMOLECULAR FORCES. POLAR GASES HAVE LARGER VALUE OF a .

ITS UNIT IS $\text{atm dm}^6 \text{ mole}^{-2}$ OR $\text{N m}^4 \text{ mole}^{-2}$

HENCE
$$P_2 = P + \frac{an^2}{V^2} \quad \text{--- (8) FOR "n" MOLES.}$$

AFTER VOLUME CORRECTION AND PRESSURE CORRECTION GENERAL GAS EQUATION BECOMES VANDER WAALS EQ

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT \quad \text{--- (10)}$$

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT \quad \text{--- (11)}$$

EQUATION (10) IS CALLED VANDER WAALS EQUATION FOR "n" MOLES OF GAS. EQ. (11) IS VANDER WAALS EQ FOR 1MOLE.

DERIVATION FOR CALCULATION OF P'

Q: \Rightarrow (PROVE THAT $P' = \frac{an^2}{V^2}$)
 THE VALUE OF P' DEPENDS UPON NO. AND STRENGTH OF ATTRACTION FORCES B/W STRIKING MOLECULES AND NO. OF MOLECULES PULLING IT BACKWARD.

THE FORCES OF ATTRACTION ARE PROPORTIONAL TO CONC. OF "A" MOLECULES STRIKING ON WALL AND CONC. OF "B" MOLECULES PULLING IT BACKWARD.

$$P' \propto C_A \times C_B$$

$$P' \propto \frac{n}{V} \times \frac{n}{V}$$

$$P' = \frac{an^2}{V^2} \quad \text{--- (12)}$$

$$\left(\text{CONC.} = \frac{\text{MOLE}}{\text{VOLUME}}\right)$$

a = CONSTANT OF PROPORTIONALITY. IT IS CALLED CO-EFFICIENT OF ATTRACTION.

FOR 1 MOLE GAS

$$V' = \frac{V}{n} \quad (n=1)$$

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CALCULATION OF UNIT OF a

DETERMINE UNIT OF a ∴ Eq. (12) CAN BE USED;

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

$$\frac{\text{atm} \times (\text{dm}^3)^2}{\text{mole}^2} = a$$

IN SI SYSTEM UNIT OF a = $\frac{\text{atm} \text{ dm}^6}{\text{mole}^2} = a$

Since $P' = \frac{N}{m^2}$, $V^3 = m^3$

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

$$\frac{N}{m^2} (m^3)^2 = a \quad \text{OR} \quad \frac{N m^4}{\text{mole}^2} = a$$

FACTORS AFFECTING VALUE OF a

THE VALUE OF a DEPEND UPON STRENGTH OF INTERMOLECULAR FORCES. THE POLAR GASES WITH LARGE SIZE HAVE STRONGER INTERMOLECULAR FORCES AND LARGER VALUE OF a . FOR EXAMPLE Cl_2 , SO_2 , NH_3 HAVE LARGE a VALUE. H_2 HAS LEAST VALUE OF a DUE TO SMALL SIZE AND NON POLAR NATURE. (SEE TABLE FROM TEXT BOOK ALSO).

WHAT IS PLASMA? How is it Formed?

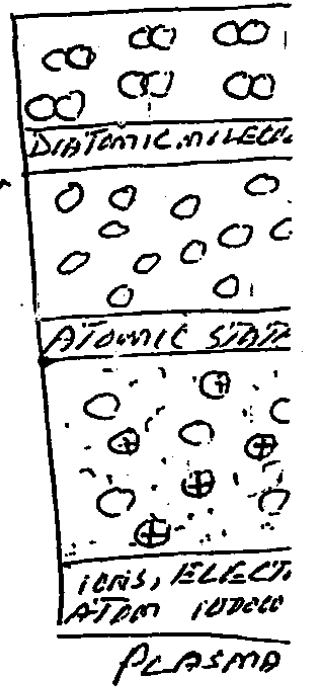
The state of matter in which significant number of particles are electrically charged and it can conduct electric current effectively is called PLASMA STATE. These charged particles are large enough that they can effect electrical properties and behaviour.

It is also called fourth state of matter. More than 99% of visible universe is composed of plasma. It was first identified by William Crookes 1879. Naturally occurring plasma is rare on earth. However there are many examples of man-made plasma e.g. fluorescent lights, neon signs, fluorescent Bulbs etc. It is everywhere in our space environment.

How is PLASMA FORMED?

When a gas is heated to about 2000°C, molecules may change into atoms by breaking of bonds. As temp. is further increased atoms begin to lose electrons and get converted into positive ion. At still high temp. more and more atoms are ionised. However 100% does not occur.

A mixture of atoms, ions and free electron is produced. This mixture is called PLASMA. It can conduct electricity, respond to electric and magnetic fields.



NATURAL PLASMA? WHERE DOES IT OCCUR? 34

Almost entire universe is plasma. It existed before any other form of matter. Plasma is found in everything from pin to quasars. Natural plasma is stuff of stars. A majority of matter in inner stellar space is plasma. All stars that shine are plasma. The sun is 1.5 million km ball of plasma. It's heated by nuclear fusion.

Natural plasma occurs at high temp or low temp. in vacuum. It does not break down or react rapidly. It is extremely hot. It can vaporize any material which come in contact.

ARTIFICIAL PLASMA Artificial plasma can be created by ionization of gas as in neon ~~gas~~ signals.

It occurs in lightning bolts, flames, ~~auroras~~ auroras and fluorescent bulbs when electric current is passed through them. Plasma at low temp. is hard to maintain because outside vacuum low temp plasma reacts with any molecule it collides. It is useful due to this property but hard too.

CHARACTERISTICS OF PLASMA

UNIQUE STATE OF MATTER: - Plasma has large number of charged particles. It shows collective

response to electric and magnetic fields. Due to motion of charge particles it creates fields and electric current within plasma density.

PLASMA DENSITY The density of charged particles in plasma is called plasma density.

Due to complex set of interactions plasma is a unique, fascinating and complex state of matter.

2) ELECTRICALLY NEUTRAL Plasma is a mixture of atoms, ions and electrons and it conducts electricity. In measurement macroscopically it is neutral. In measurement quantities electrons and ions are equal.

APPLICATIONS OF PLASMA

Plasma has a large number of applications, these are:

1) FLUORESCENT LIGHT BULBS:- A fluorescent light has a long tube which contains a gas. When electricity flows through the tube, this electricity charges up the gas. This charging and exciting of atoms produces glowing plasma inside bulb.

NEON SIGNS These are glass tubes mostly filled with Neon gas. When electricity flows through this gas, it is ionized and produces specific colours. The plasma colour depends upon the nature of gas inside the tube.

OTHER PRACTICAL APPLICATIONS Plasma is used in:

- 1) Plasma processing semiconductors
- 2) Sterilization of medical products
- 3) Lamps, Lasers, pulsed power.

Switches, Diamond coated films, high power microwave switches, etc.

POTENTIAL APPLICATIONS | They provide the foundation for

important potential applications, such as :-

ELECTRICAL ENERGY FROM FUSION POLLUTION CONTROL

REMOVAL OF HAZARDOUS CHEMICALS.

ELECTRONIC DEVICES | Plasma light up our offices and

homes, computers and electronic devices work with the help of plasma.

PARTICLE ACCELERATORS | The drive lasers and

particle accelerators. help to clean up environment
pasteurize foods and make tools corrosion resistant

FUTURE HORIZONS | Scientists are trying to use

plasma wave and wave in practical life. For this purp.
it must be able to survive without instantly colliding
and reacting with other molecules.

METASTABLE MOLECULES :- Magnetic fields create &

energy plasma in which molecules are in metastable state. These molecules do not react until they collide with another molecule with just the right energy. Thus these molecules are stable enough to react with a designated molecule.

These metastable particles may be used to solve problems like radioactive contamination.

Scientists are trying with mix of gases to work as metastable agents on plutonium and uranium.

NUMERICALS CHAPTER NO. 3

16:-(a)

$$V_1 = 100 \text{ cm}^3$$

$$P_1 = 500 \text{ Torr}$$

$$V_2 = 250 \text{ cm}^3$$

$$P_2 = ?$$

T = CONSTANT

$$P_1 V_1 = P_2 V_2$$

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

$$\frac{500 \times 100}{250} = P_2$$

Ans: $\boxed{200 \text{ Torr} = P_2}$

b)

$$T_1 = 20 + 273 = 293 \text{ K}$$

$$T_2 = 15 + 273 = 288 \text{ K}$$

By using GENERAL GAS EQ.

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

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

$$\frac{500 \times 100}{293} \times \frac{288}{250} = P_2$$

Ans $\boxed{196.58 = P_2}$

Q. NO.: 17: CALCULATE DENSITIES

DENSITY OF CH_4 AT S.T.P.

$$T = 273 \text{ K}$$

$$P = 101325 \frac{\text{N}}{\text{m}^2}$$

$$m = 16 \text{ g/mole} = 0.016 \frac{\text{kg}}{\text{mole}}$$

By using GENERAL GAS EQ

$$PM = dRT$$

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

$$\frac{101325 \frac{\text{N}}{\text{m}^2} \times 0.016 \frac{\text{kg}}{\text{mole}}}{8.3143 \frac{\text{Nm}}{\text{mole K}} \times 273 \text{ K}} = d$$

$$\frac{101325 \frac{\text{N}}{\text{m}^2} \times 0.016 \frac{\text{kg}}{\text{mole}}}{8.3143 \frac{\text{Nm}}{\text{mole K}} \times 273 \text{ K}} = d$$

$$\boxed{0.714 \text{ kg/m}^3} = d$$

SIMILARLY DENSITY OF

$$d = \frac{101325 \frac{\text{N}}{\text{m}^2} \times 0.032 \frac{\text{kg}}{\text{mole}}}{8.3143 \frac{\text{Nm}}{\text{mole K}} \times 273 \text{ K}}$$

$$\boxed{d = 1.428 \text{ kg/m}^3}$$

DENSITY OF H_2

$$d = \frac{101325 \frac{\text{N}}{\text{m}^2} \times 0.002 \frac{\text{kg}}{\text{mole}}}{8.3143 \frac{\text{Nm}}{\text{mole K}} \times 273 \text{ K}}$$

$$\boxed{d = 0.089 \text{ kg/m}^3}$$

(b) RATIO OF DENSITIES

$$d_{\text{H}_2} : d_{\text{CH}_4} : d_{\text{O}_2}$$

$$0.089 : 0.714 : 1.428$$

$$1 : 8 : 16$$

HENCE RATIO OF DENSITIES THE SAME AS THAT OF M.

18) - SAMPLE OF KRYPTON

$$V_1 = 6.25 \text{ dm}^3 \quad V_2 = 9.55 \text{ dm}^3$$

$$P_1 = 765 \text{ Torr} \quad P_2 = 375 \text{ Torr}$$

$$T_1 = 20 + 273 \quad T_2 = \text{--- ?}$$

$$293 \text{ K}$$

BY USING GENERAL GAS EQ

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

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

$$T_2 = \frac{375 \times 9.55 \times 293}{765 \times 6.25}$$

$$T_2 = 219.46 \text{ K}$$

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

$$t^\circ\text{C} = \text{K} - 273$$

$$t^\circ\text{C} = 219.46 - 273$$

$$\text{ANS. } \boxed{t^\circ\text{C} = -53.54}$$

19) WORKING ON VACUUM

$$V_1 = 255 \text{ cm}^3 \Rightarrow 0.255 \text{ dm}^3$$

$$P_1 = 10 \text{ Torr} \Rightarrow 0.0132 \text{ AT}$$

$$T = 25 + 273 \Rightarrow 298 \text{ K}$$

$$\text{MASS} = 12.1 \text{ mg} \Rightarrow 0.0121 \text{ g}$$

$$PV = nRT$$

$$PV = \frac{m}{MWT} RT$$

$$MWT = \frac{mRT}{PV}$$

$$MWT = \frac{0.0121 \times 0.0821 \times 298}{0.0132 \times 0.255}$$

$$\boxed{MWT = 87.93 \text{ g/mol}}$$

20) CALCULATE PRESSURE

$$\text{MASS OF } H_2 = 2.0 \text{ g}$$

$$\text{MASS OF } N_2 = 8.0 \text{ g}$$

$$\text{VOL OF VESSEL} = 10 \text{ dm}^3$$

$$\text{TEMPERATURE} = 273 \text{ K}$$

$$\text{MOLES OF } H_2 = \frac{2}{2} = 1.0 \text{ mol}$$

$$\text{MOLES OF } N_2 = \frac{8}{28} = 0.28 \text{ mol}$$

$$\text{TOTAL MOLES} = 1.28 \text{ mol}$$

$$PV = nRT$$

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

$$P = \frac{1.28 \times 0.0821 \times 273}{10} = \boxed{2.88 \text{ AT}}$$

20

Q: 21: RELATIVE DENSITIES

DENSITY OF GAS A $d_A = 1$

DENSITY OF GAS B $d_B = 1.5$

VOLUME OF GAS A $V_A = 150 \text{ cm}^3$

VOLUME OF GAS B $V_B = ?$

SO ACCORDING TO GRAHMS LAW

$$\frac{r_A}{r_B} = \sqrt{\frac{d_B}{d_A}}$$

SINCE VOLUME OF GAS WHICH DIFFUSES DEPEND UPON RATE OF DIFFUSION

$$\frac{V_A}{V_B} = \sqrt{\frac{d_B}{d_A}}$$

$$\frac{150}{V_B} = \sqrt{\frac{1.5}{1}}$$

TAKING OF SQUARE OF BOTH SIDES

$$\frac{150}{V_B} = 1.224$$

$$\frac{150}{1.224} = V_B$$

$$122.5 \text{ cm}^3 = V_B \text{ ANS.}$$

(b) RATE OF DIFFUSION OF $H_2 = 500 \frac{\text{cm}^3}{\text{min}}$
 RATE OF DIFF. OF $O_2 = ?$

$$\frac{r_{H_2}}{r_{O_2}} = \sqrt{\frac{MWT \text{ OF } O_2}{MWT \text{ OF } H_2}}$$

$$\frac{500}{r_{O_2}} = \sqrt{\frac{32}{2}}$$

$$\frac{500}{r_{O_2}} = 4 \quad 39$$

$$\frac{500}{4} = r_{O_2}$$

$$125 \frac{\text{cm}^3}{\text{min}} = r_{O_2} \text{ ANS.}$$

(c) LET RATE OF EFFUSION OF $H_2 =$
 THEN RATE OF EFF. OF UNKNOWN
 $= 0.279$

MWT OF $H_2 = 2.0 \text{ g/mol}$
 MWT OF UNKNOWN = ?

ACCORDING TO GRAHMS LAW

$$\frac{r_{H_2}}{r_{UNK}} = \sqrt{\frac{MWT \text{ OF UNK}}{MWT \text{ OF } H_2}}$$

$$\frac{x}{0.279x} = \sqrt{\frac{MWT \text{ OF UNK}}{2}}$$

$$\frac{1}{0.0778} = \frac{MWT \text{ OF UNK}}{2}$$

$$\frac{2}{0.0778} = MWT \text{ OF UNK}$$

$$25.8 \text{ g/mole} = MWT \text{ OF UNK}$$

25

Q. NO. 22:- NO. OF MOLECULES?

(a) $V = 20 \text{ cm}^3 = 0.02 \text{ dm}^3$

$T = 0^\circ\text{C} = 273 \text{ K}$

$P = 760 \text{ Torr} = 0.92 \text{ ATM}$

BY USING GENERAL GAS EQ.

$PV = nRT$

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

$\frac{0.92 \times 0.02}{0.0821 \times 273} = n$

$8.21 \times 10^{-4} \text{ MOLES} = n$

SINCE
 $\frac{\text{NO. OF MOLECULES}}{N_A} = \text{MOLE}$

NO. OF MOLECULES = MOLE $\times N_A$

NO. OF MOLECULES = $8.21 \times 10^{-4} \times 6.02 \times 10^{23}$
MOLECULES = 4.94×10^{20} MOLECULES

(b) NO. OF ATOMS:

1 MOLECULE OF CH_4
HAS ATOMS = 5

TOTAL NO. OF ATOMS = $5 \times 4.94 \times 10^{20}$
IN 4.94×10^{20} MOLECULES

ATOMS = 2.47×10^{21} ATOMS

NO. OF NH_3 MOLECULES:

VOLUME = $1 \text{ cc} = 10^{-3} \text{ dm}^3$

TEMP. = $100^\circ\text{C} = 373 \text{ K}$

PRESSURE = 1.5 atm

$PV = nRT$

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

$\frac{1.5 \times 10^{-3}}{0.0821 \times 373} = n$

$4.8 \times 10^{-5} \text{ MOLES} = n$

NO. OF MOLECULES = MOLE $\times N_A$
 $= 4.8 \times 10^{-5} \times 6.22 \times 10^{23}$

MOLECULES = 2.89×10^{19} MOLECULES

1 MOLECULE CONTAIN ATOMS = 4

ATOMS = $2.89 \times 10^{19} \times 4$

TOTAL ATOMS = 1.179×10^{20} ATOMS

23:- CALCULATE MASSES

NO. OF MOLECULES = 10^{20}

NO. OF MOLES = 10^{20}

6.022×10^{23}

$= 0.166 \times 10^m$

MASS = MOLES \times MOLAR MASS

MASS OF $\text{H}_2 = 0.166 \times 10^{20} \times 2$

MASS OF $\text{H}_2 = 3.32 \times 10^{-4} \text{ g}$

JK

MASS OF $O_2 = 0.166 \times 10^{-3} \times 32$

MASS OF $O_2 = 5.31 \times 10^{-3} \text{ g}$

MASS OF $CO_2 = 0.166 \times 10^{-3} \times 44$

MASS OF $CCl_4 = 7.3 \times 10^{-3} \text{ g}$

SINCE MASS DOES NOT DEPEND UPON TEMPERATURE AND PRESSURE
 \therefore MASS WILL REMAIN THE SAME AT 100°C AND 100 mm (Hg)

Q. NO. 24:- TWO MOLE NH_3

GIVEN DATA :-

$n = 2.0 \text{ MOLE}$

$V = 5.0 \text{ dm}^3$

$T = 27^\circ\text{C} + 273 = 300 \text{ K}$

$a = 4.17 \text{ atm dm}^3 \text{ mole}^{-2}$

$b = 0.0371 \text{ dm}^3/\text{mole}$

CALCULATE

$P_{\text{ideal}} = \frac{?}{?}$

$P_{\text{real}} = ?$

2) PRESSURE AS IDEAL GAS

$PV = nRT$

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

$P = \frac{2 \times 0.0821 \times 300}{5}$

$P_{\text{IDEAL}} = 9.85 \text{ atm}$

PRESSURE AS REAL GAS:-

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

$\left(P + \frac{4.17 \times 2^2}{5^2}\right)(5 - 2 \times 0.0371) =$

2×0.0821

$(P + 0.667)(4.93) = 49.26$

$(P + 0.667) = \frac{49.26}{4.93}$

$P + 0.667 = 9.99$

$P = 9.99 - 0.667$

$P_{\text{REAL}} = 9.32 \text{ ATM}$

LESSENED PRESSURE:-

$\Delta P = 9.85 - 9.32$

$\Delta P = 0.53 \text{ atm}$

b) WHEN VOL. IS INCREASE FROM 5 TO 4 dm^3 , MOLES MOVE AWAY FROM EACH OTHER IDEAL AS WELL AS REAL PRESSURES ARE DECREASED SINCE FORCES OF ATTRACTION B/W MOLECULES ARE DECREASED SO ΔP IS ALSO DECREASED

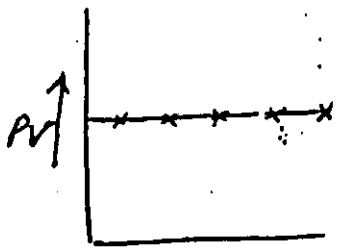
$\Delta P \text{ BECOMES} = 0.0115 \text{ atm}$

(HELP YOURSELF)

CHAPTER NO. 3 "3"
GASEOUS STATE

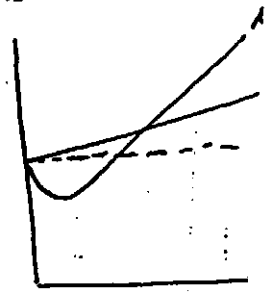
Q. NO: 1:- THE PLOT OF PV VERSUS "P" IS A STRAIGHT LINE.

ANS:- According to Boyle's law product of pressure & volume remains constant at constant temp. This is, if there is proportionate decrease in volume increase of pressure. Thus if a graph is plotted b/w P on x-axis and PV along y-axis a straight line parallel to x-axis obtained.



Q:- STRAIGHT LINE GOES AWAY FROM PRESSURE P AT HIGH PRESSURE:-

ANS. Because at high pressure total volume of a gas is reduced and actual volume is no more negligible at high pressure. Thus at high pressure real gases begin to deviate from ideal behaviour and real gas PV is greater than ideal gas PV.



Q:- "b" IS FOUR TIMES MOLAR VOLUME OF A GAS?

In Vander Waals equation "b" is excluded volume gas molecules. Since gas molecules have electronic cloud around nucleus. They do not collide actually but begin to repel each other even when they are quite far apart each other. Thus excluded volume is not in fact actual molar volume but four times greater than molar volume $b = 4V_m$.



Q: PRESSURE OF NH_3 IS LESSER WHEN CALCULATED
VANDER WAALS EQUATION THAN THAT CALCULATED
GENERAL GAS EQUATION.

ANS: In general gas equation it is assumed that
no forces of attraction or repulsion between
this is possible for an ideal gas only. The
like ammonia have forces of attraction. When
gas molecule is just going to hit walls of container
the neighbouring molecules pull it backward,
of its pressure is consumed to overcome force
attraction of neighbouring molecules. In van der
equation the pressure nullified to overcome
of attraction of neighbouring molecules is
into consideration.

Thus pressure on walls is reduced as
compared to ideal gas pressure calculated
from ideal gas equation. Thus pressure
calculated from van der Waals equation is
actual pressure which is less than ideal pressure
from general gas equation.

WATER VAPOURS DO NOT BEHAVE IDEALLY
At 273 K ($0^\circ C$) water vapours have sufficient forces
attraction among themselves. So they do not behave
at $0^\circ C$. They change into solid or liquid water
 $0^\circ C$ and do not obey gas laws at $0^\circ C$.

SO_2 IS COMPARATIVELY NON IDEAL AT 273K BUT BEHAVES IDEALLY AT 327K.

SO_2 IS AN IDEAL GAS WITH RELATIVELY HIGH BOILING pt. AT 273K (0°C) SO_2 GAS MOLECULES HAVE SOME FORCE OF ATTRACTION AND IT MAY CHANGE INTO LIQUID. BUT AT HIGH TEMPERATURES (say 327K) FORCES OF ATTRACTION ARE ALMOST NEGLIGIBLE AND SO_2 BEHAVES ALMOST IDEALLY.

SOME MORE REASONINGS FOR PRACTICE (HELP YOU)

- 1) H_2 AND He ARE ALMOST IDEAL AT ROOM TEMP. BUT SO_2 IS NON IDEAL AT ROOM TEMP. ?
(HINT: H_2, He ARE NON POLAR WITH V. LOW B.P., SO_2 IS POLAR)
- 2- IT IS DIFFICULT TO BREATHE AT HIGH ALTITUDES
- 3- PLASMA IS GOOD CONDUCTOR OF ELECTRIC CURRENT. ?
- 4- RATE OF DIFFUSION OF GASES ARE IN ORDER $\text{H}_2 > \text{He} > \text{CH}_4 > \text{O}_2$. ?
- 5- REGULAR AIR CANNOT BE FILLED IN DIVERS TANK
- 6- HIGH P & LOW TEMP. MAKE GASES NON IDEAL. ?
- 7 - 273°C IS MINIMUM POSSIBLE TEMP. ?
- 8 :- WHAT IS JOULE THOMSON EFFECT ? WHICH GAS SHOWS THIS EFFECT.
- 9 :- WHAT ARE VANDER WAALS CONSTANT & AT THEM