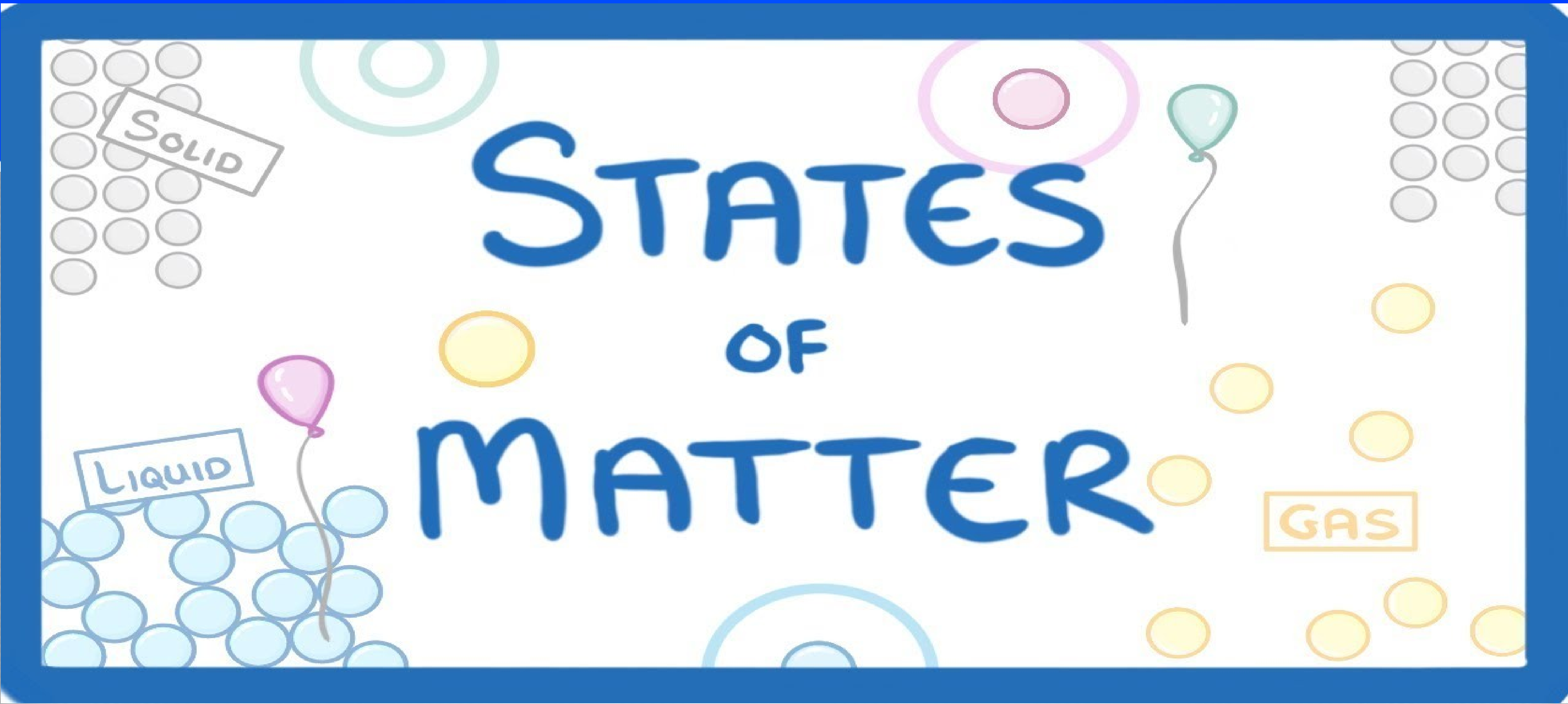
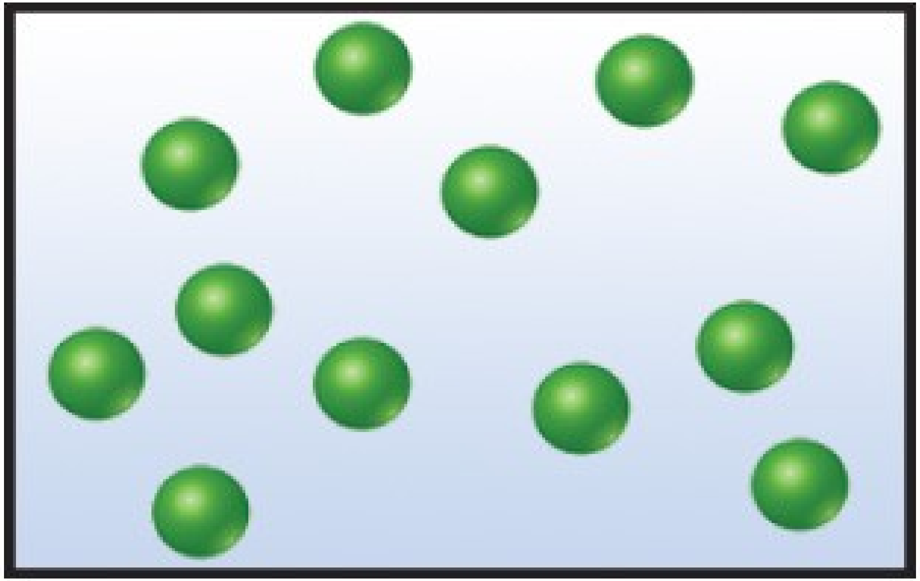


HAIZEL G.ROY
H.S.S.T. (HG) CHEMISTRY
GOVT. H.S.S. KALAMASSERY
ERNAKULAM

THE GASEOUS STATE



CHARACTERISTICS OF GASES

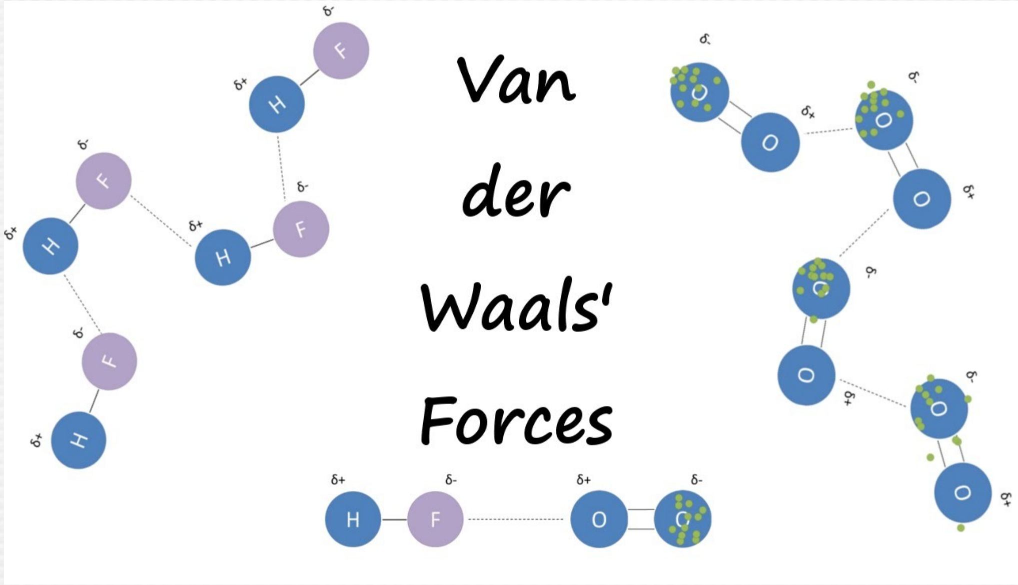
- **Gases have neither definite shape nor definite volume.**
- **The particles are far apart from one another.**
- **The intermolecular forces of attraction are very weak.**
- **Gases are highly compressible.**
- **Gases exert pressure equally in all directions.**
- **Gases have much lower density than solids and liquids.**
- **Gases mix evenly and completely in all proportions without any mechanical aid.**

INTERMOLECULAR FORCES

Intermolecular Forces are the forces of attraction and repulsion between interacting particles like atoms and molecules.

VANDER WAALS FORCES

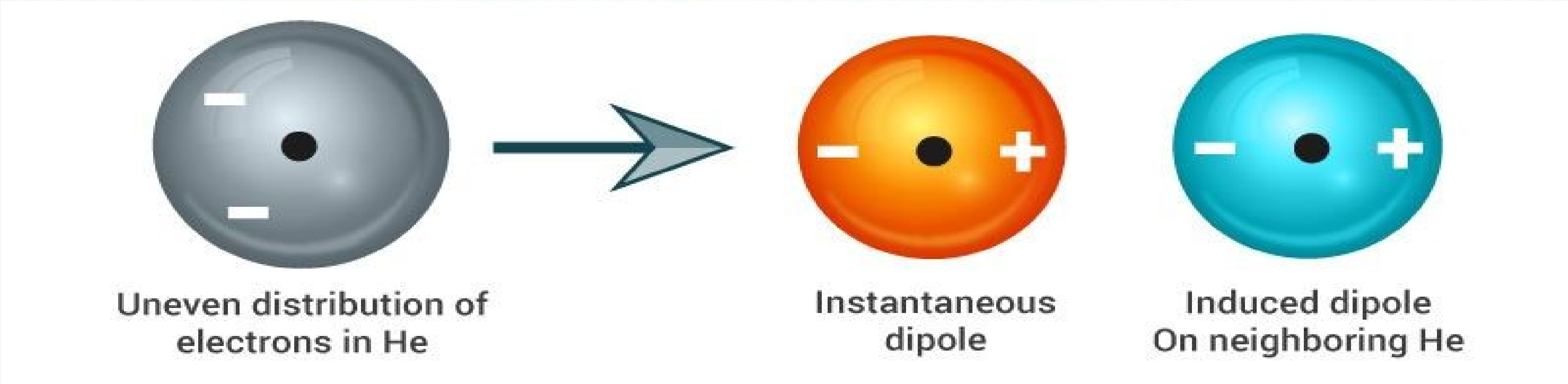
Weak, short range electrostatic attractive intermolecular forces between uncharged molecules are called Vander Waals Forces.



DISPERSION FORCES OR LONDON FORCES

- **London Force is the weakest intermolecular force.**
- **It is a temporary attractive force that results when the electrons in two adjacent atoms occupy positions that make the atoms form temporary dipoles.**

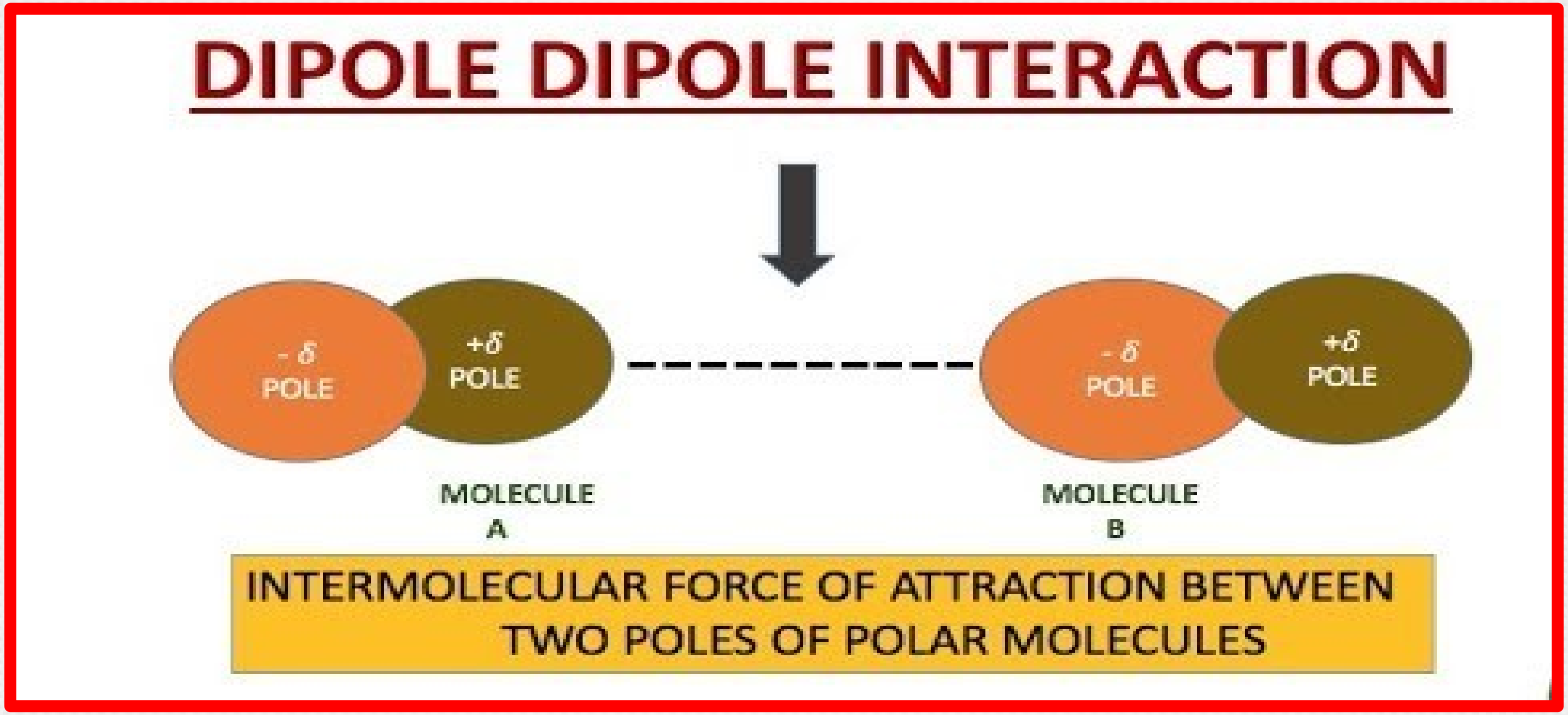
DISPERSION FORCES OR LONDON FORCES

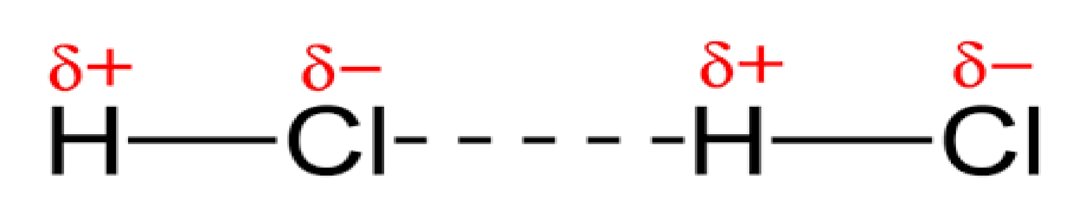


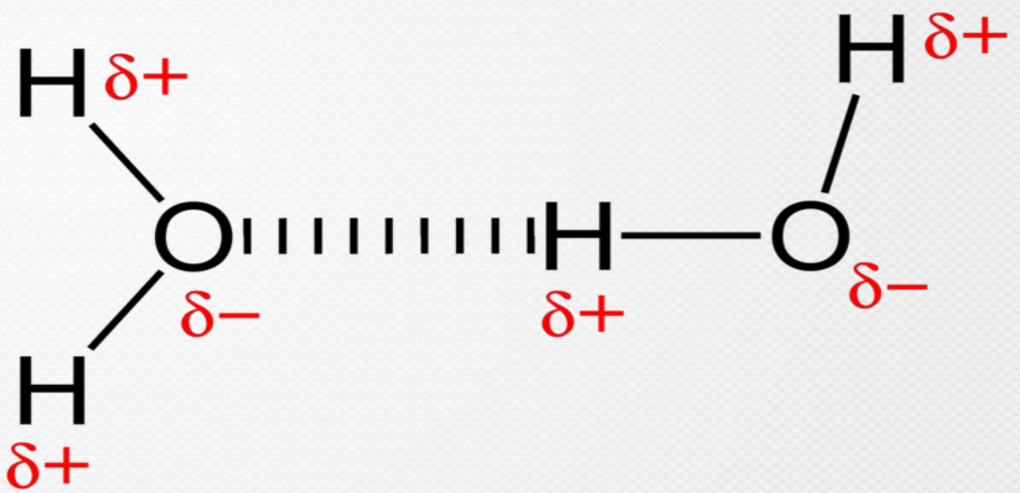
DIPOLE – DIPOLE FORCES

- **Dipole-dipole forces are attractive forces between the positive end of one polar molecule and the negative end of another polar molecule.**
- **These forces act between the molecules possessing permanent dipole.**
- **This interaction is stronger than the London Forces.**

DIPOLE – DIPOLE FORCES




δ+ δ− δ+ δ−
H—Cl- - - - - -H—Cl

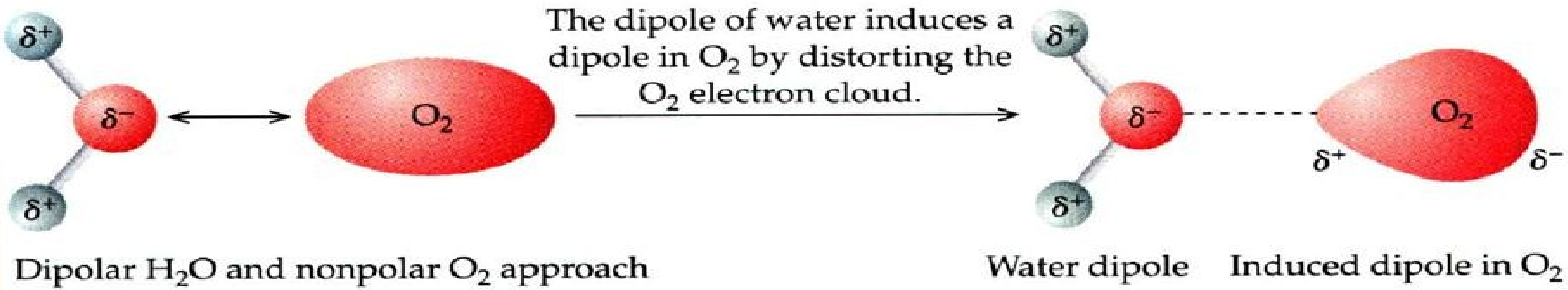

H δ+
H δ+
O
δ−
H
δ+
O
δ−
H
δ+

DIPOLE INDUCED DIPOLE FORCES

- **Dipole-induced dipole forces are weak attractive forces.**
- **These forces operate between the polar molecules and the non-polar molecules.**
- **It results when a polar molecule induces a dipole in an atom or in a non-polar molecule by disturbing the arrangement of electrons in the non-polar species.**

Dipole-induced dipole interactions

- When a non-polar molecule approaches a polar molecule (with a permanent dipole), a dipole will be induced in the non-polar molecule.



Dispersion forces exist among all molecules and contribute most to the overall van der Waals' forces.

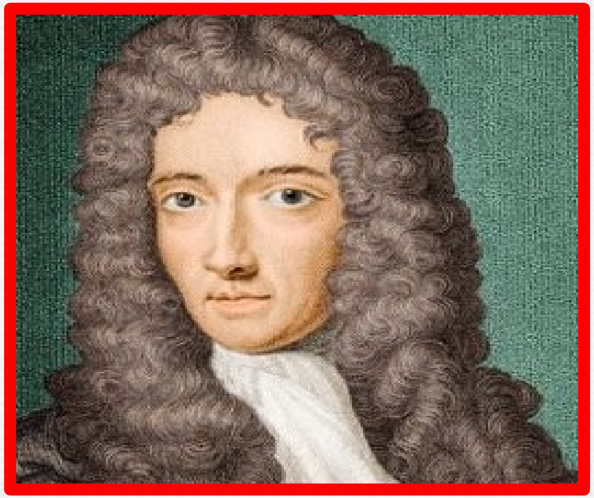
THERMAL ENERGY

- Thermal energy is the energy of a body arising from motion of its atoms or molecules.
- It is directly proportional to the temperature of the substance.
- It is the measure of average kinetic energy of the particles of the matter and is thus responsible for movement of particles.
- This movement of particles is called thermal motion.

THE GAS LAWS

BOYLE'S LAW

The law states that at constant temperature, the pressure of a fixed amount of gas varies inversely with its volume.



ROBERT BOYLE

MATHEMATICAL REPRESENTATION

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

$$PV = \text{a constant}$$

- **Consider a fixed mass of gas at a constant temperature.**
- **Let its pressure be P_1 when its volume is V_1.**
- **Let the pressure be P_2 when its volume is V_2 .**
- **Then according to Boyle's law,**

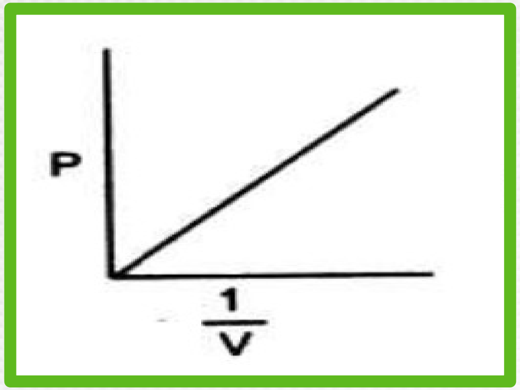
$$P_1V_1 = P_2V_2$$

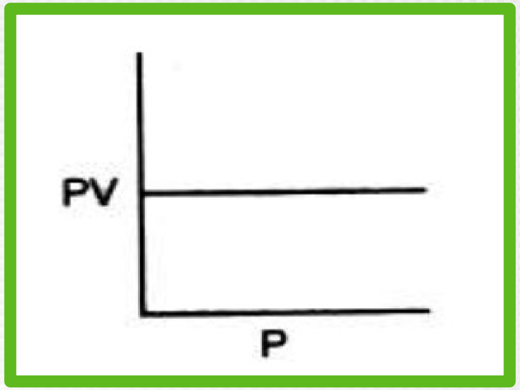
GRAPHICAL REPRESENTATION

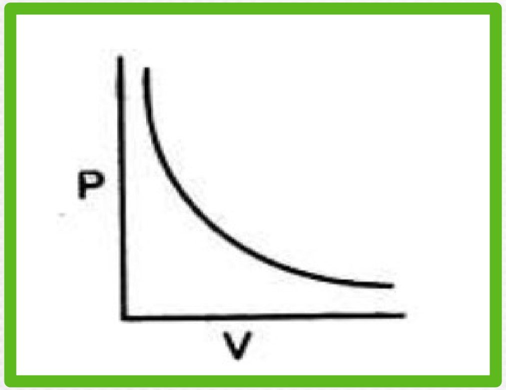
- **Boyle's law can be illustrated by plotting PV against P at a given temperature.**
- **The graph shows that PV remains constant.**

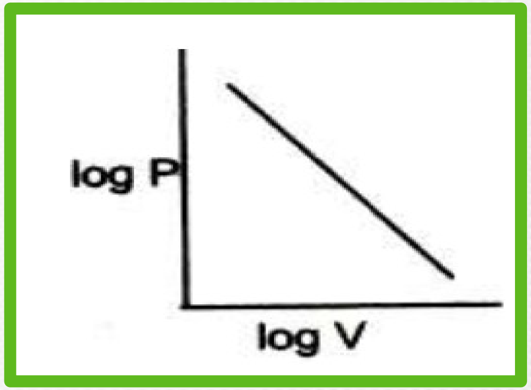
ISOTHERM

The graph obtained by plotting volume against pressure at a given temperature is called an Isotherm.


P
1/V


PV
P


P
V


log P
log V

CHARLES' LAW

The law states that at constant pressure, the volume of a fixed mass of gas is directly proportional to its absolute temperature.

JACQUES CHARLES'

MATHEMATICAL REPRESENTATION

Mathematically Charles Law can be represented as

$$V \propto T$$

V = a constant x T

$$\frac{V}{T} = \text{a constant}$$

If V_1 is the volume at a temperature T_1 and V_2 is the volume at a temperature T_2 at the same pressure.

Then according to Charles' law,

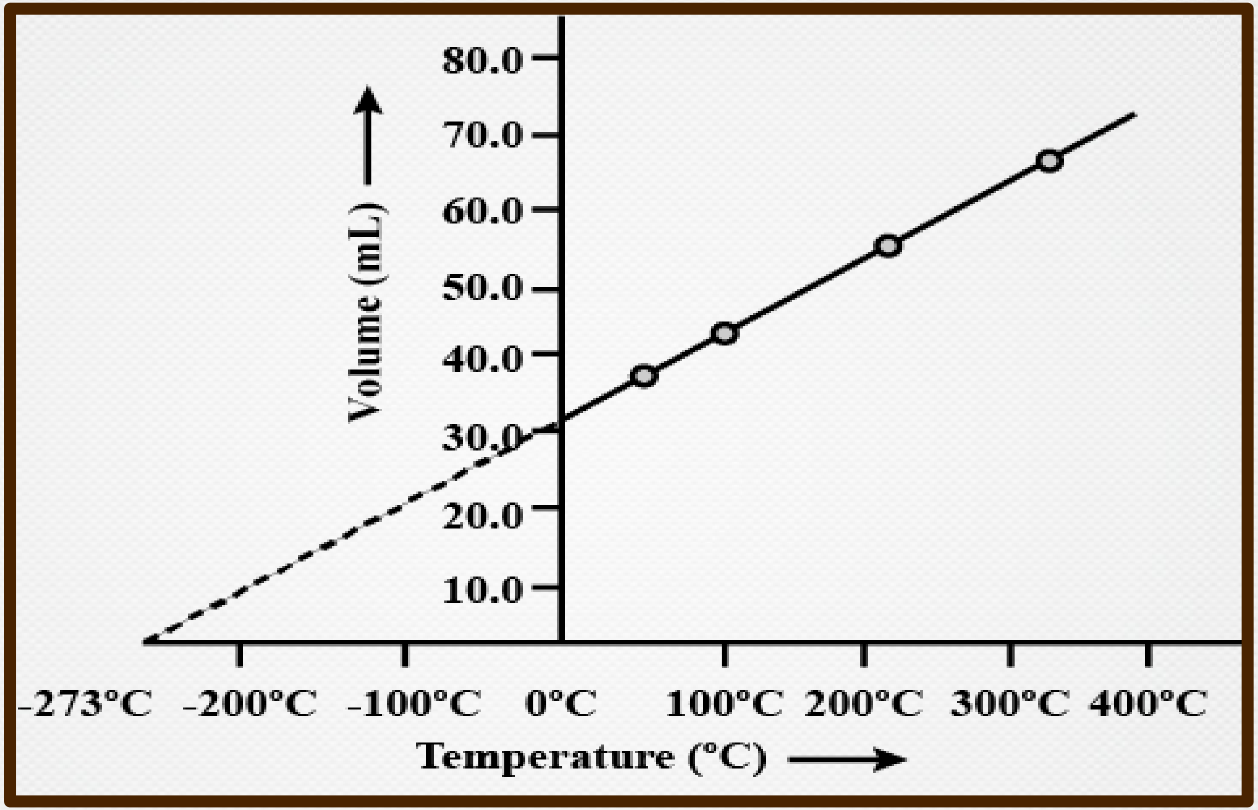
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

GRAPHICAL REPRESENTATION

Charles' law can be illustrated graphically by plotting the volume of a given mass of gas against temperature.

ISOBAR

A graph obtained by plotting the volume of a gas against temperature at constant pressure is known as Isobar.



80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
Volume (mL)
-273°C
-200°C
-100°C
0°C
100°C
200°C
300°C
400°C
Temperature (°C)

- **The isobar is found to be a straight line.**
- **It indicates that volume of the gas is directly proportional to its temperature.**
- **If we extrapolate the straight line obtained it will meet the temperature axis at —273.15°C.**
- **Thus at this temperature a gas would occupy zero or no volume.**
- **But actually all gases become liquids before this temperature is reached.**

- **The lowest hypothetical or theoretical temperature of —273.15^0 C at which all gases are supposed to occupy zero volume is called Absolute Zero Temperature.**
- **This scale of temperature based on this is known as Absolute Scale of Temperature or Kelvin Scale of Temperature.**
- **Kelvin Scale of Temperature is also known as Thermodynamic Scale of Temperature.**

- **Thus —273.15^{0} C is equal to Zero Kelvin.**
- **The relation between Kelvin Scale and Celsius scale is given as**

$T = t + 273$

AVOGADRO'S LAW

The law states that equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.

AVOGADRO

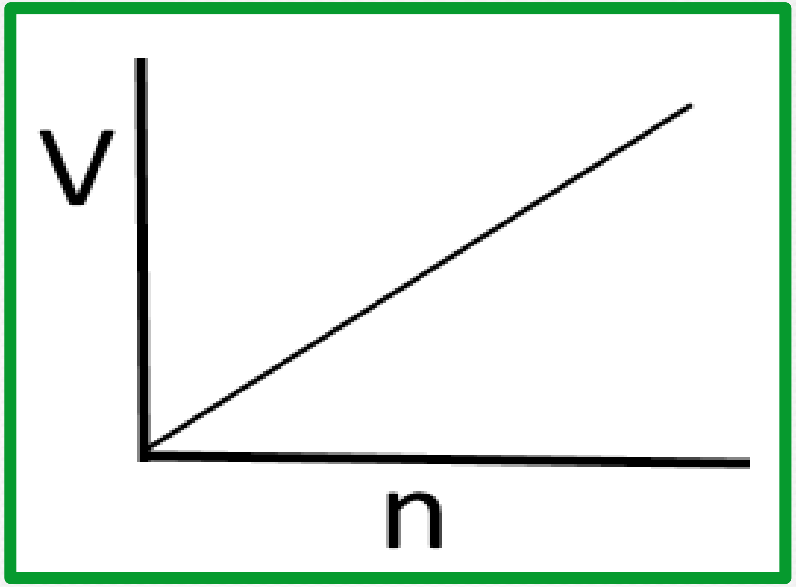
MATHEMATICAL REPRESENTATION

Mathematically Avogadro's law can be written as

$$V \propto n$$

$$V = \text{a constant} \times n$$

GRAPHICAL REPRESENTATION



STANDARD TEMPERATURE AND PRESSURE

- **One mole of each gas at standard temperature and pressure will have same volume.**
- **Standard temperature and pressure means 273.15K (0^0C) temperature and 1 bar pressure (760 mm of Hg).**

GAY LUSSAC'S LAW

At constant volume, the pressure of a fixed amount of a gas varies directly with temperature.

GAY LUSSAC

MATHEMATICAL REPRESENTATION

Mathematically Gay Lussac's Law can be represented as

$$P \propto T$$

$$\frac{P}{T} = \text{a constant}$$

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

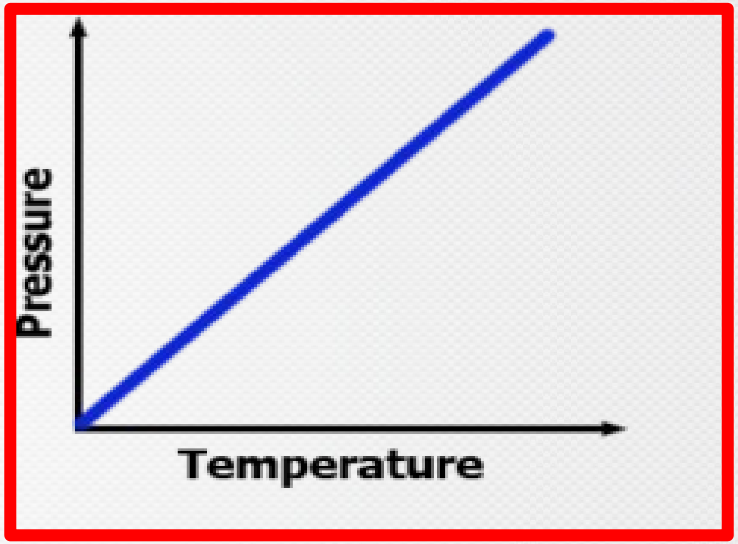
GRAPHICAL REPRESENTATION

Gay Lussac's law can be illustrated graphically by plotting the pressure along the Y-axis and the corresponding temperature along the X-axis, keeping the volume constant.

The graph obtained is called an Isochore.

ISOCHORE

The graph obtained by plotting the pressure of a gas against temperature at constant volume is known as **Isochore.**



IDEAL GAS EQUATION

A gas that follows Boyle's law, Charles' law and Avogadro's law strictly is called an **ideal gas.**

By combining Boyle's law, Charles' law and Avogadro's law, we get a general equation relating pressure, volume, absolute temperature and number of moles.

This equation is called **Ideal Gas Equation.**

DERIVATION OF IDEAL GAS EQUATION

BOYLE'S LAW	$V \propto 1/P$
CHARLE'S LAW	$V \propto T$
AVOGADRO'S LAW	$V \propto n$
IDEAL GAS LAW	$V \propto nT/p$
OR	$V = R \cdot nT/p$
	$PV = nRT$

For one mole of a gas, the ideal gas equation is

$$PV = RT$$

NUMERICAL VALUES OF R

1. $R = 0.0821$ litre atm K^{-1} mol^{-1}
2. $R = 8.314 \times 10^7$ ergK^{-1} mol^{-1}
3. $R = 1.987$ calories K^{-1} mol^{-1}
4. $R = 8.314$ JK^{-1} mol^{-1}

DENSITY AND MOLAR MASS OF A GAS

The ideal gas equation is $PV = nRT$ .... (1)

Ideal gas equation can be rearranged as $\frac{n}{V} = \frac{P}{RT}$ .... (2)

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

Substituting the value of 'n' in equation (2)

$$\frac{m}{MV} = \frac{P}{RT} \quad \text{.............................. (3)}$$

$$\frac{d}{M} = \frac{P}{RT} \quad \text{.............................. (4)}$$

Rearranging equation (4), we get

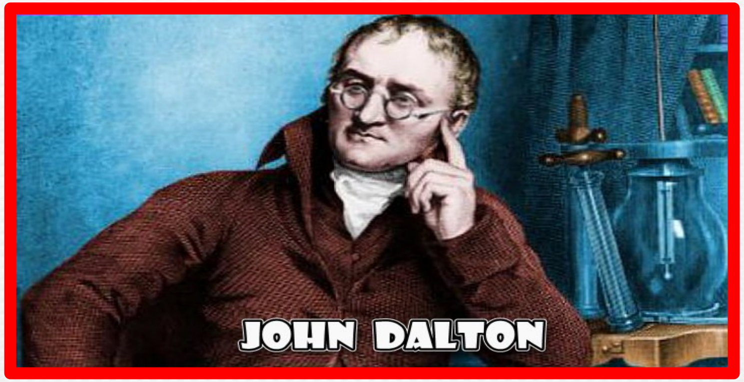
$$M = \frac{dRT}{P}$$

PARTIAL PRESSURE

When two or more non reacting gases are placed in the same vessel, the pressure exerted by each gas in the mixture is called its partial pressure.

DALTON’S LAW OF PARTIAL PRESSURES

The law states that at constant temperature, the total pressure exerted by the mixture of non reacting gases is equal to the sum of the partial pressures of individual gases.



If P_1 , P_2 , P_3 ….. are the partial pressures of the individual gases, then the total pressure ‘P’ of the mixture of the gases at the same temperature is given as

$$P_{total} = P_1 + P_2 + P_3 + \ldots\ldots$$

APPLICATIONS OF DALTON'S LAW

- **Used to calculate the pressure of a gas collected over water surface.**
- **Here the gas is always moist.**
- **Therefore, pressure of dry gas can be calculated by subtracting vapour pressure of water from the total pressure of the moist gas.**
- **Pressure exerted by saturated water vapour is called aqueous tension.**
- $P_{dry\ gas} = P_{Total}$ **– Aqueous tension**

KINETIC MOLECULAR THEORY OF GASES

- Every gas contains a large number of minute and elastic particles.
- The actual volume of the molecules is negligible compared to the volume of the gas.
- There is no force of attraction between the gas particles.
- The particles of a gas are in constant and random motion in straight line.

- **During this motion they collide with each other and also with the walls of the container.**

- **The pressure of a gas is due to the wall collisions of the particles.**

- **All collisions are perfectly elastic. i.e. the total energy of particles before and after collisions remains the same.**

- **At any particular time, different particles of a gas have different speed and hence different kinetic energy.**

- **The average kinetic energy of gas molecules is directly proportional to absolute temperature.**

DEVIATION OF REAL GASES FROM IDEAL BEHAVIOUR

- None of the real gases obey the equation $PV = nRT$ at all temperatures and pressures.
- Real gases obey the gas laws only at low pressures and high temperatures.
- The deviation of real gases from ideal behaviour can be expressed in terms of **compressibility factor, Z.**

$$Z = \frac{PV}{nRT}$$

For an Ideal Gas $\frac{PV}{nRT} = 1$, i.e., $Z = 1$

But for real gases, Z≠ 1.

This means that real gases deviates from ideal behaviour .

CAUSES OF DEVIATION

Real gases deviate from ideal behaviour due to two faulty assumptions made in the kinetic theory of gases. They are

1. The actual volume of the particles is negligible compared to the entire space occupied by the gas.

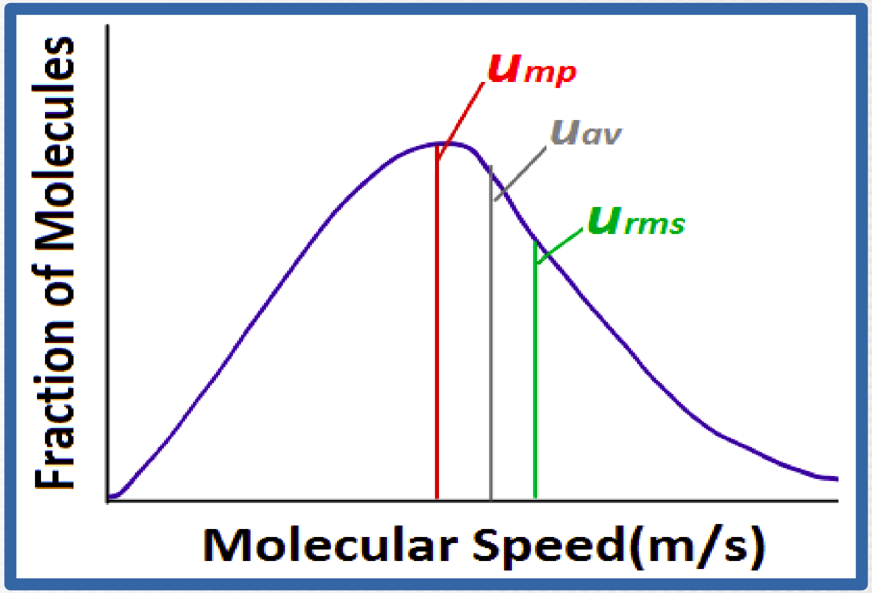
2. There are no attractive forces between the particles.

- **These two assumptions are not valid at high pressures and low temperatures.**
- **At high pressures and low temperatures, the actual volume occupied by the particles cannot be neglected.**
- **At high pressures and at low temperatures, the intermolecular distance is very small.**
- **Hence the intermolecular attraction cannot be neglected.**
- **Therefore, real gases deviate from ideal behaviour at high pressures and at low temperatures.**

MAXWELL-BOLTZMANN DISTRIBUTION OF MOLECULAR SPEEDS

- According to Kinetic molecular theory of gases, the molecules of a gas are in continuous random motion and they collide with each other.
- So the speed and the kinetic energy of the molecules are different at any particular time.
- Thus we can obtain only an average value of speed of molecules.
- The distribution of molecular speeds was first studied by Maxwell and Boltzmann by applying the theory of probability.
- This is known as Maxwell-Boltzmann Distribution of molecular speeds.

A graph is plotted between number of molecules having different speeds against molecular speeds.



DIFFERENT TYPES OF MOLECULAR SPEEDS

AVERAGE SPEED (Uave)

It is the arithmetic mean of the different speeds of molecules in a given sample of gas.

If there are 'n' molecules in a sample and u_1, u_2, u_3 .... u_n are their individual speeds,

Then average speed is given by,

$$U_{ave} = \frac{u_1 + u_2 + u_3 + \ldots\ldots\ldots + u_n}{n}$$

ROOT MEAN SQUARE SPEED (U_{rms})

It is the square root of the mean of the squares of the different speeds of the gas molecules.

It is given by

$$U_{rms} = \sqrt{\frac{u_1^2 + u_2^2 + u_3^2 + \ldots\ldots\ldots + u_n^2}{n}}$$

MOST PROBABLE SPEED (Ump)

It is the speed possessed by maximum number of gas molecules.

The three types of molecular speeds are related as

Urms > Uave > Ump

The ratio between the three speeds is

Urms = Uave = Ump = 1.224 : 1.128 : 1

BOYLE TEMPERATURE OR BOYLE POINT

Temperature at which a real gas obeys ideal gas law over an appreciable range of pressure is called Boyle Temperature or Boyle Point.

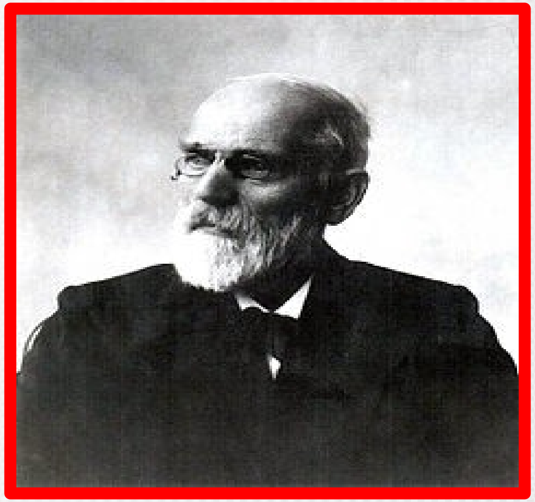
VANDER WAALS EQUATION

In 1873, Vander Waals modified the ideal gas equation.

This modified equation of state which explains the deviation of real gases from ideal behaviour is known as Vander Waals equation.

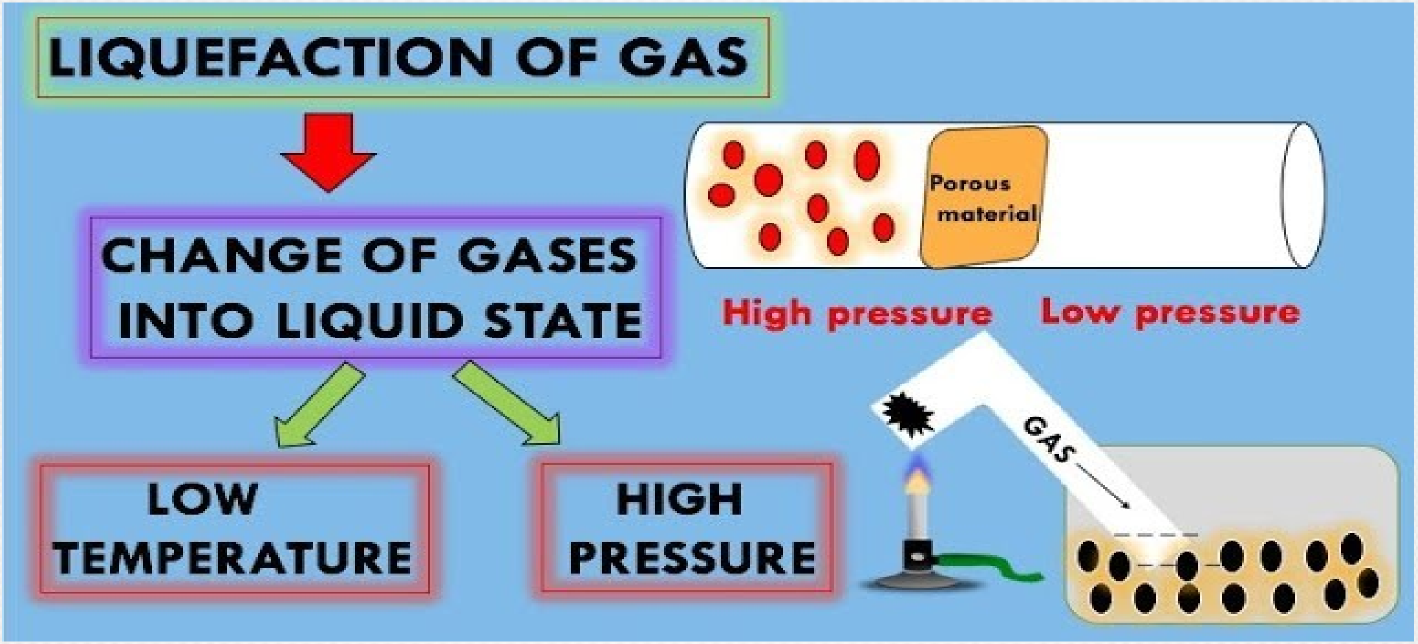
The equation is

$$\left[P + \frac{an^2}{V^2}\right] * \left[V - nb\right] = nRT$$



LIQUIFACTION OF GASES

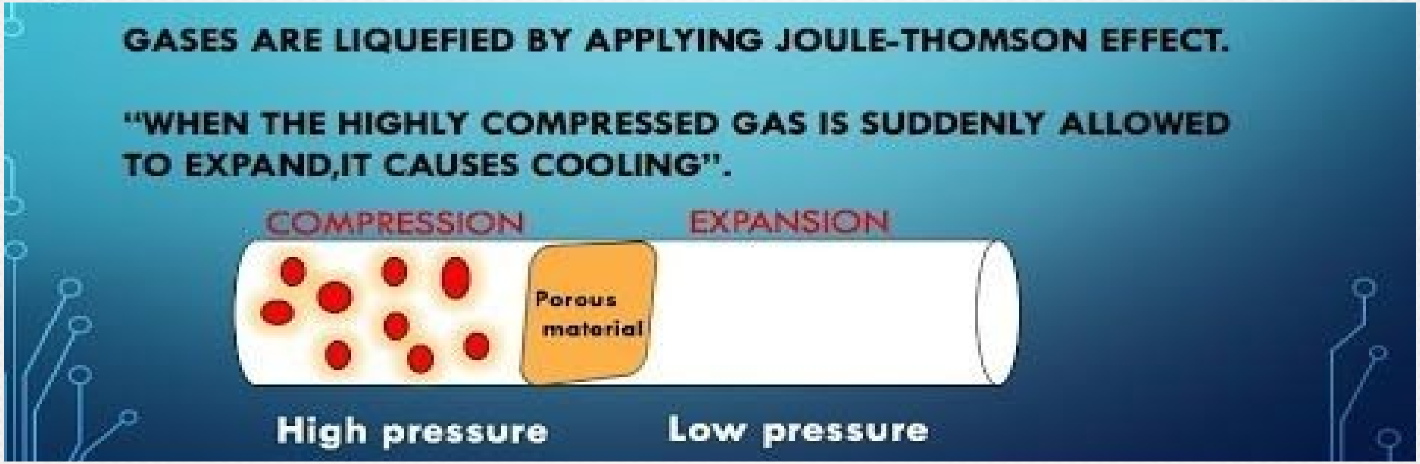
A gas can be liquified by applying low temperature and high pressure.



JOULE THOMSON EFFECT

When a gas under high pressure is allowed to expand into a region of low pressure, a cooling effect is produced.

This cooling effect is known as Joule Thomson Effect.



NEGATIVE JOULE THOMSON EFFECT

For Hydrogen and Helium, it is found that the expansion results in rise in temperature.

This is called Negative Joule Thomson Effect.

CRITICAL TEMPERATURE (Tc)

The temperature above which a gas cannot be liquified by the application of pressure.

CRITICAL PRESSURE (Pc)

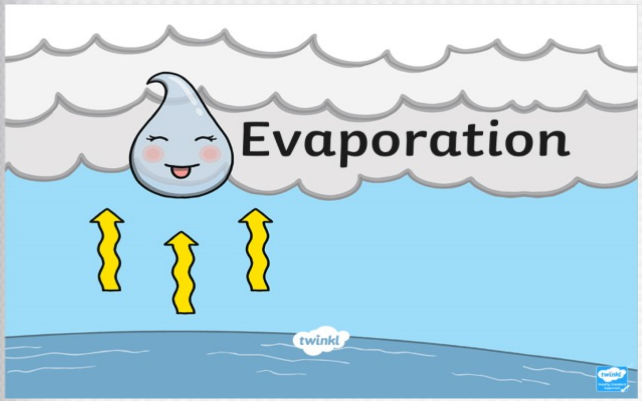
The minimum pressure required to liquify any gas at its critical temperature is called Critical Pressure.

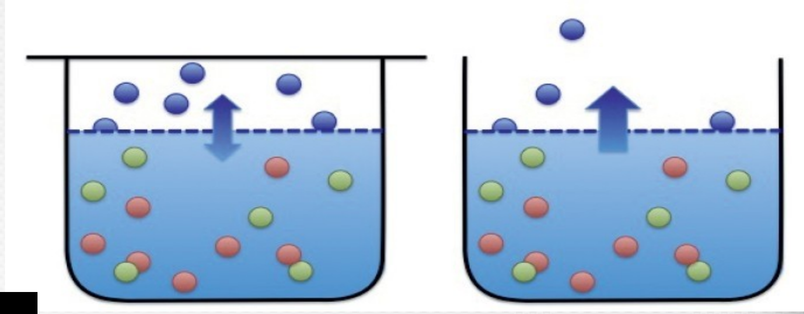
CRITICAL VOLUME (Vc)

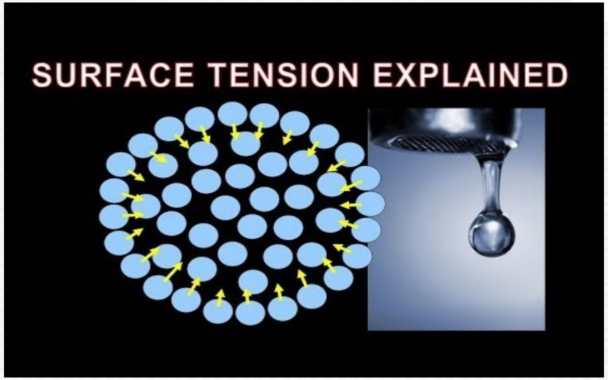
The volume occupied by one mole of a gas at its critical temperature and critical pressure is called critical volume.


Liquid State

PROPERTIES OF LIQUIDS







EVAPORATION

When a liquid is placed in an open vessel and heated, it slowly escapes into gaseous phase.

This phenomenon is called evaporation.

VAPOUR PRESSURE

The pressure exerted by the vapours above the liquid surface in equilibrium with the liquid at a given temperature is called vapour pressure

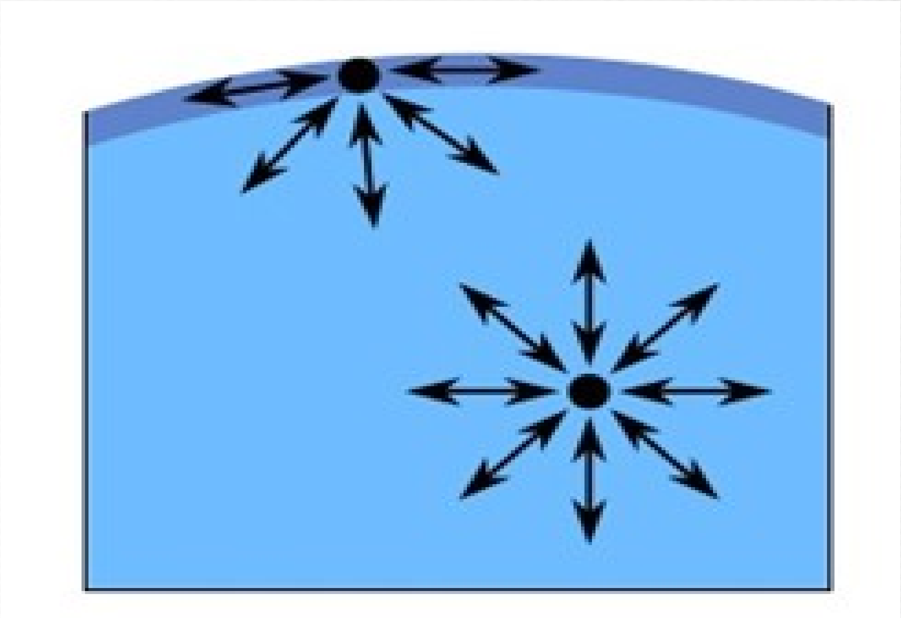
BOILING POINT

The boiling point of a liquid is defined as the temperature at which the vapour pressure of a liquid becomes equal to atmospheric pressure.

The Boiling Point of water is 100^0C.

SURFACE TENSION

The molecules of a liquid at the surface are in a different situation than those in the interior of the liquid.



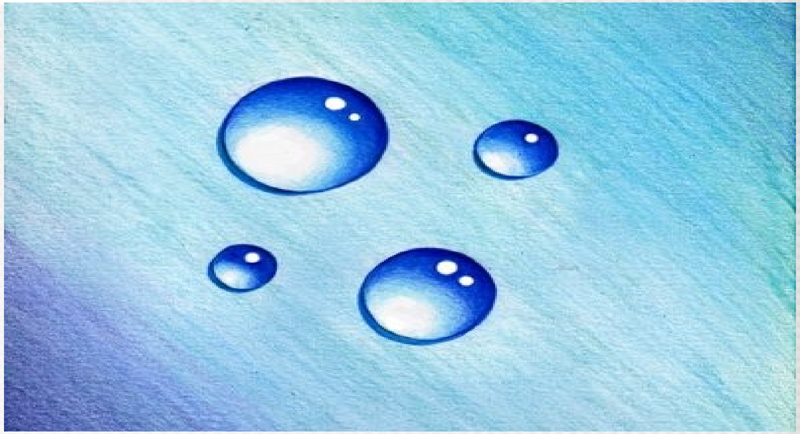
Surface tension of a liquid is defined as the amount of work that must be done to expand the surface of the liquid by unit area.

LIQUID DROPS ASSUME SPHERICAL SHAPE

Due to surface tension, liquid surface tries to have minimum surface area.

For a given volume, a sphere has the least surface area.

Hence liquid drops are spherical in shape.



VISCOSITY

The resistance that one part of the liquid flowing with one velocity offers to another part of the liquid flowing with different velocity is known as viscosity.

The viscosity of a liquid decreases with increase in temperature.

FIRE POLISHING OF GLASS

On heating, the glass melts and the surface of the liquid tends to take the rounded shape at the edges, which makes the edges smooth. This is called fire polishing of glass.


Thank you