2. States of Matter

- **Change of state**
  - A change of state occurs because heat energy breaks the force of attraction between particles. Kinetic energy of the particle increases.

- **Melting point**
  - The temperature at which a solid melts into a liquid at normal atmospheric pressure.
  - At melting point, the temperature does not change until all solid converts into liquid.

- **Latent heat**
  - The heat required to break the force of attraction between the particles at transition temperature. This heat becomes confined within the material and is called the latent heat.
  - Amount of heat required to change 1 kg of material to change its state at normal atmospheric pressure at transition temperature is called the latent heat for that transition.

- **Sublimation**
  - Solid $\rightleftharpoons$ gas [directly]
  - Example: Ammonium chloride

- **Effect of change of pressure**
  - If pressure is applied,
  - Melting point → decreases
  - Boiling point → increases

- **Dry Ice** – Solid CO_2 [directly converts to gas]

- Everything around us is composed of matter.
- There are five states of matter- solid, liquid, gaseous, plasma and Bose-Einstein condensate
- **Solid phase**
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  - Permanent change in shape is difficult
  - Negligible compressibility
  - Definite shape, size, and boundary
  - No particle motion

- **Liquid phase**
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  - No fixed shape and boundary
  - Have a fixed volume
  - Low compressibility
  - Lesser particle motion

- **Gaseous state**
    - No fixed shape, volume, and boundary
    - Highly compressible
    - Gases exert pressure
    - High particle motion

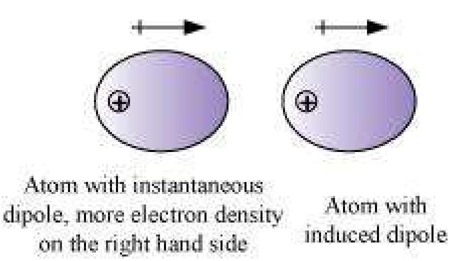
Solid	Liquid	Gas
Definite shape	No definite shape	No definite shape
Occupies space	Occupies space	Occupies space
Definite volume	Definite volume	No definite volume
Cannot be compressed	Slightly compressible	Highly compressible
Rigid	Not rigid	Not rigid
Does not diffuse in other solids	Can diffuse in other liquids	Can diffuse in other gases

- **Plasma State**
    - Super-energetic and super-excited particles
    - No definite shape and volume
    - Most common state of matter in universe
    - Influenced by electric and magnetic field
- **Bose-Einstein Condensate**
    - Super-unenergetic and super-cooled particles
    - Formed on cooling an extremely low density gas to an extremely low pressure
    - Super-fluid and super-conductive

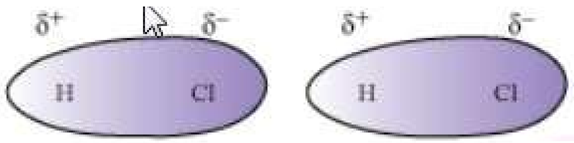
Intermolecular forces:

(Also known as **van der Waals forces**)

- Dispersion forces or London forces (Forces between atoms or non-polar molecules)

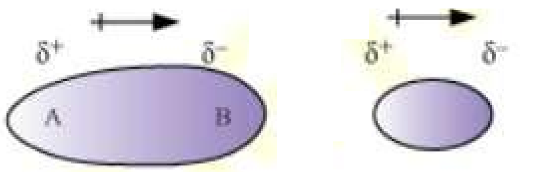


- Dipole-dipole forces (Forces between molecules possessing permanent dipole)



Dipole-dipole interaction between two HCl molecules

- Dipole-induced forces (Forces between a molecule having permanent dipole and a molecule lacking permanent dipole)

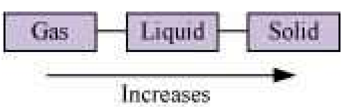


Permanent dipole (a polar molecule)   Induced dipole in a non-polar molecule

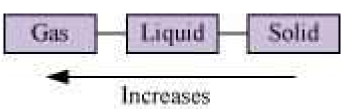
- Ion-dipole interaction (Interaction of an ion with the oppositely charged site of a polar moleule)
- Hydrogen bond (Force between hydrogen attached to an electronegative atom of one molecule and an electronegative atom of different molecule)

$$\overset{\delta+}{H}-\overset{\delta-}{F}\cdots\overset{\delta+}{H}-\overset{\delta-}{F}$$

Intermolecular interactions:



Thermal energy: Energy of a body due to motion of its atoms or molecules



Boyle's Law

- Relation between pressure (p) and volume (V)
- Statement – At constant temperature, the pressure of a fixed amount (number of moles, n) of a gas is inversely proportional to its volume.

Charles' Law

- Relation between temperature (T) and volume (V)
- Statement – At constant pressure, the volume of a fixed amount of a gas is directly proportional to its absolute temperature.

Standard Temperature and Pressure(STP)

The standard values are 0^0C or 273K for temperature and 1 atm or 760 mm of Hg for pressure and are commonly known as **S.T.P.**

Gay-Lussac's Law

- Relation between pressure and temperature
- Statement – At constant volume, the pressure of a fixed amount of a gas is directly proportional to the temperature.

Avogadro Law

- Relation between volume (V) and amount of substance (number of moles n)
- Statement – Under the same conditions of temperature and pressure, equal volumes of all gases contain equal number of molecules.

Ideal Gas

- The gas which strictly follows Boyle's law, Charles' law and Avogadro law

Ideal Gas Equation

- Equation obtained by the combination of Boyle's law, Charles' law and Avogadro law

$\Rightarrow pV = n\text{R}T$ …….(i)

R = Proportionality constant, known as Universal Gas Constant

Equation (i) is called ideal gas equation.

Deviation from ideal gas behaviour (real gas):

van der Waals equation

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

$$\text{Compressibility factor (Z)} = \frac{pV}{n\text{R}T}$$

Z=1 (for ideal gas, at all temperatures and pressures)

At very low pressures, Z ≈ 1

At high pressures, Z > 1

At intermediate pressures, Z < 1

The temperature at which a real gas obeys ideal gas law over an appreciable range of pressure is called **Boyle temperature** or **Boyle point.**

Liquefaction of gases:

A gas can be liquefied by cooling or applying pressure or by the combined effect of both.

Critical temperature (T_c), critical volume (V_c), and critical pressure (p_c):

The temperature at which a gas liquefies is called its critical temperature.

The volume of one mole of a gas at critical temperature is called its critical volume.

The pressure of a gas at its critical temperature is called its critical pressure.

Methods of Liquefaction of Air
(1) Lind process
(2) Linde-Claude process

Kinetic molecular theory of gases:

- Gases are made of large number of identical particles called molecules, which are very small. The actual volume of the molecules is negligible in comparison to the total volume of the molecules. They are considered as the point masses.
- The forces of attraction and repulsion between the particles are supposed to be negligible at ordinary temperature and pressure.
- Particles of a gas are always in constant and random motion.
- Molecules are supposed to be perfectly hard spheres and the collisions between them are perfectly elastic.
- The pressure exerted on the walls of the containing vessel is due to the collision of the molecules on the walls of the container.
- The average kinetic energy of the particles of a gas is directly proportional to the absolute temperature of the gas.

Liquid State

Vapour Pressure: Vapour pressure in the state of equilibrium between liquid phase and vapour phase.

Boiling point: The temperature at which the vapour pressure of a liquid is equal to the external pressure.

Surface tension (γ):

- Force acting per unit length perpendicular to the line drawn on the surface of liquid
- Its SI unit is Nm^{-1}.

Viscosity:

It is the measure of the resistance to flow, which arises due to the internal friction between the layers of fluid as they slip past one another while the liquid flows.

$$F = \eta A \frac{du}{dz}$$

Where, F = Force

A = Area of contact

$\frac{du}{dz}$ = Velocity gradient

= Proportionality constant known as coefficient of viscosity

Coefficient of viscosity (η) is the measure of viscosity. Its SI unit is N s m^{-2}.

Greater the viscosity, more slowly does the liquid flow.