States of Matter

1. **Intermolecular Forces and Thermal Interactions**
2. **The Gaseous State and Laws**
3. **Liquid State**

- Intermolecular forces operate between the particles of matter. Intermolecular forces are the forces of attraction and repulsion between interacting particles.These forces differ from pure electrostatic forces that exist between two oppositely charged ions. Also, these do not include forces that hold atoms of a covalent molecule together through covalent bond.
- Attractive intermolecular forces are known as van der Waals forces. It includes dispersion forces or London forces, dipole – induced dipole forces and dipole – dipole forces.
- Dispersion forces or London forces exist between neutral atoms like that of noble elements or non – polar molecules like N_2, O_2, H_2 etc.
- Magnitude of dispersion forces depends on the polarisability of the neutral molecule.
- Dipole forces occur between the molecules having permanent dipole such as H_2O, HCl, NH_3, etc.
- Hydrogen bond is a special case of dipole-dipole interaction. When hydrogen atom is bonded to atoms of highly electronegative elements such as oxygen or nitrogen, hydrogen atom forms a weak bond with the electronegative atom of the other molecule. This weak bond is called hydrogen bond.
- Dipole – Induced Dipole forces occur between the polar molecule having permanent dipole and the molecule having no permanent dipole.
- Thermal energy is the energy of a body arising due to motion of its atoms or molecules. Competition between thermal energy and inter molecular interactions determines the state of matter.

- Predominance of molecular interactions result into change of gases to liquid to solid state. But predominance of thermal energy results into change of solid to liquid to gas.
- properties of matter such as behaviour of gases, characteristics of solids and liquids and change of state depend upon energy of constituent particles and the type of interaction between them. Chemical properties of a substance do not change with change of state, but the reactivity depends upon the physical state.
- Forces of interaction between gas molecules are negligible and are almost independent of their chemical nature. Gases do not have definite volume and shape. They assume volume and shape of the container.
- Interdependence of some observable properties namely pressure, volume, temperature and mass leads to different gas laws obtained from experimental studies on gases.
- **Boyle's law** states that under isothermal condition, pressure of a fixed amount of a gas is inversely proportional to its volume. It is expressed as:

$p \propto \frac{1}{V}$ (n, T are constant)

Charles' law is a relationship between volume and absolute temperature under isobaric condition. It states that volume of a fixed amount of gas is directly proportional to its absolute temperature $(\mathrm{V} \propto \mathrm{T})$

- If state of a gas is represented by p_1, V_1 and T_1 and it changes to state at p_2, V_2 and T_2, then relationship between these two states is given by combined gas law according to which $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$

Any one of the variables of this gas can be found out if other five variables are known.

Gay Lussac's Law states that at constant volume, pressure of a fixed amount of a gas varies directly with the temperature. Mathematically, it is expressed as
$\mathrm{p} \propto \mathrm{T}$. n and v are constant

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

It is expressed as $\mathrm{V} \propto \mathrm{n}$

Dalton's law of partial pressure states that total pressure exerted by a mixture of non-reacting gases is equal to the sum of partial pressures exerted by them. Thus $p = p_1 + p_2 + p_3 + \ldots$ Relationship between pressure, volume, temperature and number of moles of a gas describes its state and is called **equation of state of the gas**.

Equation of state for ideal gas is $pV = nRT$; where R is a gas constant and its value depends upon units chosen for pressure, volume and temperature.

Postulates of Kinetic Molecular Theory of Gases:

- Gases contain large number of minute identical particles (atoms or molecules).
- Gas molecules are so far apart from each other that the actual volume of the molecules is negligible as compared to the total volume of gas.
- Particles of a gas are always in constant and random motion.
- There is no force of attraction between the particles of a gas at ordinary temperature and pressure.
- Particle of a gas move in all possible directions in straight lines. During their random motion, they collide with each other and with the walls of the container.
- Pressure is exerted by the gas as a result of collision of the particles with the walls of the container.
- Total energy of molecules before and after the collision remains same.
- At any particular time, different particles in the gas have different speeds and hence different kinetic energies.
- In kinetic theory it is assumed that average kinetic energy of the gas molecules is directly proportional to the absolute temperature.

At high pressure and low temperature inter molecular forces start operating strongly between the molecules of gases because they come close to each other. Under suitable temperature and pressure conditions gases can be liquefied. Liquids may be considered as continuation of gas phase into a region of small volume and very strong molecular attractions. Some properties of liquids e.g., surface tension and viscosity are due to strong inter molecular attractive forces.