In our present blog, we would understand and learn about these states of matters in detail. To determine the properties of substances, we deal with the aggregates of molecules. These aggregations of molecules that come within the scope of human experience that constitutes are known as matter. Matter can be divided roughly into three categories: **1. Gases 2. Liquids 3. Solids**

All these states arise due to competition between opposing molecular forces, that is a force of attraction which tends to hold the molecules together and the disruptive forces due to the thermal energy of molecules.

**Gaseous State:** Thermal energy is greater than force of attractions between molecules.

**Liquid State**: Thermal energy is smaller than the force of attractions between molecules.

**Solid State**: Thermal energy is much smaller than the force of attraction between molecules.

# Matter

Anything that occupies space, has mass and can be felt by humans is known as Matter. Example: Sugar, sand, Hydrogen, oxygen etc. Matter can be differentiated based on their compositions and can be divided into two types:

1. **Physical Composition -** Based on Intramolecular forces between molecules
2. **Chemical Composition -** Based on physical and chemical properties of substance

# Gaseous State

Variables that define state of a Gas:

**(a) Pressure:** It is denoted by P. It represents pressure exerted by the gas molecules on the wall of the container assuming negligible intermolecular force of attraction.

**(b) Volume:** It is denoted by V. It represents free volume available for motion. Free volume = volume of container – Actual Volume occupied by gas molecule. We consider the volume of gas is equal to the volume of the container if the actual volume of gas is negligible (valid only for ideal gases).

**(c) Temperature:** It is denoted by T. It is a measure of Kinetic Energy of gases.

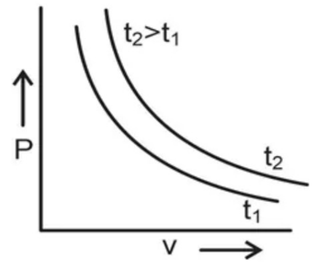
**(d) Moles:** It is denoted by n. It represents the amount of gas. SI unit: moles.

**Experimental Gas Laws:**

It is applicable for ideal gas only. It describes the relationship between the four parameters P, V, T and n.

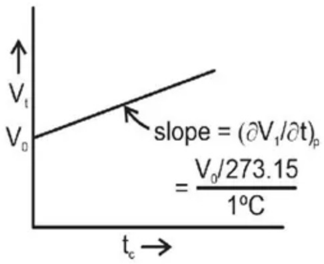
- **Boyle's Law:**

Volume of a fixed mass of gas is inversely proportional to its pressure at constant temperature. At constant Temperature: $P \propto 1/V^P$, PV = Constant This law can be represented by a plot between V and P at constant temperature. Such plots are called **Isotherms**.



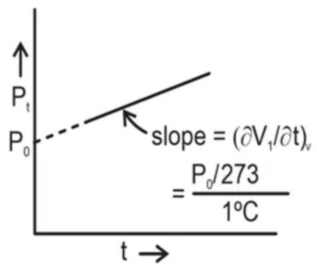

- **Charles Law:**

It states that the volume of a given mass of a gas at constant pressure increase or decrease by 1/273 of its volume of $0^oC$ for each degree rise or fall of temperature. Here, volume of a fixed mass of the gas at constant pressure is directly proportional to its temperature in Kelvin. At constant pressure: $V \propto T$, $V_1 T_2 = V_2 T_1$ . This law can be represented by a plot between V and T at constant pressure. Such plots are called **Isobar**.



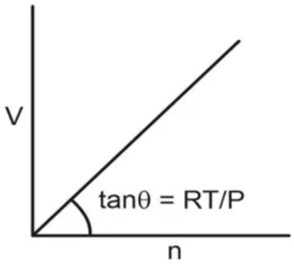

- **Gay-Lussac's Law:**

The pressure of a given mass of a gas at constant volume is directly proportional to temperature in Kelvin. At constant Volume: $P \propto T$, P / T = Constant, $P_1 T_2 = P_2 T_1$ This law can be represented by a plot between P and T at constant volume. Such plots are called **Isochore**.



- **Avogadro's Law:**

It states that an equal number of molecules of different gases under identical conditions of temperature and pressure occupy the same volume. At constant Temperature and Pressure: $V \propto N$, $V / N$ = Constant, $V_1 n_2 = V_2 n_1$ This law can be represented by a plot between V and n at constant pressure and temperature.




**Equation of State:**

This equation describes the relationship between all four variables that define the state of a gas. PV = nRT pM = dRT Here, R is a universal gas constant and is given by R = PV / nT

SI unit: R = 0.08314 bar $dm^3$ $K^{-1}$ $mol^{-1}$ , R = 8.314 J $K^{-1}$ $mol^{-1}$ = 0.0821 L atm $K^{-1}$ $mol^{-1}$ = 0.083 L bar $K^{-1}$ $mol^{-1}$ =1.98722 cal $K^{-1}$ $mol^{-1}$

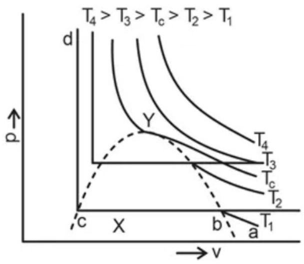
**Mixture of gases:**

**Dalton's Law of Partial pressures:** The total pressure exerted by a mixture of non-reactive gases is equal to the sum of the partial pressures of individual gases. **$P_{Total} = P_1 + P_2 +$ …….** where, $P_1$ , $P_2$ = partial pressure of gas 1 and gas 2, **$P_{Total} = n_{Total}RT$**, $n_{Total}$ = total amount of gases in mixture. Partial pressure for gas 1 and gas 2 is given by **$P_1 = n_1 / n_{total}\, P_{total}$ $X_1P_{total}$**, $X_1$ = mole fraction of gas 1, **$P_2 = n_1 / n_{total}\, P_{total}$ $X_2P_{total}$ ,** $X_2$ = mole fraction of gas 2

**Average Molecular mass of gaseous mixture:** $M_{mix}$ = Total mass of mixture / Total no. of moles in mixture = $n_1M_1 + n_2M_2$ + …. / $n_1 + n_2$ + …..

# Andrews Isotherm

In 1869, Thomas Andrews carried out an experiment in which P–V relations of carbon dioxide gas were measured at various temperatures. The types of isotherms obtained are shown in figure.




(1) At high temperatures, such as $T_4$ , the isotherms look like those of an ideal gas.

(2) At low temperatures, the curves have altogether different appearances.

**Critical Constants:**

- **Critical temperature ($T_C$ ):** The maximum temperature at which a gas can be liquefied.
- **Critical pressure ($P_C$ ):** The minimum pressure required to cause liquefaction at the temperature $T_C$ .
- **Critical volume ($V_C$ ):** The volume occupied by one mole of a gas at critical temperature $T_C$ and critical pressure $P_C$ .

# Liquid state

Properties of liquid state:

1. There exists a short-range order.
2. Close packing of molecules or atoms or ions exist to some extent in liquid state.
3. A liquid has a definite volume but not a definite shape.
4. The intermolecular forces are fairly strong in liquid state.

**Vapour Pressure:**

The Vapour pressure of a liquid at a given temperature may be defined as the pressure of the Vapour in equilibrium with the liquid at that temperature. It is a measure of the escaping tendency of molecules from the surface of the liquid. The vapour pressure of a liquid increases with the increase in temperature.

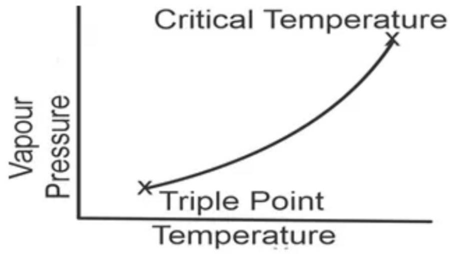
**Variation of Vapour pressure with temperature can be given by Clapeyron equation:**

$dp/ dT = \Delta_{vap}H_m /T (V_{m,v} - V_{m,l})$

where, dp/dT is the rate of change of vapour pressure with temperature, $D_{vap}H_m$ is the molar enthalpy of vaporization of liquid, $V_{m,v}$ and $V_{m,l}$ are molar volumes of vapour and liquid

**Boiling Point:**

The temperature at which its vapour pressure is equal to the external pressure is known as Boiling point of a liquid. If pressure is equal to 1 atm or 1.01325 bar, then boiling point is known as normal boiling point.




# Solid state

Solid state is a very vast topic. In this blog, we will study only about types of solids and classification of crystalline solids.

**Properties of solid state:**

1. Solids are distinguished by their tightly bound molecules.
2. Solids hold their shape and have a fixed volume.
3. One type of solid is a crystalline solid In which the molecules are arranged in a repeating pattern throughout the material. Crystals are easily identifiable by their macroscopic geometry and symmetries.
4. Another type of solid is an amorphous solid in which the molecules are not arranged in a crystal lattice at all. A polycrystalline solid is somewhere in between. It is often composed of small, single crystal structures, but without a repeating pattern.
5. They have low compressibility and are rigid and the Intermolecular distances are also short.
6. They have definite mass, volume and shape.

In this blog, we studied about different types of matter and their properties. We learned about Solid, Liquid and Gaseous states in this blog.