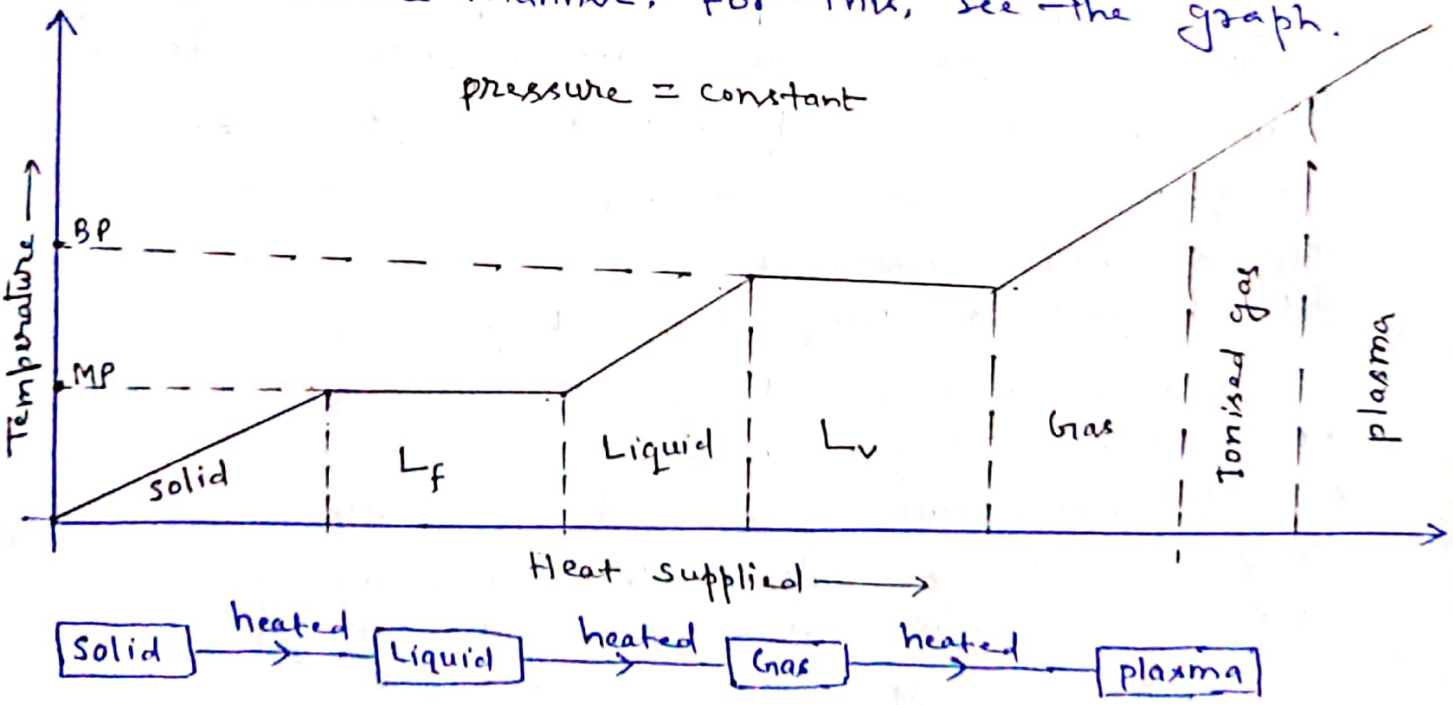
plasma :- plasma is the fourth state of matter. other three states of matter are solid, liquid and gas. The basic difference among solid, liquid and gas lies in the difference between the strengths of bonds that holds the constituent particles together. The equilibrium between the particle's thermal energy and the inter-particle binding forces determines the state of our system i.e, the system will be either in solid state or in liquid state or in gaseous state. This depends upon average kinetic energy per particle of the system.

When a solid substance is heated then it is converted into liquid form and when a liquid substance is heated then it is converted into vapour or gaseous form and when the gaseous form is heated to a very large temperature then it is converted into plasma state. This is a general principle but we will understand this very fact in a concrete manner. for this, see the graph.



From graph, it is clear that when a solid substance is heated then its temperature rises upto a fixed temp. (melting point) then after its temperature becomes constant (melting point) and solid begins to melt. The amount of heat used to melt

the solid substance completely at constant temperature (MP) is known as latent heat of fusion of the solid. Again when the liquid is heated then its temperature rises upto a fixed temperature (Boiling point) then after its temperature becomes constant (BP) and liquid begins to convert into vapour (gas) on heating at constant temperature (BP). The amount of heat used to convert the liquid completely into vapour (gas) at constant temperature (BP) is known as Latent heat of vapourisation. Again when the gas is heated to a very large temperature then the gas begins to ionise and the gas is converted into plasma state.

phase transition always takes place at constant (particular) temperature and pressure.

Since conversion of solid into liquid takes place at a particular temperature and pressure so conversion of solid into liquid is a phase transition.

Similarly conversion of liquid into vapour or gas also takes place at a particular temperature and pressure so transformation of liquid into vapour or gas is also a phase transition.

Thus these two transformations are phase transitions but transformation of gas into plasma is not a phase transition because transformation of gas into plasma does not take place at particular temperature and pressure.

When a gas is heated then the molecular gas is converted into atomic gas and when the atomic gas is heated then atomic gases collide one another and during these collisions, the valence electrons from some atoms (not from all atoms) knocked out and the gas becomes ionised.

$$M \text{ (neutral atom)} \longrightarrow \underset{\text{positive ion}}{M^+} + \underset{\text{electron}}{\bar{e}}$$

There may be two types of ionisation of gas.

* partially ionised gas: It consists of positive ions, electrons and neutral atoms.
* Fully ionised gas:— It consists of positive ions and electrons only.

Normally people say these ionised gases are plasma but this will be a mistake. We can not call all ionised gas to be plasma but ionised gas is said to be plasma only when certain conditions (criteria) are full filled by ionised gas.

Concrete Definition of plasma:- All ionised gases donot qualify to be called plasma because some amount of ionisation is almost always found in a gas.
plasma is a "quasineutral" gas of charged and neutral particles which exhibits "collective behaviour".

Quasineutrality :- plasma is electrically conducting because of its charged particles (positive ions and electrons) but total charge of a macroscopic volume of plasma is zero, so it is known as Quasineutral.

If n_e = number density of electrons in plasma
n_i = number density of positive ions in the plasma
$-q_e$ = charge of an electron
$+q_i$ = charge of a positive ion

Since total charge of a macroscopic volume is zero and here unit volume is macroscopic volume (let).

So, $q_i n_i + (-q_e \cdot n_e) = 0$

If $q_i = |-q_e|$ then $\boxed{n_i = n_e}$

Electrons are majority contributor of conduction because its mobility is high due to smaller mass. positive ions are much heavier than electrons so mobility of positive ions is very low so ions are not part of conduction of current in plasma. Ions i.e. positive ions serve to maintain charge neutrality.

Therefore plasma is a "Quasineutral" gas of charged and uncharged particles.

Collective behaviour :- plasma consists of three types of species. ii) positive ions (positively charged particles).

(ii) electrons $\bar{e}$ (negatively charged particles) and (iii) neutral atoms. and these species are in random motion in the plasma. Due to motion of ions and electrons, electromagnetic field is produced.

Electric field $\vec{E}$ is produced due to local concentration of positive ions and electrons and magnetic field $\vec{B}$ is produced due to motion of positive ions and electrons.

These fields $\vec{E}$ and $\vec{B}$ affect the motion of the charged particles (positive ions and electrons) in the plasma.

Charged particles in plasma show varities of motion. In this case, two types of forces acting on the charged particles in the plasma.

(i) Electromagnetic forces

(ii) Force due to collision (local force) → This force is effective only when the charged particles come in contact ie, when they collide.

Electromagnetic forces are long ranges forces.

$$F \propto \frac{1}{r^2} \Rightarrow F \to 0 \text{ if } r \to \infty.$$

Collisionless plasma mean collision between particles in the plasma is negligibly small. In this case, electromagnetic force dominates over the forces due to collision. This is criterion for collective behaviour.