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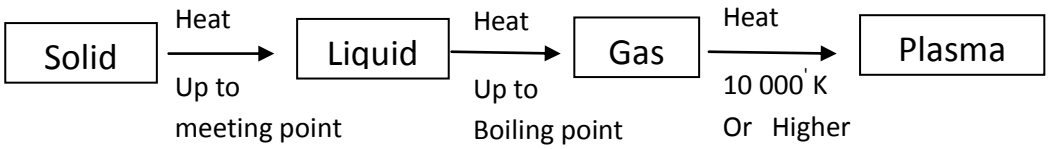
PLASMA

The word Plasma is of Greek origin meaning " formed or moulded". The term Plasma was first used by American scientist Irving Langumir in 1923.



If a gas is heated, the gas atoms get ionized producing ions and free electrons. This state of matter is called plasma.

A gas can be converted into plasma only when the electrons are released from atom.

$$\text{Atom} \rightarrow \text{Ions} + e^-$$

Plasma is a fourth state of matter. Plasma is a mixture of free electrons, positive Ions and neutral particles with a high density.

The energy required to remove an electron form atom is known as Ionization potential.

For Hydrogen atom

Ionization potential = 13.6ev

$$e\emptyset_i = 13.6ev$$

Average Kinetic energy of atom = $\frac{3}{2} K_B T$

Where K_B=Boltzmann's constant

T = Temperature of gas

$K_B = 1.38 \times 10^{-23} J/^0K$

Usually in plasma K_BT is called temperature of plasma.

At $T = 10^{4\ 0}K$

$K_BT = 1.38 \times 10^{-23} \times 10^4 = 1.38 \times 10^{-19} = 1$ ev

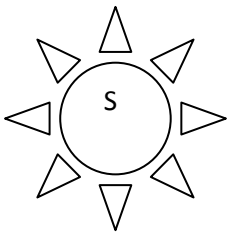
1 e v temperature correspond to $^{-}10^{4\ 0}K$

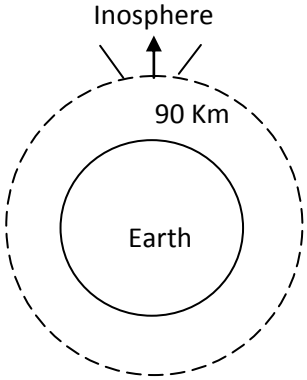
i.e. At least $10^{4\ 0}K$ temperature is required to ionize a gas.

Existence of Plasma –

1. Space plasma – Atmosphere of earth, sun, starts etc.
2. Laboratory plasma – Gas discharge tube

Nature produces plasma in our atmosphere and this process is called photo-ionization.





Sun sends solar radiations and some solar radiations is called ultraviolet light, they have photon energy.

Quantum energy of each photon $= h\nu$

Where h = Plank's constant

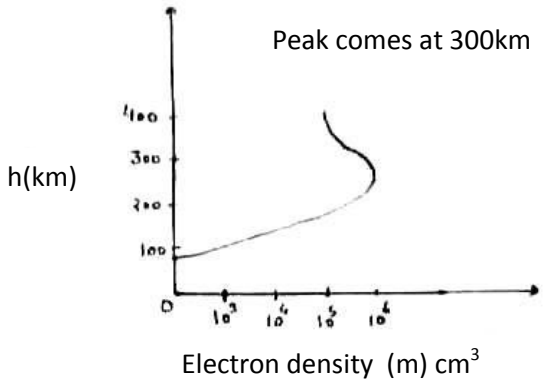
ν = Frequency

Whenever photon energy is more than ionization potential of atoms of air i.e.

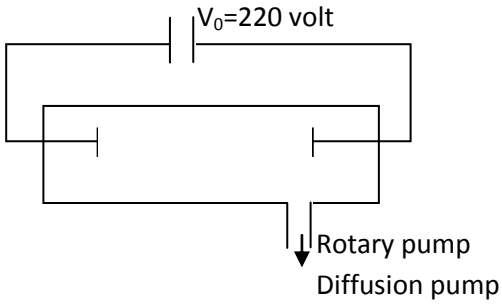
$$h\nu > e\,\emptyset_i$$

They will ionize the atoms of air. So due to this photon coming from the sun, there is a layer of air around the earth is ionized. The air starts ionizing form height of 90 Km from surface of the earth.

So, a region of atmosphere at a height of 90Km or above is called ionosphere.



Laboratory method to produce a plasma by Gas discharge tube -



Consider a tube containing the gas and a vacuum pump to create a vacuum in the interior of tube by using a rotary pump and by a diffusion pump. These two pump can give a pressure of 10^{-3} Torr

Pressure$\sim 10^{-3}$ Torr

1 Torr$\sim$ 1mm of Hg

$= \frac{1}{760}$ Atmospherice pressure

1 Torr $= 130$ N/m^2

So rotary pump and diffusion pump create a pressure inside the tube of the order of 10^{-6} atmospheric pressure

On applying a dc voltage between the electrodes like 220 volt, then electric field will produce in it

Electric field

$$E=\frac{V_0}{L} \text{ ie } 220 \text{ Volt per meter}$$

This electric field ionize the gas inside the tube and produce free electrons and positive ions. These electrons are then pulled towards anode by electric field and they move until they collide with a neutral atom. So the distance an elections covers between two collision in called mean free path.

Mean free path $\lambda_m = \frac{1}{n_m q}$

where n_m=density of atoms (m^3)

q=collision cross section

$q = \pi a^2$ where a =radius of atom

$q \sim 10^{-19}\ m^2$

$n_m \sim 2.5 \times 10^{19}\ m^{-3}$

$\therefore \lambda_m \sim 40cm$

It means in the tube electrons will have a time to travel a distance of 40 cm before it hits another atom. In this process, it can acquire enough kinetic energy

$$\text{Kinetic energy} = \frac{V_0}{L} e \lambda_m$$

$$\text{If } \frac{V_0}{L} e \lambda_m > e \phi_i$$

It will cause brisk ionization i.e. one electron will produce ionize one atom. So that number of electrons will be doubled after one collision and then those two elections will be accelerated by electric field and they will ionize more atoms and so on. So one can have multiple ionizations and even the gas can get ionized doubly or triply and this is the process of dc breakdown of gas

The dc field can be replaced by radio frequency field (RF field) and that can be applied with great ease by using a coil. This is the simple technique to produce plasma.