28/4/20

UNIT – 7

CHAPTER – 11

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- Dual Nature Of Radiation and Matter -

* Elementary Knowledge of Electron -

In 1879 the scientist William Crookes in his experiment found that at ordinary pressure generally all gases are the bad conductors of electricity.

J. J thomson discovered the electrons by his experiment. He took a discharge tube, consists of a glass tube of about 50 cm in diameter having a side tube with a vaccum pump. Two electrodes, namely a cathode C and an anode A are enclosed in the tube. A high potential difference of the order of 10,000 volt is applied by means of an induction coil across the two electrodes. The pressure of gas inside the tube can be decreased by the vaccum pump.

When the pressure of gas inside discharge tube becomes 10^{-2} MM

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of Hg, The entire tube becomes dark and inside the tube some invisible rays are emitted normally from the cathod surface which on striking the glass tube produces fluorescence. These rays are called as cathode rays. The flow of electricity in gases at a low pressure is called electric discharge.

NOTES

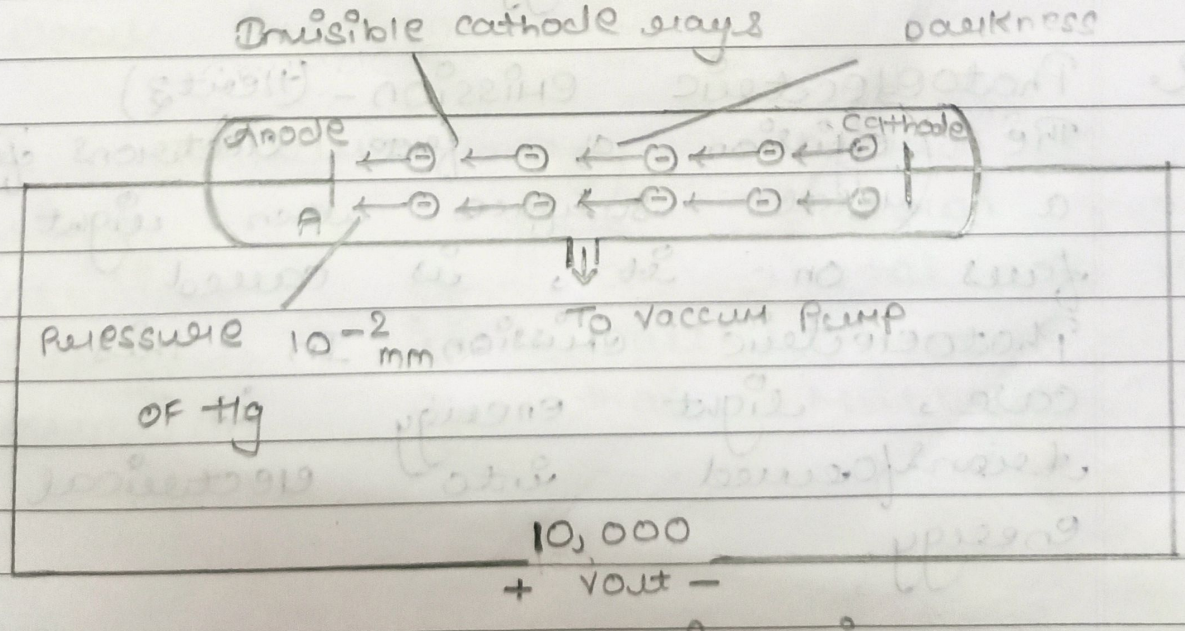
① The notation of electron is e^-.

② The electron is an elementary particle of an atom.

③ The charge on electron is -1.6×10^{-19} C.

④ The mass of an electron is -9.1×10^{-31} kg.

⑤ specific charge of electron is e/m.



Production of Cathode Rays -

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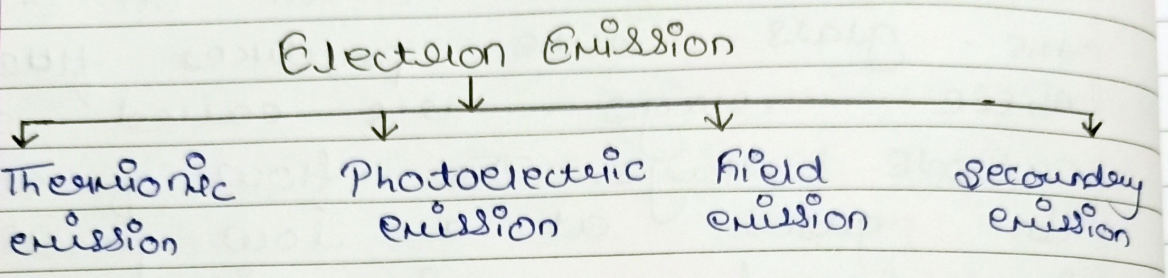
* Electron Emission -
The emission of electrons from the metal surface is called as electron emission.



1. Thermionic emission -
The emission of free electrons from a metal surface when heat energy is impacted to it is called Thermionic emission.
The electrons so emitted are called the thermions.
This Phenomena was first discovered the scientist edison. In the phenomena heat energy is converted into electrical energy.

2. Photoelectric emission - (Hertz)
The emission of free electrons from a metal surface when light falls on it, is called photoelectric emission. In this case, light energy is transformed into electrical energy.

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3. Field Emission-

The emission of free electron from a metal surface in presence of strong electric field is called field emission. It is also called the cold cathode emission.

4. Secondary emission-

When large number of electrons moving with a very high velocity strikes a metal surface, other free electrons are emitted from that metal. The energy imparted exceeds the work function of the metal, the free electrons are emitted out from the metal surface. These electrons are known as secondary electrons.

BMP defination-

1. Work function-

The maximum energy required to bring a free electron from interior of a metal to its surface is called work function of that material.

The minimum frequency of incident light which emits the electrons from the metal surface is called the threshold frequency for that metal.

Stopping / cut-off Potential –

The negative potential applied on anode of photoelectric cell at which the photoelectric current become zero is called the stopping potential or cut-off Potential.

Laws of Photoelectric effect –

The photoelectric emission occurs only when the frequency of incident light on the metal surface is greater than a definite minimum value (threshold frequency).

Photoelectrons ~~not~~ are not emitted when the frequency of incident light is below threshold frequency.

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2. The maximum kinetic energy of the emitted electrons is directly proportional to the frequency of incident light.

3. The number of electrons emitted is proportional to the intensity of incident rays or light.

4. Electrons are emitted from the metal surface when or as soon as light falls on it.

Q. How The work function of a metal is 0.1 e.v. Calculate the threshold frequency for Photoelectric emission.

Given – work function $\phi = 0.1$ e.v.

$= 0.1 \times 1.6 \times 10^{-19}$ J

Threshold frequency $\nu_0 = \frac{\phi}{h}$

$h = 6.6 \times 10^{-34}$ J/sec

$$\nu_0 = \frac{0.1 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$$

or

$$\boxed{\nu_0 = 0.029 \times 10^{15} \text{ Hz}.}$$

...ave on Metal ...

If p is the momentum of the ~~Photon~~ Particle the wavelength of the wave is associated with it is given as:

$$\boxed{\lambda = \frac{h}{p}}$$

Proof -

Energy of Photon = $E = h\nu$ — (1)

But from Mass-energy equivalence, energy of Photon is $E = mc^2$ — (2)

$h\nu = mc^2$ (From eq. 1 and 2)

$$m = \frac{h\nu}{c^2}$$

Momentum of Photon $P = mc$

$$\left(\frac{h\nu}{c^2}\right)c = \frac{h\nu}{c}$$

$$\boxed{P = \frac{h\nu}{c}}$$

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Since $\nu = \frac{h}{\lambda}$

$$P = \frac{hc/\lambda}{c}$$

$$P = \frac{h}{\lambda}$$

$$\boxed{\lambda = \frac{h}{P}}$$

This is called de-broglie wave equation.

* Elementary Knowledge Of Photon-

According to Plank's Quantum theory light travel in the form of small packets of energy. Each packet is called quanta or Photon.

Photon is a bundle quanta of energy or which is emitted from the source of radiation and travels with the speed of light in a straight line.
The energy and momentum of each photon is directly proportional to the frequency of light.

If ν is the frequency of light and λ is the wavelength, then energy is

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$E \propto \nu$

or $E = h\nu = \frac{hc}{\lambda}$ (since $\nu = c/\lambda$)

and momentum of each photon -

$$P = \frac{h\nu}{c} = \frac{h}{\lambda}$$

* Rel. b/w energy and momentum of photon -

The energy of photon and its momentum p are related as :-

$$E = Pc \text{ or } \boxed{P = \frac{E}{c}}$$

h is a universal constant which is called the Plank's constant.

$$h = 6.6 \times 10^{-34} \text{ J} \times \text{S}$$

Ques Q. Calculate -

Calculate the energy and momentum of a wavelength $\lambda = 600 \text{ Å}$.
($c = 3 \times 10^8 \text{ m s}^{-1}$, $h = 6.6 \times 10^{-34} \text{ Js}$).

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Sol^n -

Given : $\lambda = 600\,\text{Å} = 6 \times 10^{-7}\,m$

Energy of Photon $E = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})\times(3\times10^{8})}{6\times10^{-7}}$

$= 3.3\times10^{-19}\,J$

But $1eV = 1.6\times10^{-19}\,J$

$E = \frac{3.3\times10^{-19}\,eV}{1.6\times10^{-19}} = 2.0625\,eV$

Momentum of Photon $P = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{6\times10^{-7}}$

$= 1.1\times10^{-27}\,kg\,ms^{-1}$

Einstein Photoelectric Equation

In 1905, Einstein explained the phenomenon of photoelectric effect on the basis of Plank's quantum theory. According to it, light travels in form of small bundles or packets of energy with speed of light. The bundle of light is called the photon.

The energy of photon is $h\nu$ and momentum is $\frac{h}{\lambda}$.

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where. h = Plank's constant
ν = frequency of light
λ = wavelength of light

- when photon of energy $h\nu$ incident on any substance its energy use in two ways:

(1) A part of energy is used to eject the electron from the surface which is called work function denoted by ϕ and is different in different substance.

(2) Remaining energy is used to increase the Kinetic energy of emitted electrons.

therefore, $h\nu = \phi + E_K$ ——— (1)

If ν_0 is a threshold frequency and maximum velocity of and electron is V_{max}.

$\therefore \phi = h\nu_0$

and $E_K = \frac{1}{2} m V^2_{max}$

From equation — (1)

$$h\nu = h\nu_0 + \frac{1}{2} M V^2_{Max}$$

Or

$$\boxed{\frac{1}{2} M V^2_{Max} = h(\nu - \nu_0)} \quad — (2)$$

Eq. (2) is einstein equation.