Modern physics

- Dual Nature of radiation & matter
  - Dual Nature of radiation
  - Matter wave
- Atoms
- Nuclei

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[light = wave nature / particle nature]

[PEE] (Photoelectric effect)

i) Interference   ii) Diffraction   iii) Polarisation

wave nature of light

{PEE by hertz, Compton effect, Stark effect} explained quantum theory of light which light assumed to made up packet of energy known as photon or quantum of light

$$\boxed{\text{Energy of photon} = E = h\nu = \frac{hc}{\lambda}}$$

h = plancks const = 6.62×10^{-34} J-s

Various type of electron emission:- • 1°e⁻ → striking striked

i) Thermionic emission:- when metal is heated, e⁻ are emitted

ii) field emission:- when strong electric field applied across the metal surface, e⁻ are emitted.

iii) Photoelectric emission:- when light suitable frequency is incident on the metal surface, e⁻ are emitted.

iv) Sec. emission:- when beam of highly energetic e⁻

is incident on a metal surface e^- are emitted.

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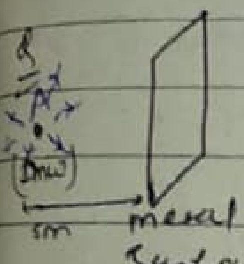
Photoelectric effect :- when light of sufficiently low wavelength falls on a metal surface e^- are emitted.



light falls $\perp$ to the surface assume wave theory of light
X also light falling on a circular area of radius 1 nm is completely absorbed by a single e^- on the surface.

If work function of surface = 2eV then calculate time required by e^- to receive sufficient energy to come out?

energy falling on unit area p.u. time on a sphere of radius 5m

$$= \frac{P}{4\pi r^2}$$

energy absorbed p.u. time

$$= P/4\pi r^2 \times \pi(10^{-9})^2$$

let after time (t) e^- get $2 \times 1.6 \times 10^{-19}$ J of energy

$$\frac{P}{4r^2}(10^{-9})^2 = 2 \times 1.6 \times 10^{-19}$$

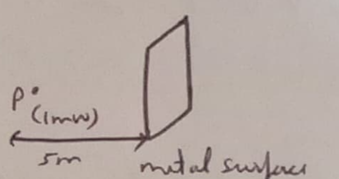
$$\frac{10^{-3} \times 10^{-18}}{4(5)^2} t = 3.2 \times 10^{-19}$$

$$t = \frac{3.2 \times 10^{-19} \times 100}{10^{-21}} = 3.2 \times 10^{4} s$$

Photo electric effect :-

- when light of sufficiently low wavelength falls on a metal surface electrons emitted.

Q light falls ⊥ on the surface, assume wave theory of light and also light falling on a circular area of radius 1nm is completely absorbed by a single e^- on the surface, if work function of surface is 2eV, then calculate time required by the e^- to recieve sufficient energy to come out -



⇒ energy falling on unit area p.u time on a ~~surface~~ sphere of radius 5m $= \frac{P}{4\pi r^2}$

⇒ energy absorbed p.u. time $= \frac{P}{4\pi r^2}\pi(10^{-9})^2$

let after time 't' electron get $2\times1.6\times10^{-19}$J of energy

$$\frac{P}{4r^2}(10^{-9})^2 t = 2\times1.6\times10^{-19}$$

$$\Rightarrow \frac{10^{-3}\times10^{-18}}{4(5)^2} t = 3.2\times10^{-19}$$

$$\Rightarrow t = \frac{3.2\times10^{-19}\times100}{10^{-21}} = 3.2\times10^{4}s$$

Quantum (Photon) theory of light :-

Properties of photon :-

(a) Light behaves as if it is made up of particles called photons which ~~travel~~ travel in straight line with speed of light.

(b) Rest mass of photon is zero

(c) each photon has a definite energy + linear momentum

$$\boxed{\begin{array}{l} * \; E = h\nu = \frac{hc}{\lambda} \\ * \; p = \frac{E}{c} = \frac{h}{\lambda} = \frac{h\nu}{c} \end{array}}$$

(d) Photon energy is independent of intensity of light or power of source.

eg:- 5W, 200nm
50W, 200nm } Photons have same energy, but power is different.

$$\boxed{P = nE}$$

where, P = Power of source
E = Energy of photon
n = number of photons emitted /s

note:- more intensity means more no. of protons crossing pu. area, pu time.

note:- Quality of photons represents its energy / wavelength / frequency
Quantity of photons represents its power / intensity.

(e) Photons are electrically neutral & ∴ there is no effect of electric & magnetic field

(f) Total energy & total momentum are conserved in photon - particle collision.
(although total no. of photons may vary.)

Experimental results of P.E.E :-

↳ PE.E. supports quantum nature of light.

1) for a given metal, there exists a certain minimum cut off frequency k/a Threshold frequency of incident radiation below which no emission takes place irrespective of intensity of radiation.

2) maximum kinetic energy of photoelectrons depends only on frequency of light & not on its intensity.

3) Even when surface is faintly illuminated, the photoelectrons leave the surface immediately.

4) P.E.E is an instantaneous process

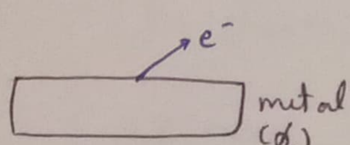
Q Calculate energy of Photon & no. of photons emitted /sec by a source and wavelength of 400 nm.

$$E = \frac{hc}{\lambda} = \frac{12400\,(eV\text{-}\mathring{A})}{\lambda\,(\mathring{A})}$$

$$= \frac{12400}{4000} = 3.1\,eV$$

$$P = nE \Rightarrow n = \frac{10}{3.1 \times 1.6 \times 10^{-19}} = 2 \times 10^{-19} \text{ photons /sec}$$

Einstein's Photoelectric equation :-



× 1 proton interacts with 1 electron only

ϕ_0 = work function

$$\phi_0 = \frac{hc}{\lambda_0} = \frac{12400\,(eV\text{-}\mathring{A})}{\lambda_0\,(\mathring{A})}$$

$$\phi_0 = h\nu_0$$

where, ν_0 = threshold frequency

λ_0 = threshold wavelength

$$\boxed{K_{max} = E - \phi_0}$$

where, K_{max} = K.E energy of fastest e⁻ [max. K.E of photo e⁻]

Kinetic energy of ejected photo electrons,

$$0 \le K \le K_{max}$$

$$K_{max} = E - \phi_0$$

Since, K.E ≥ 0

$$E \geq \phi_0$$

or $K_{max} = h\nu - h\nu_0$

or $K_{max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

A (e⁻) emission to take place :- $E \geq \phi_0$

$\nu \geq \nu_0$

$\lambda \leq \lambda_0$

Q if frequency of incident radiation is doubled than K_{max} will become ?

=)

Q radiations falling on a surface as intensity of 10 W/m² and $\lambda = 6000$ Å , calculate no. photons incidents on 2m² area in 2 sec.

=) ~~$\underset{\text{(Photons/sec)}}{n} = \frac{P}{E} \Rightarrow \underset{\text{(Photons/sec p.u area)}}{\frac{n}{A}} = \frac{P}{AE} = \frac{I}{E}$~~

$$\boxed{\Rightarrow \underset{\text{(Photons/sec)}}{n} = \frac{P}{E} \Rightarrow \underset{\text{(Photons per sec p.u area)}}{\frac{n}{A}} = \frac{P}{AE} = \frac{I}{E}}$$

So, no. of Photons in 2m² in 2s $\Rightarrow \frac{I}{E} \times 2 \times 2$

$$= \frac{10 \times 600 \times 2 \times 2}{12400 \times 1.6 \times 10^{-19}}$$

$$= 12 \times 10^{+19} = 1.2 \times 10^{20}$$