- characteristic of photoelectric effect
- Einstein photo electric effect

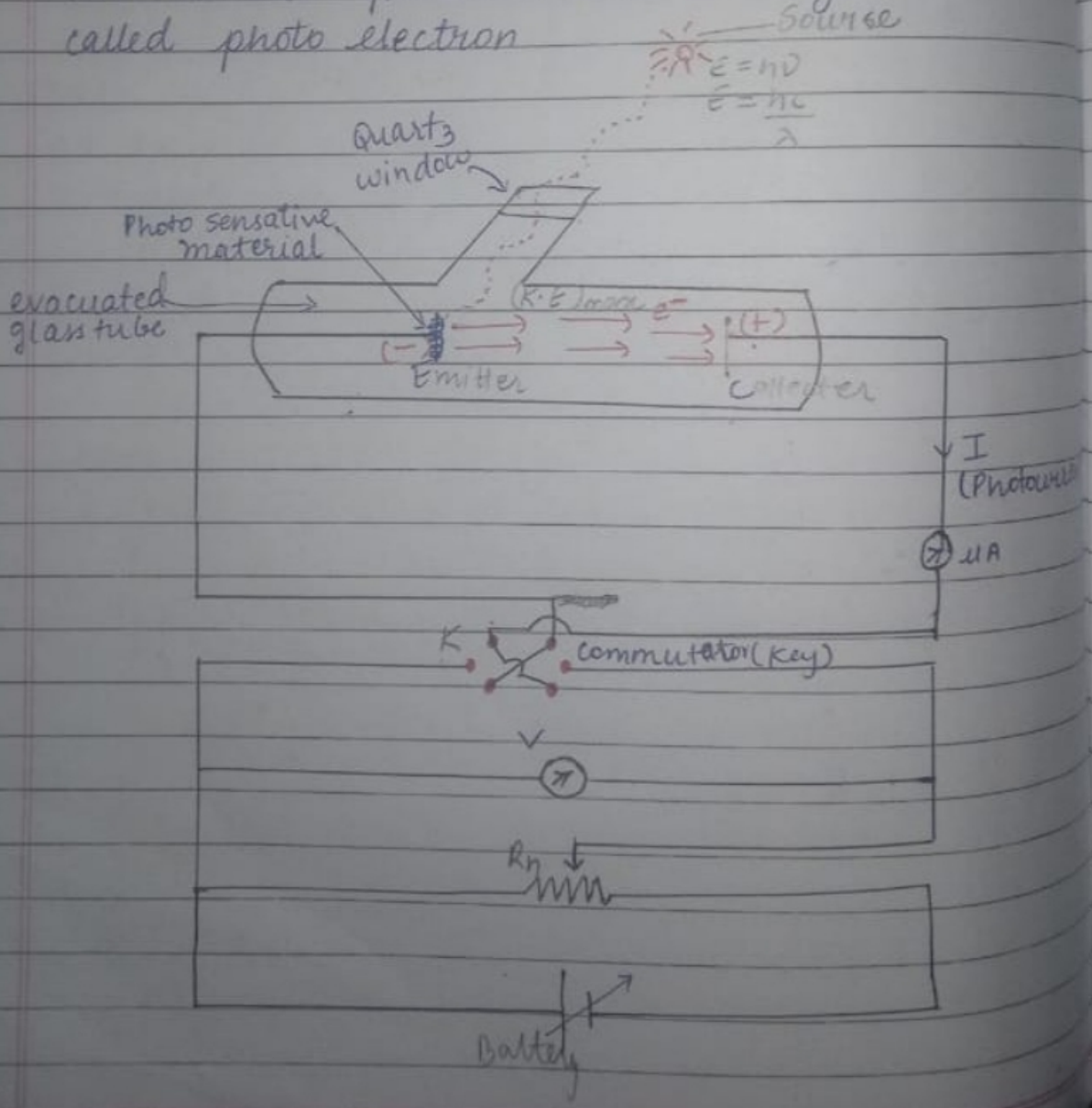
Dual nature of radiation and matter

↓ two

↓ light

Briefly The phenomenon of emission of electron when the light suitable frequency or radiation falls on it is called Photoelectric effect

The electron produced due to light is called photo electron



Rubidium
Sodium
Potassium

Principal of working

When a particular frequency of light fall on emitter plate the electron comes out this phenomenon is called photo electric current

Construction

E = emitter
C = collector
w = quartz window
v = volt meter
k = commutator key (reverse key)
R_h = rheostat

Working

When light falls on emitter plate the electrons come out from it which is collected by collecter plate which act as positive (anode). This electrons give rise to same current which is observed in micro Ammeter (μA) and it it proves photoelectric current

frequency [n = num of rotation, f = current, ν = light colour]

Some important definations

1. **Stopping potential. (V_s)**
The minimum negative potential applied to collector plate for which photoelectric current become zero is called stopping potential (V_s)

Formula:-

$$(K.E)_{max} = e \times V_s$$

$$\boxed{V_s = \frac{(K.E)_{max}}{e}}$$

2. **Threshold frequency [ν_0]**
The mimum frequency required by the electron to eject (come out) of metal surface (emitter) is called as threshold frequency [ν_0]

$$w_0 = h\,\nu_0$$

$$\boxed{\nu_0 = \frac{w_0}{h}}$$

h = Planks constant
$= 6.63 \times 10^{-34}$ Js.
w_0 = work function.

3 Photon travel with speed of light $c = 3 \times 10^8$ m/s.

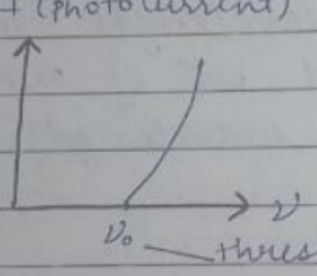
4 Photon at rest has zero mass

5 Photon has momentum P and energy.

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

Graph related to photoelectric effect

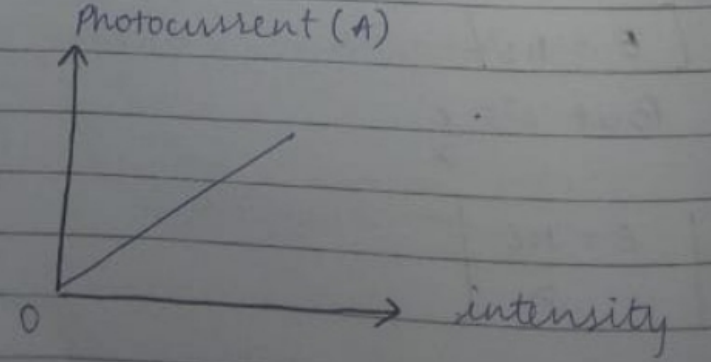
1 EFFECT OF FREQUENCY (ν)



i) Intensity is kept constant.

ii) The graph indicate before threshold frequency no photocurrent flows. At particular frequency the photocurrent start flowing which is called as threshold frequency.

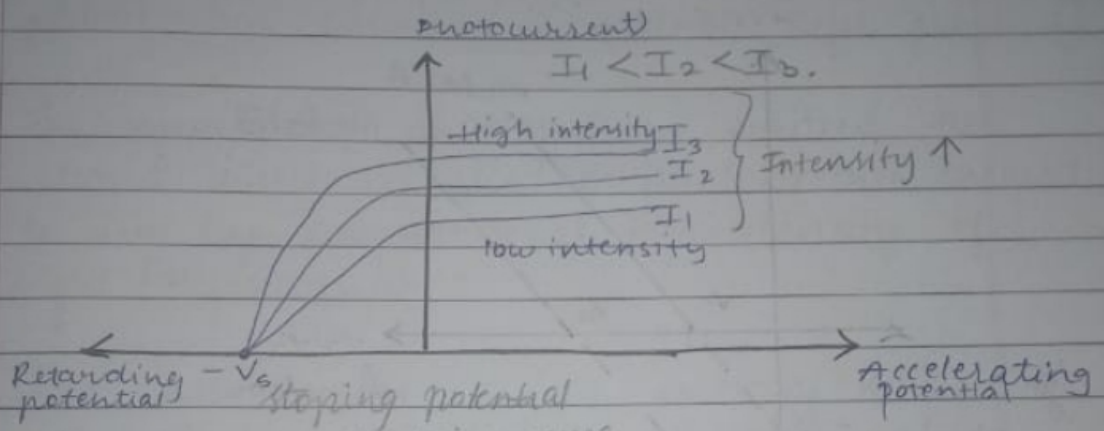
2. EFFECT OF INTENSITY (I)



i Frequency is kept constant
ii The graph indicate as ~~photocurrent~~ the intensity increase then photocurrent also increases that means they are directly proportional

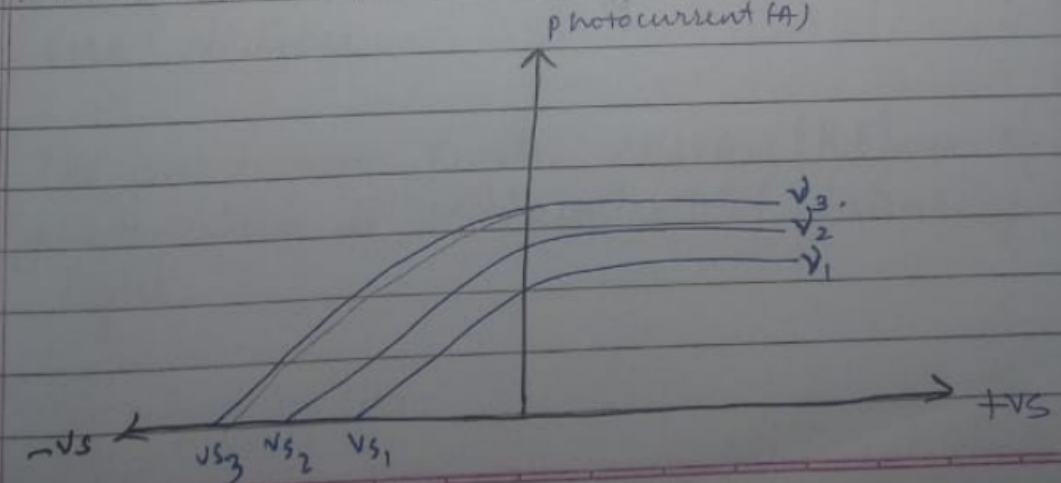
3. POTENTIAL V/S PHOTO CURRENT

Imp



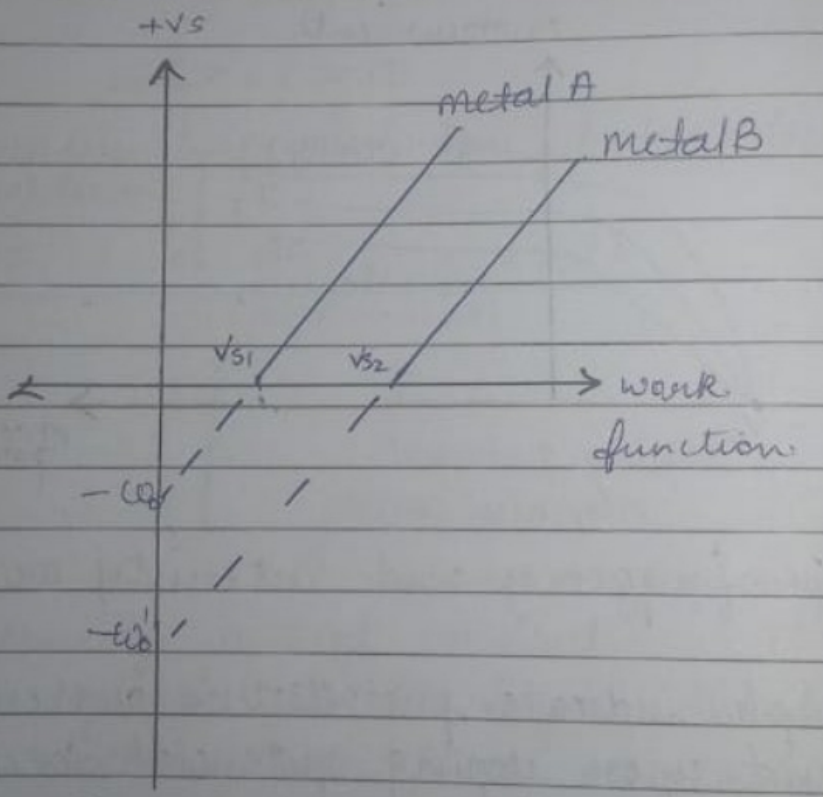
In this frequency and intensity are kept constant
The graph indicate photoelectric current does not depend upon stoping potencial because if the intensity of light increases stoping potential remain same

Imp 4 FREQUENCY V/S STOPING POTENTIAL.



The graph indicate stoping potential depends on frequency
As the frequency increases stoping potential also increases and meet on x-axis

5 STOPING POTENTIAL V/S. WORK FUNCTION



The above graph indicate.
For different metal the slope of the graph remain same but frequency and stoping potential are different.

Explain law of photoelectric effect.
State the characteristic of Photoelectric effect

1. For a given substance there is minimum value of frequency of incident light called as threshold frequency (ν_0), below which no photoelectric emission is possible [Refer graph 1]

2. The number of photoelectron emitted per second which is called as photoelectric current is directly proportional to intensity of light [Refer graph 2].

Imp 3. The maximum Kinetic energy $(K.E)_{max}$ of photoelectron is directly proportional to frequency.

$$KE_{max} \propto \nu$$

4. The process of photoelectric emission is instantaneous process.

5. The photoelectric emission is one to one process i.e one photon is equal to one electron

6. The maximum Kinetic energy $(K.E)_{max}$ of photoelectron is independent of intensity of light.

$$\text{Energy} = w_0 + (KE)_{max}$$

$$(KE)_{max} = \text{Energy} - w_0$$

$$= h\nu - h\nu_0$$

$$(KE)_{max} = h(\nu - \nu_0)$$

But $\nu = \frac{c}{\lambda}$ $\quad \nu_0 = \frac{c}{\lambda_0}$

$$(KE)_{max} = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_0}\right)$$

$$(K.E)_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

Verification of laws of photoelectric emission

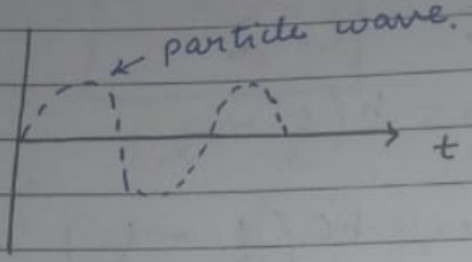
Case I :- If $\nu > \nu_0$ → Photoelectric emission takes place and K.E is +ve

Case II :- If $\nu < \nu_0$ → Photoelectric emission does not take place and K.E is -ve

$\nu = \nu_0$ → Photoelectron are just emitted

DeBroglie - Hypothisis

According to DeBroglie a moving particle is associated with wave and particle nature which is called as matter wave



According to DeBroglie nature ~~he~~ is symmetric and also every particle has momentum (P)

Derive the expression ~~of~~ for DeBroglie wavelenth (λ) and momentum (P)

The energy of photon is given by

$$E = h\nu \quad \text{---(I)}$$

$$\frac{hc}{\lambda}$$

According to Eienstien energy mass ~~&~~ relation

$$E = mc^2 \quad \text{---(II)}$$

From eq^n (I) and (II)

$$mc^2 = \frac{h\nu}{\lambda}$$

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

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

But momentum (P) = mv
= mc

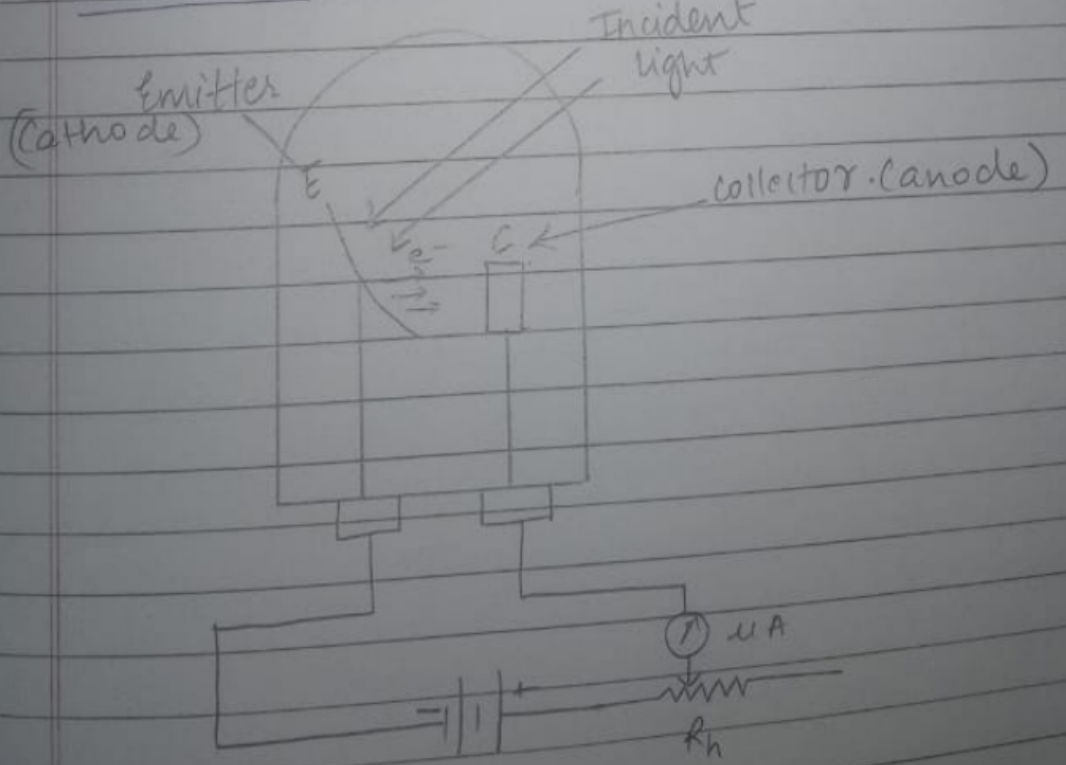
$$\lambda = \frac{h}{P} \quad \text{---} (1)$$

$$P = \frac{h}{\lambda} \quad \text{---} (2)$$

Draw and explain the construction of photocell

Photocell is a device which convert light energy into electrical energy

Construction :-



Working :-

When light of suitable fuequency fall on emitter plate which is coated by photosensitive material the electrons eject (comes out) from the metal plate and it is attracted towards collector plate which is observed by diflection of micro ammeter which indicate flow of photo current.

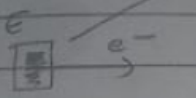
Application :-

1) Traffic light
2) Burglar alarm

Type I

P.B.O work function of a metal

$w_0 = \phi_0$



$w_0 = h\nu_0$

- ν_0 → threshold frequency
- h → plank constant 6.63×10^{-34} J/sec
- w_0 → Joule → eV

J to eV = ÷ by 1.6×10^{-19}

eV to J = × by 1.6×10^{-19}

Imp

Q Calculate work function of metal having frequency 5×10^{14} Hz.

→ Give.

$h = 5 \times 10^{14}$ Hz.

$\nu_0 = 6.63 \times 10^{-34}$ J/sec.

To find

$w_0 = ?$

Formula

$w_0 = h\nu_0$

Soln:-

$w_0 = h\nu_0$

$= 6.63 \times 10^{-34} \times 5 \times 10^{14}$

$= 33.15 \times 10^{-20}$ J

$= 3.315 \times 10^{-19}$ J

converting to eV.

$w_0 = \frac{33.15 \times 10^{-20}}{1.6 \times 10^{-19}}$

$= \frac{331.5 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= \frac{3315}{16}$

$= 207.1$ eV.

thus work function is 33.15×10^{-20} J.

B.Q

Q If a metal surface require 7×10^{14} Hz of frequency. What will be the work function by an e^-

→ Given

$\nu_0 = 7 \times 10^{14}$ Hz.

$h = 6.63 \times 10^{-34}$.

$w_0 = ?$

Formula

$w_0 = h\nu_0$.

Soln:-

We know

$w_0 = h\nu_0$

$= 6.63 \times 10^{-34} \times 7 \times 10^{14}$

$= 46.41 \times 10^{-34+14}$

$= 46.41 \times 10^{-20}$

$= 4.641 \times 10^{-19}$ J

42
6.63
× 7
4641

Converting Joule to ev.

÷ by 1.6×10^{-19}.

$w_0 = \frac{4.641 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= 2900$ eV.

Q If the work function of a metal is 4×10^{-20} J. Calculate the frequency of the source.

→ Given.

$w_0 = 4 \times 10^{-20}$ J

$h = 6.63 \times 10^{-34}$

$\nu_0 = ?$

Formula

$w_0 = h\nu_0$

Sol^n:-

We know

$w_0 = h\nu_0$

$\nu_0 = \frac{h}{w_0}$

$= \frac{6.63 \times 10^{-34}}{4 \times 10^{-20}}$

$= \frac{6.63}{4} \times 10^{-34+20}$

$= 1.$

$\nu_0 = \frac{w_0}{h}$

$= \frac{4 \times 10^{-20}}{6.63 \times 10^{-34}}$

$= \frac{4}{663} \times 10^{16}$

$= \frac{4000}{663} \times 10^{13}$

Ans Frequency of the source is 1.6574×10^{-14} Hz.

$w_0 = \frac{4000}{663} \times 10^{13}$

$w_0 = \text{Ant}\,[\log 4000 - \log 663] \times 10^{13}$

$= \text{Ant}\left[\frac{3.6021}{2.8215}\right] 10^{13}$

$= 6034 \times 10^{13}$ Hz

Q The work function is 3eV. What will be the frequency

→ Given

$w_0 = 3eV = 3 \times 1.6 \times 10^{-19} = 4.8 \times 10^{-19} J$

$h = 6.63 \times 10^{-34}$.

$\nu_0 = ?$

Formula :-

$w_0 = h\nu_0$

Soln

We know

$w_0 = h\nu_0$.

$\nu_0 = \frac{w_0}{h}$

$\nu_0 = \frac{4.8 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= \frac{48 \times 10^{-20}}{663 \times 10^{-36}}$

$= \frac{48}{663} \times 10^{-20+36}$

$= At\,[\log 48 - \log 663]\, 10^{16}$.

$= At \begin{bmatrix} 1.6812 \\ 2.8215 \\ \bar{2}.8597 \end{bmatrix} 10^{16}$.

$= At\,[\bar{2}.8597]\, 10^{16}$.

$= 7.240 \times 10^{-2} \times 10^{16}$

$= 7.240 \times 10^{14}\ Hz$.

Ans The frequency is $7.240 \times 10^{14}\ Hz$

Q If the threshold wavelength is 7000 Å Calculate its work function.

→ Given.

$\lambda_0 = 7000$

$h = 6.634 \times 10^{-34}$

Formula

$w_0 = h\nu_0$

But

$\nu_0 = \frac{c}{\lambda_0}$

$\therefore w_0 = \frac{hc}{\lambda_0}$

Sol^n:-

$$w_0 = \frac{hc}{\lambda_0}$$

$$= \frac{6.634 \times 10^{-34} \times 3 \times 10^8}{7000}$$

$$= \frac{6634 \times 3 \times 10^{-34+8-3}}{7}$$

$$= \frac{6634 \times 3 \times 10^{-29}}{7 \times 10^{-10}}$$

$$= \frac{19902 \times 10^{-29+10}}{7}$$

$$= 2831 \times 10^{-29+10}$$

$$= 2.831 \times 10^3 \times 10^{-29+10}$$

$$= 2.831 \times 10^{-29+10}$$

$$= 2.831 \times 10^{-19} J$$

$$= 2831 \times 10^{-19} J$$

Q What will be the energy of each photon in monochromatic light of frequency 5×10^{14} Hz.

→ Given

$\nu_0 = 5 \times 10^{14}$ Hz.

$h = 6.634 \times 10^{-34}$

$w_0 = ?$

Soln

$w_0 = h\nu_0$

$= 6.634 \times 10^{-34} \times 5 \times 10^{14}$.

$= 6.634 \times 5 \times 10^{-34+14}$.

$= 3.315 \times 10^{-19}$ J.

$w_0 = \frac{3.315 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= 2.071$ eV.

3.12
6.634
5
33170

Prob 6 The photoelectric work function of a tungsten is 4.5 eV. Calculate threshold wavelength

→ $w_0 = 4.5 eV = 4.5 \times 1.6 \times 10^{-19}$

$= 7.20 \times 10^{-19}$

$\lambda_0 = ?$

Soln:-

$w_0 = h\nu_0$

$\nu_0 = \frac{w_0}{h}$

$= \frac{7.20 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= \frac{720 \times 10^{-21}}{663 \times 10^{-36}}$

$= \frac{720 \times 10^{-21+36}}{663}$

$= At\,[\log 720 - \log 663]\,10^{15}$

$= At \left[\frac{2.8573}{2.8215}\right] 10^{15}$

$= At\,[0.0358]\,10^{15}$

$= 1.086 \times 10^{15}$

To conver in Å

$\nu_0 = 1.086 \times 10^{15} \times 10^{-10}$

$= 1.086 \times 10^{5}$

$w_0 = h\nu_0$

$w_0 = \frac{hc}{\lambda_0}$

$\lambda_0 = \frac{hc}{w_0}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{4.5 \times 1.6 \times 10^{-19}}$

$= \frac{6.63 \times 10^{-34+8} \times 3}{7.20 \times 10^{-19}}$

$= \frac{19.83 \times 10^{-7}}{7.2}$

$= 2.754 \times 10^{-7}$.

To convert in Å

$\lambda_0 = 2.754 \times 10^{-7} \times 10$

$= 2754 \times 10^{-10}$

$= 2754$ Å

P.B.O De Broughi Hypothesis.

$\lambda = \frac{h}{p}$ $\quad p = \frac{h}{\lambda}$ $\quad \lambda = \frac{h}{mv}$

wavelength momentum kg m/s wavelength

Q Estimate the De Broglie wavelength with the association of earth orbiting around the sun with the speed of 3×10^6 m/s.

→ Data:

$v = 3 \times 10^6$ m/s.

$h = 6.63 \times 10^{-34}$

$m_e = 6 \times 10^{24}$ Kg (constant)

Soln:-

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

$$= \frac{6.63 \times 10^{-34}}{6 \times 10^{24} \times 3 \times 10^6}$$

$$= \frac{663 \times 10^{-36}}{18 \times 10^{30}}$$

$$= \frac{663 \times 10^{-66}}{18}$$

$$= 36.89 \times 10^{-66}$$

$$= 3.689 \times 10^{-65} \text{ m}$$

Q Find the momentum of e^- having De Broglie wavelength 0.5 Å

→ Data

$\lambda = 0.5 Å = 0.5 \times 10^{-10}$

$h = 6.63 \times 10^{-34}$.

Sol^n:-

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

$p = \frac{6.63 \times 10^{-34}}{0.5 \times 10^{-10}}$.

$= \frac{663 \times 10^{-36}}{5 \times 10^{-11}}$

$= \frac{663}{5} \times 10^{-36+11}$

$= 132.6 \times 10^{-25}$

$= 1.326 \times 10^{-23}$ Kg m/s.

$\frac{663}{81}$ 132.6

$\frac{36}{-11}$ / 25

Imp Q On the Basis of De Broglie Hypothesis obtain the relation bet^n wavelength of an e^- and potential difference 'V' volt.

→ OR.

SHOW that $\lambda = \frac{1.228}{\sqrt{V}}$.

→ For a particle having mass 'm' moving with velocity v then its K.E is $\frac{1}{2}mv^2$

$$K.E = \frac{1}{2}mv^2$$

$$v^2 = \frac{2KE}{m}$$

$$v = \sqrt{\frac{2K.E}{m}} \quad \text{—(1)}$$

De Broglie wavelenth is given by

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

$$\lambda = \frac{h}{m \times v}$$

$$\lambda = \frac{h}{m \times \sqrt{\frac{2KE}{m}}} \quad \text{From (1)}$$

$$\lambda = \frac{h}{m} \times \frac{\sqrt{m}}{\sqrt{2KE}}$$

x by and ÷ by $\sqrt{m}$.

$$\lambda = \frac{h}{m} \times \frac{\sqrt{m}}{\sqrt{2KE}} \times \frac{\sqrt{m}}{\sqrt{m}}$$

$$\lambda = \frac{h\sqrt{m}}{m\sqrt{2KEm}}$$

$$\lambda = \frac{h}{\sqrt{2K.Em}}$$

The K.E of charged particle is $q \times V$

$K.E. = q \times V$.

$\therefore \lambda = \frac{h}{\sqrt{2 \times q \times V \times m}}$

$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.6 \times 10^{-19} \times V \times 9.1 \times 10^{-7}}}$

$\lambda = \frac{1.228}{\sqrt{V}} \times 10^{-9}\ m$

$\lambda = \frac{1.228}{\sqrt{V}}\ nm.$

Type 3.

P.B.O ~~Calculating~~ will be photo electric effect take place or not.

Q The energy required to remove the e^- from the sodium is 2.3ev. Does sodium shows photoelectric effect for orange light of wavelength 6800 Å.

→ Given :-

$\omega_0 = 2.3 ev. = 2.3 \times 1.6 \times 10^{-19} J.$

$\omega_0 = 3.68 J. \times 10^{-19}$

$\lambda' = 6800 Å$

$\lambda = 68 \times 10^2 \times 10^{-10}$

$= 68 \times 10^{-8} m$

$\begin{array}{r} 23 \\ \times 16 \\ \hline 138 \\ 23\times \\ \hline 368 \end{array}$

27+42 = 21/63

To find :-
Does sodium shows Photoelectric effect

Formula :-
$\omega_0 = h\nu_0$

$\omega_0 = \frac{hc}{\lambda_0}$

$\boxed{\lambda_0 = \frac{hc}{\omega_0}}$

if $\lambda \ll \lambda_0$ ⇒ photoelectric effect take place.

$\not\ll \lambda_0$ ⇒ photoelectric effect does not take place.

Soln :-

$\lambda_0 = \frac{hc}{\omega_0}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3.68\ J.}$

$= \frac{6.63 \times 3}{3.68} \times 10^{-34+8}$

$= \frac{6.63 \times 3}{3.68} \times 10^{-26}$

$= \frac{19.89}{3.68} \times 10^{-26}$

$= \frac{19.89}{3.68 \times 10^{-19}}$

check.

$= \text{Antilog}\left[\log(19.89) - \log 3.68\right] 10^{-26+11}$

$= \text{Antilog}\left[1.2785 - 0.5658\right] 10^{-26+19}$

$= \text{Antilog}\left[0.7127\right] 10^{-26+19}$

21
34
8
26

663
× 3
1989

5.129
+ 6
5.135

26
19
7

$= At[0.7105] 10^{-26+19}$

$= 5.135 \times 10^{-7}$

As $\lambda > \lambda_0$

i.e $68 \times 10^{-8} > 5.135 \times 10^{-7}$ $\quad 68 \times 10^{-8} > 51.35 \times 10^{-8}$

∴ Photoelectric effect will not take place