Photons

* Quantum theory of radiation (by Max. plancks)
- 1901 AD.

According to this theory, radiant energy is quantized and is emitted or absorbed only in discrete (not continuous) values, called quantum.

Thus,

$E = nhf$; $n = 1, 2, 3$

f = frequency of photon.

→ One quantum of energy is called photon. The energy of photon is therefore,

$E = h \cdot f$ — (i)

where,

f = frequency of photon

h = plancks constant $= 6.625 \times 10^{-34}$ joule/sec

Photon moves in air or vacuum with velocity $c = 3 \times 10^{8}$ ms^{-1}

⇒ Velocity of radiator $(c) = f\lambda$ $\begin{pmatrix} \lambda = \text{lamba} \\ f = \text{frequency} \end{pmatrix}$ wavelength

$$\boxed{\therefore f = c/\lambda} \text{ — (2)}$$

with eqn (2), eqn (1) becomes

$$\boxed{E = hf = hc/\lambda} = \text{energy of photon}$$

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* photoelectric effect :-

when a radiation of certain frequency is incident on a material, electrons are emitted (or ejected) from the material surface. these electrons are called photoelectrons and this type of electron emission is called photo electric (or effect)

* Work function (w_0 or ϕ_0)

the minimum amount of energy required to just eject an electron (with negligible kinetic energy) from the surface of a metal is known as the work function of that metal. the work function of alkali metals is small. for example: the work function of sodium is 2.28 ev to 2.36 ev.

* theshhold frequency (v_0 or f_0):-

the minimum frequency of a radiation required to just eject an electron (with negligible kinetic energy) from a metal surface is known as the threshhold frequency of that metal.

thus,

$\phi_0 = hf_0$; $\boxed{f_0 = \phi_0 / h}$

h = Plank's constant $\Rightarrow 6.625 \times 10^{-34}$ Js.

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* Threshhold wavelength (λ_0):

The wavelength of radiation corresponding to threshhold frequency for a metal is known as threshhold wavelength for that metal.

Thus,

$$\phi_0 = hf_0 = \frac{hc}{\lambda_0} \quad \left[\because c = f\lambda \atop = f_0\lambda_0\right]$$

$$\boxed{\therefore \lambda_0 = \frac{hc}{\phi_0}}$$

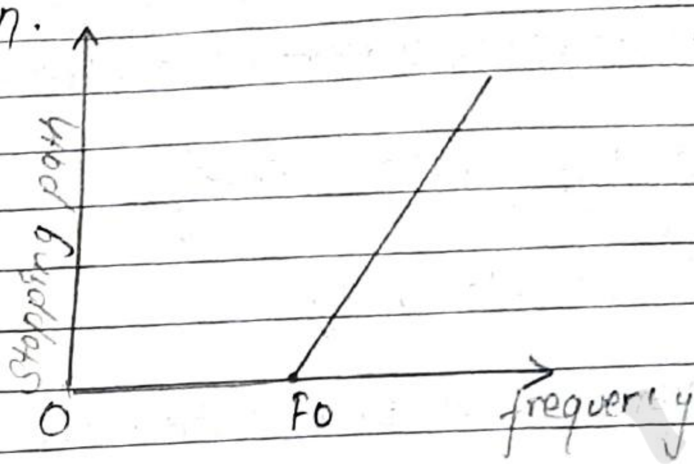
* Laws of photoelectric emission (Lenard Laws):-

(1) The photoelectric effect is an instantaneous process (the time lag between the photon and emission of photon electron is negligible $\simeq 10^{-8}$ sec)

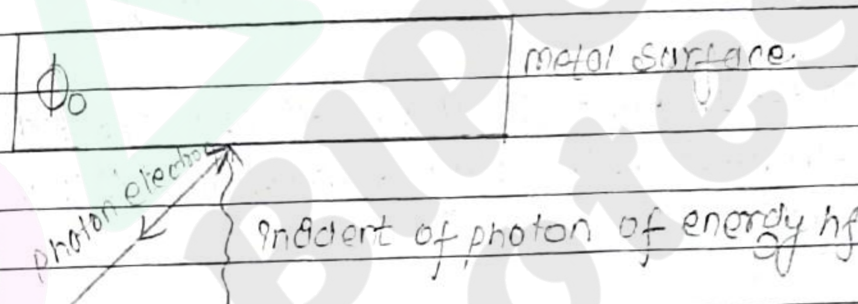
(2) The number of emitted photoelectron (hence photocurrent) depends on intensity of incident radiation and is independent of the frequency of incident radiation.

(3) The max. kinetic energy of emitted photon electron is independent of the intensity of incident radiation and depends on the frequency of incident radiation (photon)

(4) The stopping potential is independently of the intensity of incident radiation and depends on the frequency of incide nt photon.



Imp * Einstein's photoelectric equation:-



Let a photon of frequency 'f' hence energy 'hf' strikes a metal surface having work function $\phi_0 = hf_0$ where f_0 is threshhold frequency from the metal. If $f > f_0$, then the maximum kinetic energy of limited photoelectron will be ~~maximum kinetic energy of limited photoelectron will be~~:

$$KE_{max} = \frac{1}{2} m v^2_{max}.$$

From the law of conservation of energy in this case:

Energy of incident photon = (work function of metal + maximum K.E of photoelectron)

$\therefore hf = \phi_0 + KE_{max}$

$\therefore KE_{max} = (hf - \phi_0) = \frac{1}{2} mv^2_{max}$ — (1)

Eqn (1) is Einstein's ~~prin~~ photo electric equation,

$\therefore$ Energy of photon $= hf = \frac{hc}{\lambda}$

$\phi_0 = hf_0 = hc/\lambda_0$

Therefore, eqn (1) can be written as:

$$\frac{1}{2} mv^2_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \quad (2)$$

- Note: In practice, the electron is ejected out of the metal surface gets +vely charged and the work function increase.

* Explanation of the laws of photoelectric emission on the basis of Einstein's photoelectric equation.

(Einstein received Nobel prize for this in 1922 which was awarded in 1921)

$\frac{1}{2} mv^2_{max} = h(f - f_0)$ — (1)

Case (I) :- when $f > f_0$, then only $\frac{1}{2} mv^2_{max}$ is +ve and photoelectrons will be emitted.

case (II) :- If 'f' increases then $\frac{1}{2} mv^2_{max}$ will increase but the increase in intensity of radiation (i.e number of photon) will not increase $\frac{1}{2} mv^2_{max}$ but increase the

the number of photoelectrons.

Case (III) :- Photoelectric effect is the elastic collision between photon and electron of metal which involves transfer of photon's energy into K.E of photoelectron instantaneously.

* stopping potential (V_s or V_d):-

The negative potential to anode needed to just stop the emission of photoelectron from a metal surface is called stopping potential of that metal. Thus, from the law of conservation of energy in this case;

(work done by stopping potential on photoelectron) = (Max K.E of photoelectron)

Thus, $\boxed{eV_0 = 1/2\ mv_{max}^2}$

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* Millikan's experiment for verification of Einstein's photo electron equation OR
(Determination of plank's constant.

In 1916 R.A Millikan verified Einstein's photoelectric equation experimentally. Fig(13) below shows the experimental arrangement for this experiment.

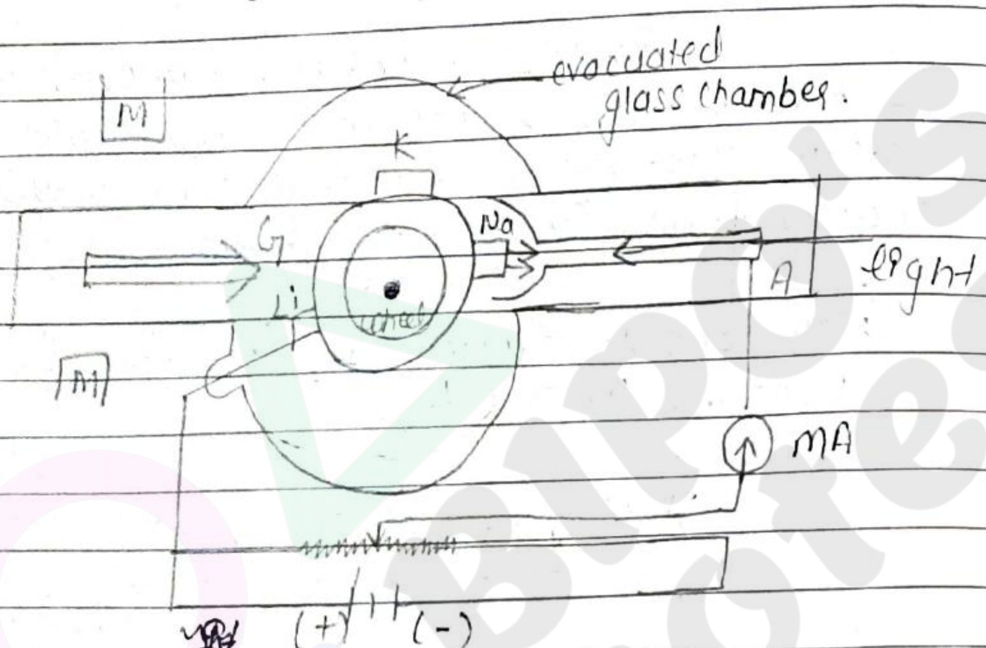


fig:-13

It has a wheel having three cylindrical blocks of alkali metals lithium (Li), sodium (Na) and Pottasium (K). The wheel can be roated with electromagnet. 'G' is a knife. that removes the oxides from metal surfaces. The knife edge 'G' is operated with a Magnet 'M' fitted outside the tube.

When electromatic light is incident on alkali metal, photoelectrons are emitted from metal surface and are collected by anode 'A'. when the negative potential on anode is slowly increased photoelectric current decreases. for a certain negative potential V_0 on anode, the collection of photoelectrons stops and the current in milliammeters becomes zero.

At this stage,

eV_0 = work done against the stopping potential
= KE_{max}.

$$\therefore eV_0 = 1/2\, m v^2_{max} \quad \text{---(1)}$$

from Einstein's photoelectric equation.

$$1/2\, m v_{max}^2 = (hf - hf_0) \quad \text{---(2)}$$

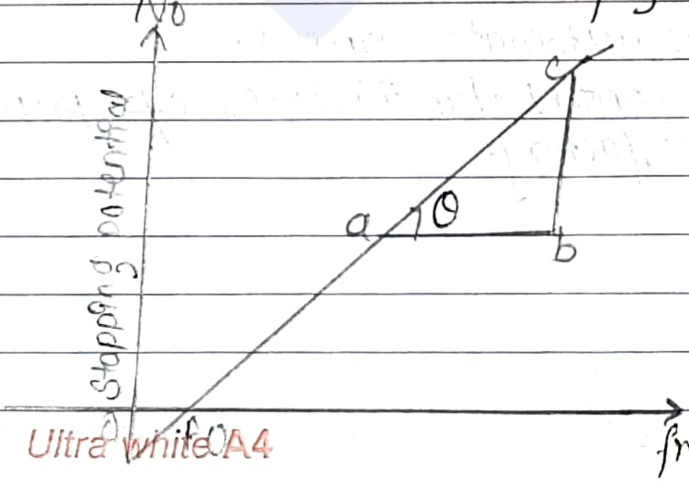
from (1) and (2), we get.

$$eV_0 = (hf - hf_0)$$

$$\therefore V_0 = \left(\frac{h}{e}\cdot f - \frac{hf_0}{e}\right) \quad \text{---(3)}$$

Eqn (3) represents the eqn of straight line $y = mx + c$, with slope $\frac{h}{e}$ and -ve intercept on y-axis $\left(-\frac{h}{e} f_0\right)$

Millikan plotted experimental graph between V_0 and f for Li, Na, and K metals and the graphs were of similar nature as shown in fig (14)



The graph obtained is in good arrangement of Einstein's photoelectric equation.

Also from the graph

$$\text{Slope} = \tan\theta = \frac{h}{e}$$

$$\therefore \frac{bc}{ab} = \frac{h}{e}$$

$$\therefore h = e \cdot \left(\frac{bc}{ab}\right) \quad -(4)$$

The value of planck's constant (h) was calculated and found to be $\boxed{h \approx 6.62 \times 10^{-34}}$ J.s.

* Some important applications of photoelectric effect

i) It is used in reproduction of sound in cinema film and in T.V transmission (प्रसारण)

ii) It is used in astronomy to find the intensity of light coming from stars and to find temprature of star.

iii) It is used to control the temperature of furnance

iv) It is used in photocell (solar cell) automatic fire, alarm, automatic theif alarm (i-e burglar's alarm, automatic street light, etc)

v) It is used in automatic camera.

vi) It is used to control the thickness of paper and other materials in a factory.

* Photocell:-

It is a device to convert light ~~ener~~ energy into electrical energy. It works on the principal of photoelectric effect. It is of three types as follows:-

(i) Photo - emissive cell.
(ii) Photo - Voltaic cell.
(iii) Photo - Conductive cell.

A photocell has many applications such as:- In automatic switch of street lamps, in automatic fire alarm, in burglar's alarm etc.

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Numerical:-

(1) A photon of green light has wavelength, 520 mm. find photo frequency, momentum and energy.

⇒ Soln:
Given,
Plancks constant (h) = 6.625×10^{-34}
wavelength (λ) = 520 mm
$= 520 \times 10^{-9}$ m.

Now,
(i) For photon frequency (f) = ?
we know,
$c = f \cdot \lambda$
$\therefore f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{520 \times 10^{-9}} = \cancel{5.76 \times 10^{-8}} \times 10^{+9}$
$= 5.76 \times 10^{-17} \times 10^{-3}$
$= (5.76 \times 10^{14})$ Hz

(ii) For momentum (m) = ?
We know,
$E = mc^2$
and $E = hf$
or, $mc^2 = hf$
$\therefore mc = \frac{hf}{c} = \frac{6.625 \times 10^{-34} \times 5.76 \times 10^{14}}{3 \times 10^{8}}$
$= \frac{38.16 \times 10^{-20}}{3 \times 10^{8}}$
$= 12.72 \times 10^{-28}$
$= (1.27 \times 10^{-27})$ N·sec

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(3) Energy of photon $(E) = hf$

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{520 \times 10^{-9}}$$

$$= \frac{19.875 \times 10^{-26}}{520 \times 10^{-9}}$$

$$= 3.82 \times 10^{-2-26+9}$$

$$\Rightarrow (3.82 \times 10^{-19})\ ev\ \#.$$

(2) An excited nucleus emits γ-ray photon of energy 2.45 Mev.

(i) What is photon frequency?

(ii) What is photon wavelength?

$\left[\begin{array}{l} Mev \rightarrow ev = 10^{6} \\ ev \rightarrow Joule \Rightarrow 1.6 \times 10^{-19} \end{array}\right]$

$\Rightarrow$ Soln;

Here,

Energy $(E) = 2.45$ Mev.

$= 2.45 \times 10^{6} \times (1.6 \times 10^{-19})$ J.

$= 3.92 \times 10^{-13}$ J.

We know,

(i) $E = hf$

$$\therefore f = \frac{E}{h} = \frac{3.92 \times 10^{-13}}{6.625 \times 10^{-34}}$$

$$= 5.91 \times 10^{-1} \times 10^{-13+34}$$

$$= (5.91 \times 10^{20})\ Hz\ \#$$

(ii) Wavelength $(\lambda) = ?$

We know,

$$f = \frac{c}{\lambda} = 3 \times 10^{8}$$

(3) The predominent wavelength emitted by an ultravoilet lamp is 2·48 nm. If the total emitted power is 12 watts, find the number of photons emitted per second.

Soln;

Given,

$$\text{wavelength } (\lambda) = 2\cdot48\ nm$$
$$= 2\cdot48 \times 10^{-9}\ m.$$

$$\text{power } (P) = 12\ \text{watts}.$$

$$\text{no. of photons emitted per second } \left(\frac{N}{t}\right) = ?$$

Now,

$$\text{Power } (P) = \frac{\text{total energy emitted}}{\text{time taken}}$$

$$\text{or}\quad P = \frac{N\cdot(hf)}{t}$$

$$\text{or}\quad \cancel{P} = \cancel{\frac{N}{t}\cdot h\left(\frac{c}{\lambda}\right)} \qquad [c = f\lambda]$$

$$\text{or}\quad \frac{N}{t} = \frac{P}{hf}$$

$$\text{or}\quad \frac{N}{t} = \frac{P}{h\times c/\lambda}$$

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

$$= \frac{12\times 2\cdot48\times10^{-9}}{6\cdot625\times10^{-34}\times 3\times10^{8}}$$

$$= \frac{29\cdot76\times10^{-9}}{19\cdot875\times10^{-34+8}}$$

$$= \frac{29\cdot76\times10^{-9}}{19\cdot875\times10^{-26}}$$

$$\Rightarrow 1\cdot497\times10^{-9+26}$$

$$\Rightarrow (1\cdot497\times10^{17})\ \text{Photons/sec}$$

(4) A clean nickel surface is exposed to light of wavelength 235 nm. What is max speed of emitted photoelectron?
[workfunction of N is 5.1eV]

$\Rightarrow$ Soln:
Given,
wavelength $(\lambda) = 235\,nm$
$= 235\times10^{-9}\,m.$

$\phi = 5.1\,eV$
$= 5.1\times1.6\times10^{-19}\,J.$
$= 8.16\times10^{-19}\,J.$

According to Einstein's photoelectron eqn;

$$\frac{1}{2}mv_{max}^2 = hf - \phi_0.$$

$$f = c/\lambda = \frac{3\times10^8}{235\times10^{-9}} = 1.27\times10^{-2+8+9} = (1.27\times10^{15})\,Hz$$

$$\therefore V_{max} = \sqrt{\frac{2(hf-\phi_0)}{m(\text{mass of electron})}}$$

$$= \sqrt{\frac{2(6.625\times10^{-34}\times1.27\times10^{15} - 8.16\times10^{-19})}{9.1\times10^{-31}}}$$

$$= \sqrt{\frac{2(8.41\times10^{-19} - 8.16\times10^{-19})}{9.1\times10^{-31}}}$$

$$= \sqrt{\frac{2(10^{-19}(8.41-8.16))}{9.1\times10^{-31}}}$$

$$= \sqrt{\frac{2(10^{-19}\times0.25)}{9.1\times10^{-31}}}$$

$$= \sqrt{\frac{2\times2.5\times10^{-20}}{9.1\times10^{-31}}}$$

$$= \sqrt{\frac{5\times10^{-20}}{9.1\times10^{-31}}}$$

$$= \sqrt{5.49\times10^{-1-20+31}}$$

$$= \sqrt{5.49\times10^{10}}$$

$$= (2.3\times10^{5})\,ms^{-1}$$

(5) Photoelectric work function of potassium is 2ev. What P.D must be applied between collecting electrode and potassium surface to just stop the collection of electron in λ = 350 nm?
(ii) Also find Vmax and KE max.

Soln:
Given,

$\lambda = 350\times10^{-9}$.

$\phi_0 = 2ev \Rightarrow 2\times1.6\times10^{-19}$ J

(i) $V_0 = ?$ (stopping potential)
(ii) $V_{max} = ?$
(iii) $K.E_{max} = ?$

Now

(i) $eV_0 = KE_{max}$.

$$\Rightarrow \boxed{eV_0 = \frac{1}{2}mv_{max}^2 = hf - \phi_0}$$

$$\Rightarrow eV_0 = \frac{hc}{\lambda} - \phi_0$$

$$\Rightarrow V_0 = \frac{\left(\frac{hc}{\lambda} - \phi_0\right)}{e} = \frac{\left(\frac{6.625\times10^{-34}\times3\times10^{8}}{350\times10^{-9}} - 2\times1.6\times10^{-19}\right)}{1.6\times10^{-19}}$$

$$\Rightarrow \frac{\left(\frac{19.875\times10^{-26}}{350\times10^{-9}} - 2\times1.6\times10^{-19}\right)}{1.6\times10^{-19}}$$

$$\Rightarrow \frac{\left(5.67\times10^{-2}\times10^{-17} - 3.2\times10^{-19}\right)}{1.6\times10^{-19}}$$

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$$= \frac{(5.67\times10^{-19} - 3.2\times10^{-19})}{1.6\times10^{-19}}$$

$$= \frac{10^{-19}(5.67-3.2)}{1.6\times10^{-19}}$$

$$\Rightarrow \frac{10^{-19}\times 2.47}{1.6\times10^{-19}}$$

$$\Rightarrow \frac{\cancel{2.47\times10^{-19}}}{1.6\times10^{-19}}$$

$\Rightarrow$ 1.5 volt Ans.

(6) When light of frequency 5.4×10^{14} Hz is shone on a metal surface the max. K.E of emitted photoelectron is 1.2×10^{-19} J when same surface was illuminated with light of frequency 6.64×10^{14} Hz, the max. K.E. of emitted photoelectron was 2×10^{-19} J. find the value of plank's constant.

$\Rightarrow$ soln;

here,

In case (I), frequency $(f_1) = 5.4\times10^{14}$ Hz.

$(K.E\,max)_1 = 1.2\times10^{-19}$ J.

work function $= \phi$ is same.

$\therefore (K.E\,max)_1 = hf_1 - \phi_0$ — (1)

In case (II)

frequency $(f_2) = 6.6\times10^{14}$

$(K.E\,max)_2 = 2\times10^{-19}$ J.

work function $= \phi$.

$\therefore (K.E\,max)_2 = hf_2 - \phi_0$ — (ii)

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Eqn (I) − (II) gives,

$$(KE\,max)_1 = hf_1 - \cancel{\phi_0}$$
$$-\quad (K.E\,max)_2 = hf_2 - \cancel{\phi_0}$$
$$\quad - \quad (+)$$

or, $(K.E\,max)_1 - (KE\,max)_2 = h(f_1 - f_2)$

or, $h = \dfrac{(KE\,max)_1 - (KE\,max)_2}{(f_1 - f_2)}$

$$= \frac{1.2\times10^{-19} - 2\times10^{-19}}{5.4\times10^{14} - 6.6\times10^{14}}$$

$$= \frac{(1.2-2)\times10^{-19}}{(5.4-6.6)\times10^{14}}$$

$$= \frac{\cancel{-}\,0.8\times10^{-19}}{\cancel{-}\,1.2\times10^{14}}$$

$$= 6.67\times10^{-1-19-14}$$

$$= \boxed{6.67\times10^{-34}}\ \text{Joule. sec}$$

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(7) The maximum kinetic energy of photoelectron from a metal surface is 1.2×10^{-19} J. when photon of frequency 7.5×10^{14} Hz is incident on metal surface. Find minimum frequency for which photoelectron will be emitted from same surface.
($h = 6.6\times10^{-34}$ J.s)

⇒ Given,

$KE_{max} = 1.2\times10^{-19}$ J.

Frequency $(F) = 7.5\times10^{14}$ Hz.

$h = 6.6\times10^{-34}$ Js.

Minimum frequency i.e (F_0) = Threshold = ?

we know,

$$KE_{max} = hf - \phi_0$$

$$\text{or, } KE_{max} = hf - hf_0$$

$$\text{or, } hf_0 = hf - KE_{max}$$

$$\text{or, } f_0 = \frac{hf - K.E_{max}}{h}$$

$$= \frac{6.6\times10^{-34}\times7.5\times10^{14} - 1.2\times10^{-19}}{6.6\times10^{-34}}$$

$$= \frac{49.5\times10^{-20} - 1.2\times10^{-19}}{6.6\times10^{-34}}$$

$$= \frac{49.5\times10^{-1}\times10^{-19} - 1.2\times10^{-19}}{6.6\times10^{-34}}$$

$$= \frac{4.95\times10^{-19} - 1.2\times10^{-19}}{6.6\times10^{-34}}$$

$$= \frac{(4.95 - 1.2)\times10^{-19}}{6.6\times10^{-34}}$$

$$= \frac{3.75\times10^{-19}}{6.6\times10^{-34}}$$

$$= 5.6\times10^{-1-19+34}$$

$$= 5.6\times10^{14} \text{ Hz}$$

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(8) photon of frequency 5×10^{14} Hz ejects photoelectron of energy 2.31×10^{-19} J from a metal surface. What should be the wavelength of light to eject photoelectron of energy 8.93×10^{-19} J from same surface?

⇒ soln;
here

$h = 6.625\times10^{-34}$ J·s

for case (I)

$KE_1 = hf_1 - \phi_0$ — (1)

where,

Frequency $(f_1) = 5\times10^{14}$ Hz.

$KE_1 = 2.31\times10^{-19}$ J.

for case (II)

$KE_2 = 8.93\times10^{-19}$ J.

wavelength $(\lambda_2) = ?$, also, frequency $(f_2) = ?$

Eqn (I) − (II) gives,

$KE_1 = hf_1 - \cancel{\phi_0}$

$KE_2 = hf_2 - \cancel{\phi_0}$

(−) (+)

$KE_1 - KE_2 = h(f_1 - f_2)$

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or, $(f_1-f_2)=\frac{(KE_1-KE_2)}{h}$

or, $f_2=f_1-\frac{(KE_1-KE_2)}{h}$

$=5\times10^{14}-\frac{(2.31\times10^{-19}-8.93\times10^{-19})}{6.625\times10^{-34}}$

$=5\times10^{4}-\frac{[10^{-19}(2.31-8.93)]}{6.625\times10^{-34}}$

$=5\times10^{14}-\frac{(-6.62\times10^{-19})}{6.625\times10^{-34}}$

$=5\times10^{14}+1.9\times10^{-1-19+34}$

$=5\times10^{14}+9.9\times10^{14}$

$=10^{14}(5+9.9)$

$=(14.9\times10^{14})\ Hz.$

Now,

$f_2=c_2/\lambda_2$

$\therefore \lambda_2=\frac{c_2}{f_2}=\frac{3\times10^8}{14.9\times10^{14}}$

$=2\times10^{-1+8-14}$

$=2\times10^{-7}$ meter Ans.

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(9) For cesium $\phi_0 = 1.35$ ev. find.

(i) λ_{max} for electron emission.
(ii) V_{max} if $\lambda = 4\times10^{-7}$ m.
(iii) V_0 to just prevent the emission of photoelectron.
mass of electron $(m) = 9\times10^{-31}$ kg.
planck's constant $(h) = 6.625\times10^{-34}$ J.s.

⇒ Given,
we know,

$$\therefore eV_0 = 1/2\, m v_{max}^2 = (hf - \phi_0) \quad \text{---(i)}$$

Also,

$$\phi_0 = hf_0 = h\left(\frac{c}{\lambda_{max}}\right) \quad \left[\begin{array}{l} \because c = f\lambda = f_{min}\cdot\lambda_{max} \\ \Rightarrow c = f_0\cdot\lambda_{max}\end{array}\right]$$

(i) ⇒

$$\therefore \lambda_{max} = \frac{hc}{\phi_0}$$

$$= \frac{6.625\times10^{-34}\times3\times10^{8}}{1.35\times1.6\times10^{-19}}$$

$$= \frac{(19.875\times10^{-26})}{2.16\times10^{-19}}$$

$$= (9.2\times10^{-7}) \text{ meter}$$

(ii) ⇒

$$\frac{1}{2} mV_{max}^2 = hf - \phi_0$$

$$\therefore V_{max} = \sqrt{\frac{2(hf - \phi_0)}{m}}$$

$$= \sqrt{\frac{h\left(\frac{hc}{\lambda} - \phi_0\right)}{m}}$$

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$$= \sqrt{\frac{2\left(\frac{6.625\times10^{-34}\times3\times10^{8}}{4\times10^{-7}} - 1.35\times1.6\times10^{-19}\right)}{9\times10^{-31}}}$$

$$= \sqrt{\frac{2\left(\frac{19.875\times10^{-26}}{4\times10^{-7}} - 2.16\times10^{-19}\right)}{9\times10^{-31}}}$$

$$= \sqrt{\frac{2\left(4.96\times10^{-19} - 2.16\times10^{-19}\right)}{9\times10^{-31}}}$$

$$= \sqrt{\frac{5.6\times10^{-19}}{9\times10^{-31}}} = \sqrt{6.2\times10^{-1}\times10^{-19+31}}$$

$$= \sqrt{6.2\times10^{12}}$$

$$= (7.8\times10^{5})\,ms^{-1} \text{ \#}$$

(iii) $\Rightarrow eV_0 = hf - \phi_0$

or, $V_0 = \frac{hf - \phi_0}{e}$

$$= \frac{\left(\frac{hc}{\lambda} - \phi_0\right)}{e}$$

$$= \frac{\left(\frac{6.625\times10^{-34}\times3\times10^{8}}{4\times10^{-7}} - 1.35\times1.6\times10^{-19}\right)}{1.6\times10^{-19}}$$

$$= \frac{4.96\times10^{-19} - 2.16\times10^{-19}}{1.6\times10^{-19}}$$

$$= \frac{(4.96-2.16)\times\cancel{10^{-19}}}{1.6\times\cancel{10^{-19}}} = 2.8/1.6$$

$$= 1.75 \text{ volt \#}$$

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(10) Photoelectric threshhold wavelength of tungsten surface is 272 nm. calculate KE max of photoelectron by ultraviolent radiation of frequency 1.43×10^{15} Hz. Express answer in mev.

⇒ Given,

Threshhold wavelength (λ_0) = 272 nm

$= 272 \times 10^{-9}$ m.

Frequency (F) = 1.45×10^{15} Hz.

K.E max = ?

we know,

$KE\,max = hf - \phi_0$

$= hf - hf_0$

$= h(f - c/\lambda_0)$

$= 6.625 \times 10^{-34} \left(1.45 \times 10^{15} - \frac{3 \times 10^{8}}{272 \times 10^{-9}}\right)$

$= 6.625 \times 10^{-34} \left(1.45 \times 10^{15} - 1.1 \times 10^{-2\cancel{8}+8+9}\right)$

$= 6.625 \times 10^{-34} \left[10^{15}(1.45 - 1.1)\right]$

$= 6.625 \times 10^{-34} \times 0.35 \times 10^{15}$

$= 2.3 \times 10^{-19}$ Joules.

When expressed in ev,

$= \frac{2.3 \times 10^{\cancel{-19}}}{1.6 \times 10^{\cancel{-19}}}$ ev

$= \boxed{1.4\ ev}$ #

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(11) A 75 watt light source consumes 75 W power. Assume all this goes into light of wavelength 600 nm, find.

(i) frequency of emitted light.

(ii) the number of photons emitted per second.

⇒ Given,

Power (P) = 75 watt.

Wavelength (λ) = 600 nm.

$= 600 \times 10^{-9}$ m.

Now,

(i) Frequency (f) $= c/\lambda = \frac{3 \times 10^8}{600 \times 10^{-9}}$

$= 5 \times 10^{-3+8+9}$

$= \boxed{5 \times 10^{14}}$ Hz #

(ii) We know,

$$\text{Power } (P) = \frac{\text{energy (work done)}}{\text{time}}$$

$$\text{or, } P = \frac{N(hf)}{t}$$

$$\text{or, } \frac{P}{hf} = \frac{N}{t}$$

$$\text{or, } \frac{N}{t} = \frac{75}{6.625 \times 10^{-34} \times 5 \times 10^{14}}$$

$$= \frac{75}{33.125 \times 10^{-20}}$$

$$= (2.26 \times 10^{20}) \text{ Photons/sec } \#$$

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(iii) When ultraviolent light with wavelength 254nm falls upon a clean copper surface ; the stopping potential is 0.185 volt. What is the photoelectric threshhold wave length and workfunction?

⇒ Given,

Wavelength $(\lambda) = 254\ nm$
$= 254 \times 10^{-9}\ m.$

Stopping potential $(V_0) = 0.181$ volt.
Threshhold (min. frequency) $f_0 = ?$
workfunction $(\phi_0) = ?$

We know,

$$eV_0 = 1/2\, m v_{max}^2 = hf - \phi_0$$

(i)

$$\therefore \phi_0 = hf - eV_0$$
$$= \frac{hc}{\lambda} - eV_0$$
$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{254 \times 10^{-9}} - 1.6 \times 10^{-19} \times 0.81$$
$$= 7.82 \times 10^{-2-34+8+9} - 0.28 \times 10^{-19}$$
$$= 7.82 \times 10^{-19} - 0.28 \times 10^{-19}.$$
$$= (7.82 - 0.28) \times 10^{-19}$$
$$= (7.54 \times 10^{-19})\ \text{joules.}$$

In ev; $\frac{7.54 \times \cancel{10^{-19}}}{1.6 \times \cancel{10^{-19}}}$ ev

$\Rightarrow \boxed{4.71}$ ev //

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(ii) Also,

$$\phi_0 = hf_0 = \frac{hc}{\lambda_0}$$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{\lambda_0}$$

or $\lambda_0 = \frac{19.88 \times 10^{-26}}{7.54 \times 10^{-19}}$

$\Rightarrow 2.64 \times 10^{-7}$

$\Rightarrow 264 \times 10^{-2} \times 10^{-7}$

$\Rightarrow 264 \times 10^{-9}$ m

i.e $\Rightarrow \boxed{264 \text{ nm}}$ #

(13) A photon has momentum of magnitude 8.24×10^{-28} kgms-1.

(a) What is the energy of this photon in (ev & Joule)
(b) Wavelength of this photon.

$\Rightarrow$ Given,
Momentum of photon $(p) = 8.24 \times 10^{-28}$ kgms-1

Now,

(a) Energy of photon $(E) = mc^2$
$= mc \cdot c$ / where $p = mc$ = linear momentum

$= \cancel{8.24 \times 10^{-28} \times 3 \times 10^8}$

$= 8.24 \times 10^{-28} \times 3 \times 10^8$

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$= 24.72 \times 10^{-20}$

$= 24.72 \times 10^{-1} \times 10^{-19}$

$= 2.47 \times 10^{-19}$ Joule.

i.e $= \frac{2.47 \times 10^{-19}}{1.6 \times 10^{-19}}$ ev

$= \boxed{1.55}$ ev #.

(b) Wavelength of this photon (λ) = ?

we know,

$E = hf$

or, $E = \frac{h \times c}{\lambda}$

or, $\lambda = \frac{hc}{E} = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{2.47 \times 10^{-19}}$

$= \frac{19.87 \times 10^{-26}}{2.47 \times 10^{-19}}$

$\Rightarrow 8.04 \times 10^{-7}$

$= 804 \times 10^{-2} \times 10^{-7}$

$\Rightarrow 804 \times 10^{-9}$ m

i.e $\Rightarrow \boxed{804 \text{ nm}}$ #