Case II → 7 degrees of freedom

$C_v = \frac{7}{2}RT$ $\qquad C_v = \frac{dU}{dT} = \frac{d}{dT}\left(\frac{7}{2}RT\right) = \frac{7}{2}R$

$C_p = C_v + R = \frac{7}{2}R + \frac{R}{1} = \frac{7R + 2R}{2} = \frac{9}{2}R$

$\gamma = \frac{C_p}{C_v} = \frac{\frac{9}{2}R}{\frac{7}{2}R} = \frac{9}{7} = 1.29$ $\qquad \gamma = \frac{\frac{9}{2}}{\frac{7}{2}} = \frac{9}{7}$

(3) Triatomic → 6 degrees of freedom

$C_v = 6 \cdot \frac{1}{2}RT$

$= \frac{\cancel{6}^{3}}{\cancel{2}}RT$

$= 3RT$

$C_v = \frac{dU}{dT} = 3R$ $\qquad \gamma = \frac{C_p}{C_v}$

$\therefore C_p = C_v + R$ $\qquad = \frac{(3+1)}{3}$

$= 3R + R = 4R$ $\qquad = 4/3$

$\therefore \gamma = \frac{4R}{3R} = \frac{4}{3} = 1.33$

05/09/18

Modern Physics — Atomic and molecular physics

Particle properties of waves

Photon – If λ is the wavelength of the light then frequency $\nu = \frac{c}{\lambda}$ ——— (i)

Quantum of energy of this radiation, $E = h\nu$

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

Acc. to Einstein energy equation, $E = mc^2$.

$\therefore m = \frac{E}{c^2}$

Mass of photon $\Rightarrow m = \frac{h\nu}{c^2}$

Momentum of the photon $= mv$

$= \frac{h\nu}{c^2} \times c = \frac{h\nu}{c} = \frac{h}{\lambda}$

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

A photon has zero rest mass. It has zero charge and spin = 1 quantum unit $= \hbar$

Photons interacts with all the charge particles and also with some neutral particles.

Photon linear momentum in terms of wave vector.

A wave number, $k = \frac{2\pi}{\lambda}$

$p = \frac{h \times 2\pi}{2\pi \times \lambda} = \hbar k$

$\boxed{p = \hbar k}$

Photon energy in terms of angular velocity.

$E = h\nu$

$= h\nu \times \frac{2\pi}{2\pi} \quad [\omega = 2\pi\nu]$

$= \frac{h}{2\pi} \times 2\pi\nu = \hbar\omega$

$\boxed{E = \hbar\omega}$

Q.1 A certain spectral line has a wavelength 4000 Å. Calculate the energy of the photon.

Sol

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

$$= \frac{6.63\times10^{-34} \times 3\times10^{8}}{4000\times10^{-10}}$$

$$= \frac{19.89\times10^{-26}}{4000\times10^{-10}} = \frac{19.89\times10^{-26}}{4\times10^{-7}} = \frac{19.89\times10^{-19}}{4}$$

$$= \frac{4.9725\times10^{-19}\,J}{1.6\times10^{-19}}$$

$$= 3.1\ eV.$$

Q.2 Calculate the frequency and wavelength of a photon whose energy is 75 eV.

Sol

$$E = h\nu$$

$$75\times1.6\times10^{-19} = 6.63\times10^{-34}\times\nu$$

$$\Rightarrow \nu = \frac{75\times1.6\times10^{-19}\ J}{6.63\times10^{-34}\ Js}$$

$$= 1.809\times10^{+16}\ Hz.$$

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

$$\Rightarrow \lambda = \frac{hc}{E} = \frac{19.89\times10^{-26}}{75\times1.6\times10^{-19}} = 1.6575\times10^{-8}\ m$$

$$= 165.75\times10^{-10}\ m$$

$$= 165.75\ Å$$

Q.3 How many photons of red light of wavelength 7800 Å constitute 2 Joules of energy.

Sol

$$E = \frac{hc}{\lambda} = \frac{19.89\times10^{-26}}{7800\times10^{-10}} = \frac{19.89\times10^{-26}}{78\times10^{-8}}$$

$= 0.255 \times 10^{-18}$ J.

$= 2.55 \times 10^{-19}$ J.

$= 7.85 \times 10^{18}$

No. of photons $= \frac{2.55 \times 10^{-19} J}{2 J} = 1.275 \times 10^{-19}$

$= 0.1275 \times 10^{-18}$

$= 0.1275 \times 10^{-18}$.

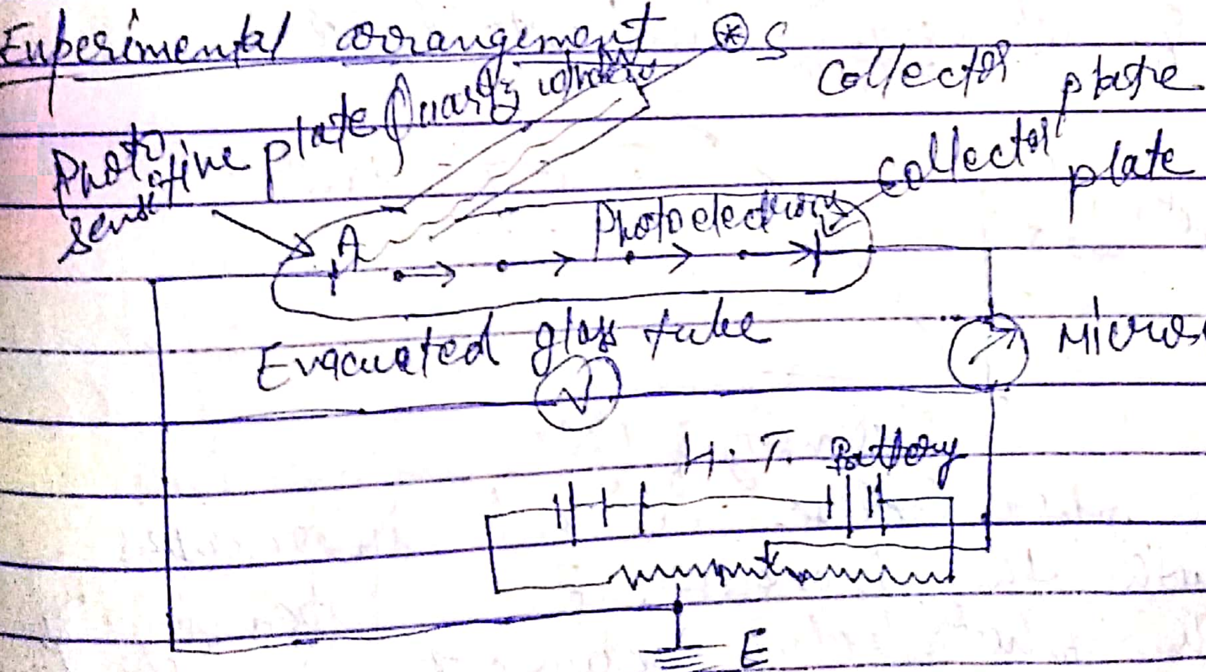
06/09/19

Photoelectric effect

It is the phenomena of ejection of electrons from a metal plate when a light of suitable wavelength. The electrons which are ejected are known as photo ~~electric~~ effect electrons.

Ex- Alkali metals like, Na, K, Cs are sensitive even to ~~raise~~ rays from the visible part of spectrum whereas Zn, Cd, etc. are sensitive only to ultra violet light.

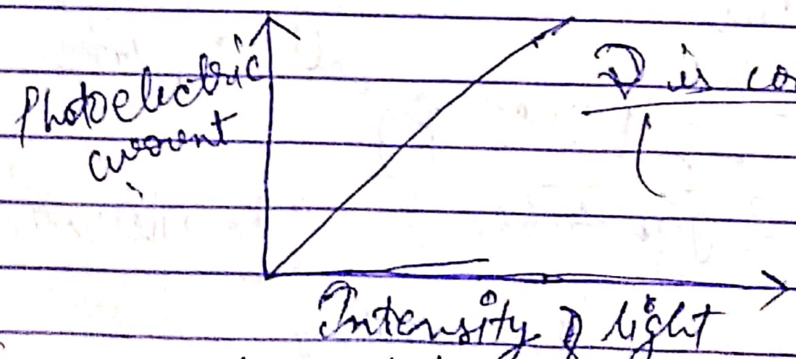
Experimental arrangement



It consists of evacuated glass tube and a quartz window W for allowing the ultraviolet light to fall on the plate source C. Another plate known as the collector plate is shield at the other end. The collector plate can be given +ve or a -ve potential by the potential dividing arrangement as shown in figure. Voltmeter V is connected across the plates to measure the potential diff whereas a microammeter measures the current flowing in the circuit. when a light of suitable frequency is made to fall on the photo sensitive plate from a source S through the window W where the collector is kept at a +ve potential and the collector plate is kept at +ve potential. The electric current flows in the outer circuit which is produced due to the ejection of photoelectrons.

07/08/19

(1) Effect of intensity of incident light

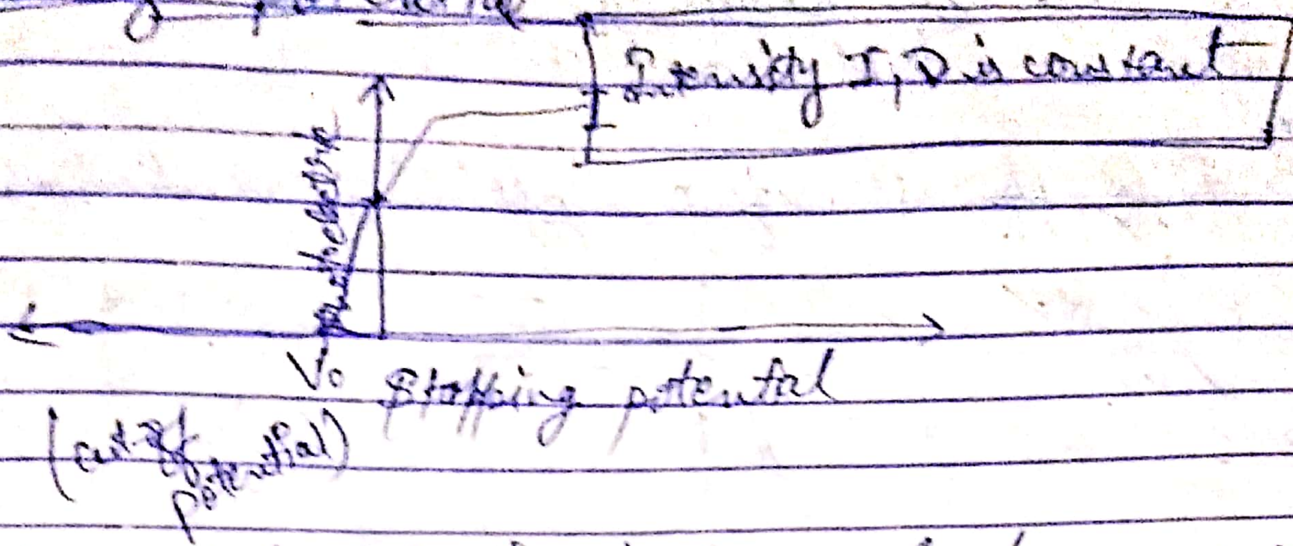


ν is constant.

when The photoelectric current increases linearly with the increase in intensity of light. The photoelectric current increases because the no. of photoelectrons ejected increases due to the increase in intensity of light.

Anode (+)

(ii) Effect of potential



When the potential is increased from zero the photoelectric current increases and when the potential is further increase, the photo electric current saturates. This happens because as the potential is increased the collector plate, tends to pull more and more photoelectrons towards it and therefore the current increases

A situation comes when all the photoelectrons are absorbed by the collector plate after which there is no further increase in the value of current and the current saturates.

When the polarity is interchanged and increased in the -ve direction. The photoelectric starts decreasing and at a certain value of retarding potential, the photoelectric current becomes zero such potential is known as cut-off potential (Vo)

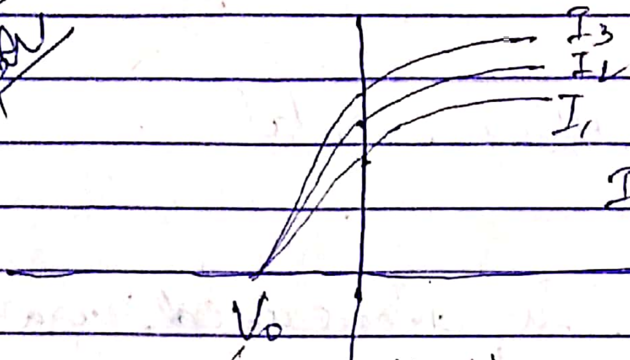
$Q = ne$

Quantisation of charge. Available in fixed amount

In this, the frequency and the intensity of light is kept constant.

③ Effect of intensity on stopping potential (V_0)

N.V.I. Graph



ν is constant

$I_3 > I_2 > I_1$

V_0 is same for all intensities

(cut-off potential)

Threshold frequency - minimum frequency $\nu \geq \nu_0$
Threshold wavelength - maximum wavelength $\lambda \leq \lambda_0$

Photoelectric effect

09/09/19 It was discovered by Heinrich Rudolf Hertz in 1887. It establishes relation between the particle behaviour of electromagnetic radiation. When electromagnetic radiation of high frequency is incident on a metal surface, electrons are emitted from the surface. This process is called photoelectric effect.

Emitted electrons are called photo electrons.

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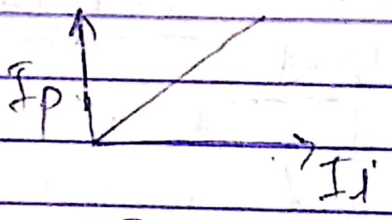
(iii) photo-electric emission is instantaneous means there is no time to eject an electron from metal surface.
(iv) Stopping potential is proportional to frequency of incident light.

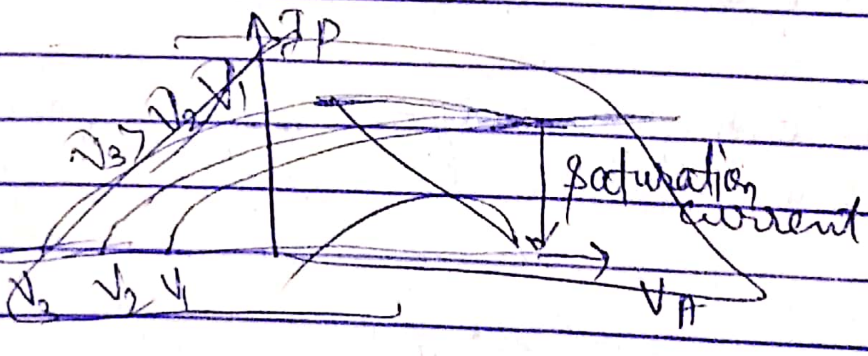
Saturation current depends on intensity of light (I)

Laws of photo-electric emission:-
(i) for a given ν above the ν_0, photo current $(I_p) \propto$ Intensity of radiation.
(ii) Saturation current $\propto$ Intensity.
Stopping potential depends on frequency.
(iii) Below threshold frequency photo electric effect not takes place.
(iv) photo-electric

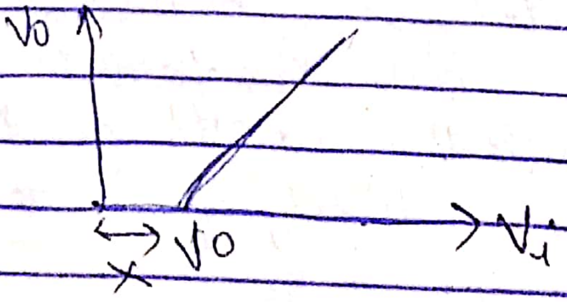
(i)



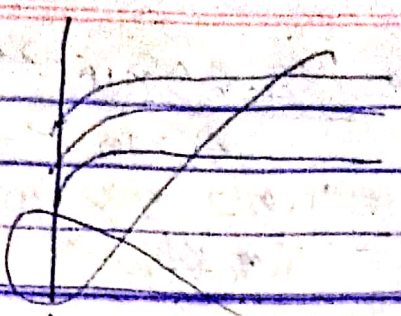
(ii)



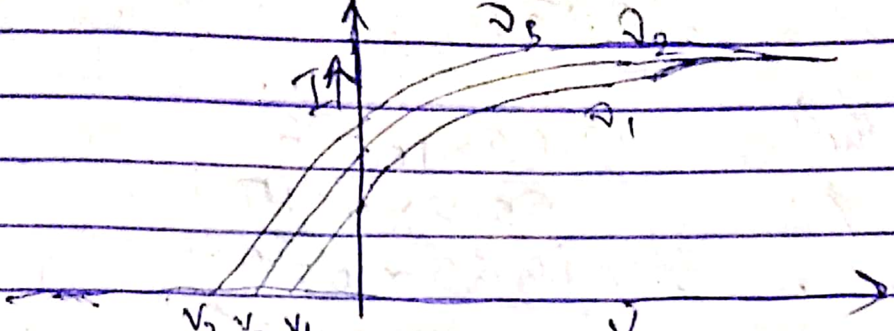
(iii)



~~(ii)~~



(II)



~~Stopping potential- It is the potential to s~~
Retarding potential- It is also called -ve potential.

③ Let frequency ν_1. Apply +ve potential ~~on~~ till the current just gains the saturation value. Now decrease (retarding potential) the potential and make it more negative till current becomes zero, we get V_1. Consider source of frequency ν_2. Positive potential applied to collector plate till current gains saturation current. Again decrease the potential, we get stopping potential V_2. Repeat the same for ν_3. This shows that stopping potential depends on frequency of light. $\boxed{\nu_3 > \nu_2 > \nu_1}$.

Work function- Minimum energy required to ~~excite~~ free an electron from a substance, in the photoelectric effect.

$n\gamma e = \frac{P_{eq}}{} \frac{6.63\times10^{-34}\times3\times10^{8}}{19.89\times10^{-26}}$

11/09/19

Q.1) Ans $E = \frac{hc}{\lambda} = \frac{19.89\times10^{-26}}{4\times10^{-7}}$

$= \frac{4.9725\times10^{-19} J}{1.6\times10^{-19}}$

$= 3.1\,eV.$

Q.3 Ans $E = \frac{hc}{\lambda} = \frac{19.89\times10^{-26}}{5500\times10^{-10}}$

$= \frac{19.89\times10^{-26}}{55\times10^{-8}} = 0.361\times10^{-18}$

$\therefore n = \cancel{19.89\times10^{-2}}\ \frac{1.5 J}{\frac{19.89\times10^{-26}}{55\times10^{-8}}}\ 0.361\times10^{-18}$

$= \frac{55\times10^{-8}\times1.5}{19.89\times10^{-26}}$

$= 4.15\times10^{18}$

Q.9) $E = \frac{1}{2}mv^2 = eV$

$\Rightarrow mv^2 = 2\times1.6\times10^{-19}\times2\times m$

$mv = p = [m\times4\times1.6\times10^{-19}]^{1/2}$

$p = \frac{h}{\lambda} = \frac{h\nu}{c} = \frac{E}{c}.$

$\Rightarrow p = E = pc$

$= 3\times10^{8}[9.1\times10^{-31}\times4\times1.6\times10^{-19}]^{1/2}$

$= 3\times10^{8}\times7.631\times10^{-25}$

$= \frac{22.893\times10^{-17}}{1.6\times10^{-19}}\,eV = 14.3\times10^{2}\,eV$

$= 143\times10^{1}\,eV$

$= 1430\,eV.$

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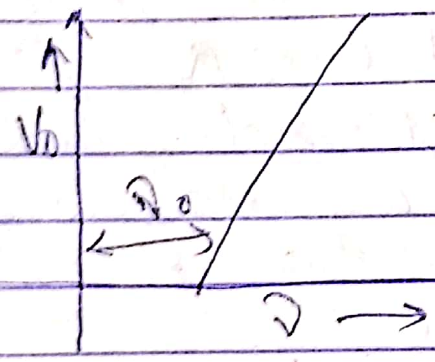
Q.1 (i) $W_0 = h\nu_0 = \frac{hc}{\lambda_0}$

$= \frac{19.89 \times 10^{-26}}{68 \times 10^{-8}} = 2.925 \times 10^{-19}J$

$\therefore \frac{2.925 \times 10^{-19}}{1.6 \times 10^{-19}} eV = 1.828 eV$

(ii) $W_0 = \frac{19.89 \times 10^{-26}}{62 \times 10^{-8} \times 1.6 \times 10^{-19}} = 2.005 eV.$



$K.E = h\nu - h\nu_0$

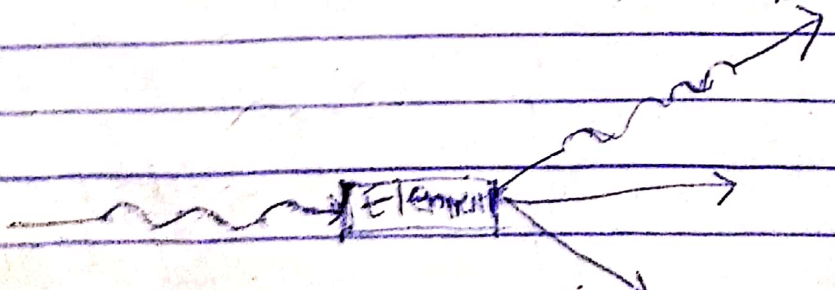
$\frac{1}{2} mv^2_{max} = h\nu - h\nu_0$

Einstein's photoelectric equation:-

7/03/19

Compton effect Particle nature of wave

When a x-ray incident on element then it scatter and ~~wavelength of~~ the scattered wavelength is longer than the wavelength of x-ray.

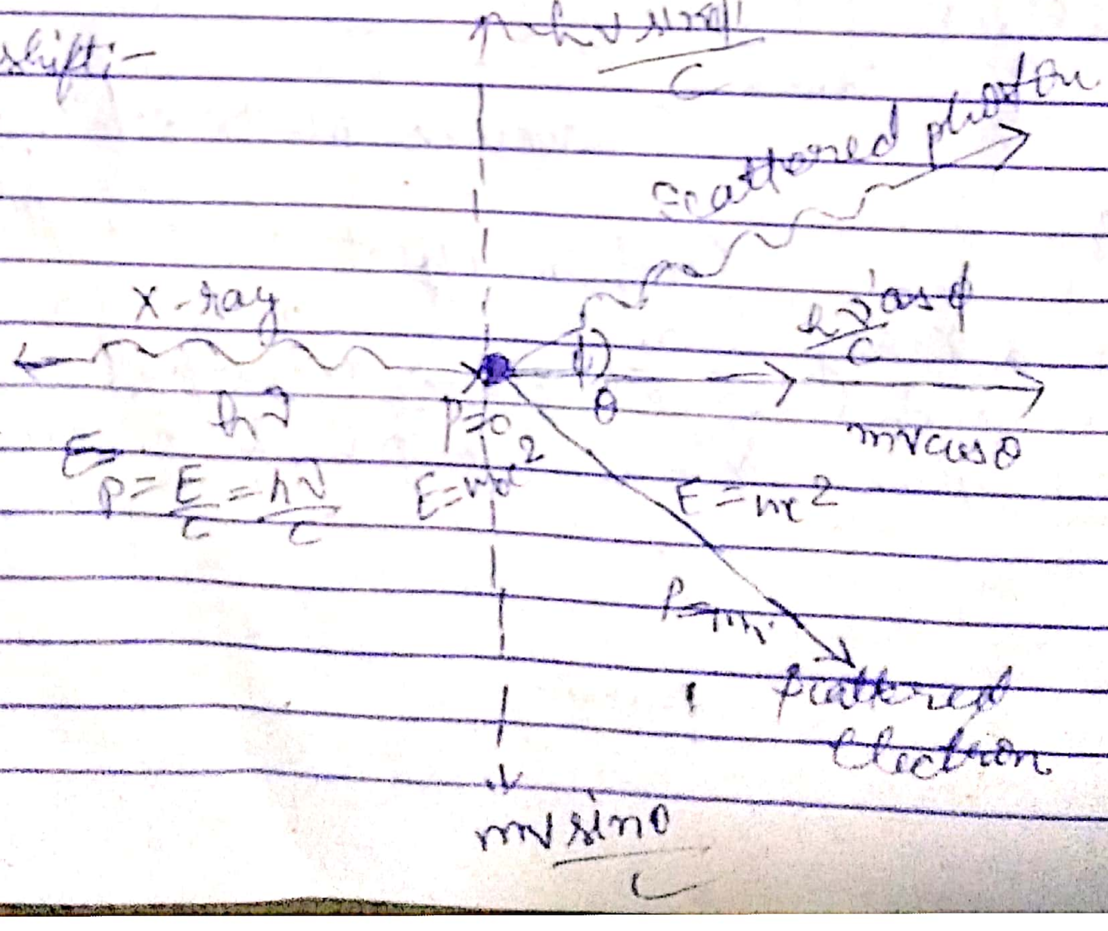


$\boxed{2d \sin\theta = n\lambda}$ Bragg's Law

Compton effect - When x-rays fall on matter a part of it is scattered without any change in wavelength known as unmodified or coherent or classical scattering.

In 1922, Compton found using Bragg's crystal spectrometer scattering in addition to the classical scattering in which the wavelength of the x-rays remains unchanged. The secondary radiations contains x-rays of lower frequency or longer wavelength than those of the incident beam. This is known as C.E. or modified or incoherent scattering. Such phenomena is known as CE. In such a case an e^- is ejected with energy depending on its direction. This electron is Compton recoil electron.

Compton shift:-



Applying conservation of energy

$h\nu + m_0c^2 = h\nu' + mc^2$ — (i)

$mc^2 = h(\nu - \nu') + m_0c^2$ — (ii)

Squaring both sides,

$m^2c^4 = h^2(\nu - \nu')^2 + m_0^2c^4 + 2h(\nu - \nu')m_0c^2$

$= h^2(\nu^2 + \nu'^2 - 2\nu\nu') + m_0^2c^4 + 2h(\nu - \nu')m_0c^2$ — (iii)

Applying conservation of momentum

Along x-axis,

$\frac{h\nu}{c} = \frac{h\nu'}{c}\cos\phi + mv\cos\theta$ — (iv)

Along y-axis

$0 = \frac{h\nu'}{c}\sin\phi - mv\sin\theta$ — (v)

$\frac{h\nu'}{c}\sin\phi = mv\sin\theta\, c$ — (vi)

~~Squaring~~ from (iv),

$mv\cos\theta = \frac{h\nu}{c} - \frac{h\nu'\cos\phi}{c}$

$= \frac{h}{c}(\nu - \nu'\cos\phi)$

$mvc\cos\theta = h(\nu - \nu'\cos\phi)$ — (vii)

Squaring (vi) & (vii) and adding, we get:—

$m^2v^2c^2\sin^2\theta + m^2v^2c^2\cos^2\theta = h^2\nu'^2\sin^2\phi + h^2(\nu - \nu'\cos\phi)^2$

$\Rightarrow m^2 v^2 c^2 (\cos^2\theta + \sin^2\theta) = h^2 \nu'^2 \sin^2\phi + h^2(\nu^2 + \nu'^2\cos^2\phi - 2\nu\nu'\cos\phi)$

$\Rightarrow m^2 v^2 c^2 = h^2\nu'^2\sin^2\phi + h^2\nu^2 + h^2\nu'^2\cos^2\phi - 2\nu\nu' h^2\cos\phi$

$= h^2\nu'^2(\sin^2\phi + \cos^2\phi) + h^2\nu^2 - 2\nu\nu' h^2\cos\phi$

$m^2 v^2 c^2 = h^2\nu'^2 + h^2\nu^2 - 2\nu\nu' h^2\cos\phi$ —— (viii)

$m^2 c^2 v^2 = h^2(\nu^2 + \nu'^2 - 2\nu\nu'\cos\phi)$ —— (ix)

~~Eq~~ subtracting equ (ix) from (viii), we get —

$m^2c^4 - m^2v^2c^2 = h^2(\nu^2 + \nu'^2 - 2\nu\nu') + 2h(\nu - \nu') m_0c^2 - h^2(\nu^2 + \nu'^2 - 2\nu\nu'\cos\phi) + m_0^2c^4$

$\Rightarrow m^2c^2(c^2 - v^2) = -2h^2\nu\nu' + 2h(\nu - \nu')m_0c^2 + m_0^2c^4 + 2h^2\nu\nu'\cos\phi$

$= -2h^2\nu\nu'(1 - \cos\phi) + 2h(\nu - \nu')m_0c^2 + m_0^2c^4$ —— (x)

Putting $m = \dfrac{m_0}{\sqrt{1 - v^2/c^2}}$

$\Rightarrow \dfrac{m_0^2c^2}{1 - \frac{v^2}{c^2}}(c^2 - v^2) = -2h^2\nu\nu'(1 - \cos\phi) + 2h(\nu - \nu')m_0c^2 + m_0^2c^4$

$\Rightarrow \dfrac{m_0^2c^2(c^2 - v^2)}{\frac{c^2 - v^2}{c^2}} = -2h^2\nu\nu'(1 - \cos\phi) + 2h(\nu - \nu')m_0c^2 + m_0^2c^4$

$$\Rightarrow m_0^2 c^4 = 2h^2\nu\nu'(1-\cos\phi) + 2h(\nu-\nu')m_0c^2 + m_0^2c^4$$

$$\Rightarrow +2h^2\nu\nu'(1-\cos\phi) = 2h(\nu-\nu')m_0c^2$$

$$\Rightarrow h\nu\nu'(1-\cos\phi) = (\nu-\nu')m_0c^2$$

$$\Rightarrow \frac{h}{m_0c^2}(1-\cos\phi) = \frac{\nu-\nu'}{\nu\nu'}$$

$$\Rightarrow \frac{h}{m_0c^2}(1-\cos\phi) = \frac{\nu}{\nu\nu'} - \frac{\nu'}{\nu\nu'}$$

$$\Rightarrow \boxed{\frac{h}{m_0c^2}(1-\cos\phi) = \frac{1}{\nu'} - \frac{1}{\nu}}$$

$$\Rightarrow \frac{h}{m_0c^2}(1-\cos\phi) = \frac{\lambda'}{c} - \frac{\lambda}{c}$$

$$\Rightarrow \frac{h}{m_0c^2}(1-\cos\phi) = \frac{1}{c}(\lambda'-\lambda)$$

$$\Rightarrow \frac{h}{m_0c}(1-\cos\phi) = \lambda'-\lambda$$

$$\therefore \Delta\lambda = \frac{h}{m_0c}(1-\cos\phi)$$ proved $[\because \lambda'-\lambda = \Delta\lambda]$.

[Compton effect]

18/09/19 [Visible light (4000Å – 8000Å)]

Wavelength of scattered photon:-

$$\lambda' = \lambda + \frac{h}{m_0c}(1-\cos\phi)$$

For $\phi = 90°$

$$\boxed{\Delta\lambda = \frac{h}{m_0c}} \qquad \Delta\lambda = 0.0242\,Å$$

X-ray has wavelength of approximately 1Å.

$$E = \frac{19.89 \times 10^{-26}}{10^{-10}} = \frac{19.89}{1.6} \times \frac{10^{-16}}{10^{-19}} \text{ J}$$

$$\cong 12.43 \times 10^{3} \text{ eV}$$

$$E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-10}}$$

$$\simeq 2 \text{eV (approx)}.$$

The compton wavelength for an atom of carbon is given by $\lambda = \frac{h}{m_0 c} = 1.1 \times 10^{-6} \text{Å}$

Resolving power $= \frac{\lambda}{\Delta\lambda} = \frac{6000 \text{Å}}{1.1 \times 10^{-6} \text{Å}}$

$$\cong 5 \times 10^{9}$$

To observe the scattering the resolving of the instrument has to be very very high therefore it not possible to observe the compton scattering with visible light.

Q.1 An x-ray photon is found to have double its wavelength on being scattered by $90°$. Find the energy & wavelength of the incident photon.

Q2 Derive a relation between the angle of scattering of photon and that of electron in compton effect.

ϕ

$$\lambda' = \lambda + \frac{h}{m_0 c}(1-\cos\phi)$$

Given, $\lambda' = 2\lambda$ $\therefore$ Δ $2\lambda - \lambda = \Delta\lambda$, $\lambda = \Delta\lambda$

$$\Rightarrow 2\lambda = \lambda + \frac{6.63\times10^{-34}}{9.1\times10^{-31}\times 3\times10^{8}}(1-\cos 90)$$

$$\Rightarrow \Delta\lambda = \frac{6.63\times10^{-34}}{27.3\times10^{-23}} = 0.02425\times10^{-10} m.$$

$$= 0.02425 Å$$

$$E = \frac{hc}{\lambda} = \frac{19.89\times10^{-26}}{0.02425\times10^{-10}} J = 820.206\times10^{-16} J$$

$$= \frac{820.206\times10^{-16}}{1.6\times10^{-19}} eV$$

$$= 512.7\times10^{3}$$

$$= 0.5127\times10^{6} eV$$

$$= 0.51 MeV.$$

$\lambda = \Delta\lambda$

$= 0.02425 Å$

$$E = \frac{19.89\times10^{-26}}{0.02425\times10^{-10}} = \frac{820.206\times10^{-16}}{1.6\times10^{-19}} = 0.51\times10^{6} eV$$

$= 0.51$ MeV.

$$= \frac{19.89\times10^{-26}}{0.02425\times1.32\times10^{-10}} = 15.06\times10^{-11} J$$

$$= \frac{15.06\times10^{-11+19}}{1.6} eV = 9.4\times10^{8} eV$$

$$= 0.94\times10^{9} eV = 0.94 GeV.$$

18/03/19 (2) Conservation of momentum

Initial = Final

Horizontal

$$\frac{h\nu}{c} + 0 = \frac{h\nu'}{c}\cos\phi + mv\cos\theta$$

$$\frac{h\nu}{c} - \frac{h\nu'}{c}\cos\phi = mv\cos\theta \quad \text{---(i)}$$

Vertically, $0 = \frac{h\nu'}{c}\sin\phi - mv\sin\theta$

$$\Rightarrow \frac{h\nu'}{c}\sin\phi = mv\sin\theta \quad \text{---(ii)}$$

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On dividing (i) by (ii), we get:-

$$\Rightarrow \frac{\frac{h\nu}{c} - \frac{h\nu'}{c}\cos\phi}{\frac{h\nu'}{c}\sin\phi} = \cot\theta$$

$$\Rightarrow \cot\theta = \frac{\nu - \nu'\cos\phi}{\nu'\sin\phi} = \frac{\nu/\nu' - \cos\phi}{\sin\phi} \quad \text{—— (iii)}$$

Compton scattering (shift) $\boxed{\Delta\lambda = 2\lambda_c \sin^2\phi/2}$ Imp.

$$\Rightarrow \lambda' - \lambda = \frac{2h}{m_0 c}\sin^2\frac{\phi}{2}$$

$$\Rightarrow \frac{c}{\nu'} - \frac{c}{\nu} = \frac{2h}{m_0 c}\sin^2\frac{\phi}{2}$$

Multiply by ν/c

$$\frac{c}{\nu'}\frac{\nu}{c} - 1 = \frac{2h\nu}{m_0 c^2}\sin^2\frac{\phi}{2}$$

$$\Rightarrow \frac{\nu}{\nu'} = \left(1 + \frac{2h\nu}{m_0 c^2}\sin^2\frac{\phi}{2}\right) \quad \text{—— (iv)}$$

Putting this in (iii),

$$\cot\theta = \frac{\frac{2h\nu}{m_0 c^2}\sin^2\frac{\phi}{2} + (1 - \cos\phi)}{\sin\phi}$$

$$= \frac{\frac{2h\nu}{m_0 c^2}\sin^2\frac{\phi}{2} + 2\sin^2\phi/2}{2\sin\frac{\phi}{2}\cos\frac{\phi}{2}}$$

$$\Rightarrow \frac{2\sin^2 \frac{\phi}{2}\left(\frac{h\nu}{m_0c^2}+1\right)}{2\sin\frac{\phi}{2}\cos\frac{\phi}{2}} = \cot\theta .$$

θ = angle of deflection,

ϕ = angle of scattering

$$\Rightarrow \cot\theta = \frac{\sin\frac{\phi}{2}\left(\frac{h\nu}{m_0c^2}+1\right)}{\cos\phi/2}$$

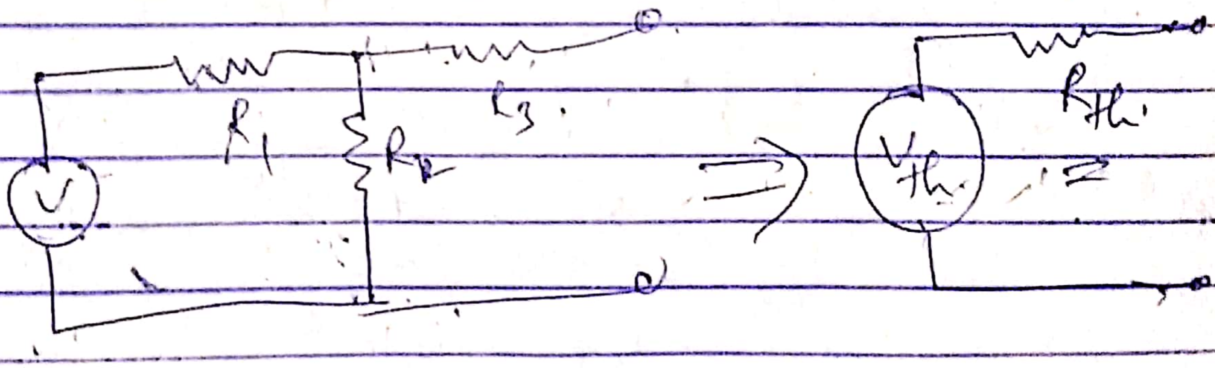
$$\cot\theta = \tan\frac{\phi}{2}\left(\frac{h\nu}{m_0c^2}+1\right)$$

proved.

27/03/19

λ ϕ.

Thevenin theorem.

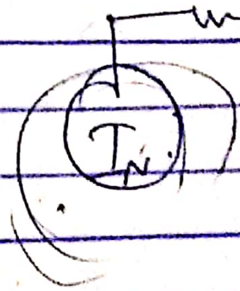


$R_{th} = ?$

Norton

$R_{th} = R_N$

$$V_{th} = \frac{V}{R_1+R_2} R_2 = (\ \ )$$



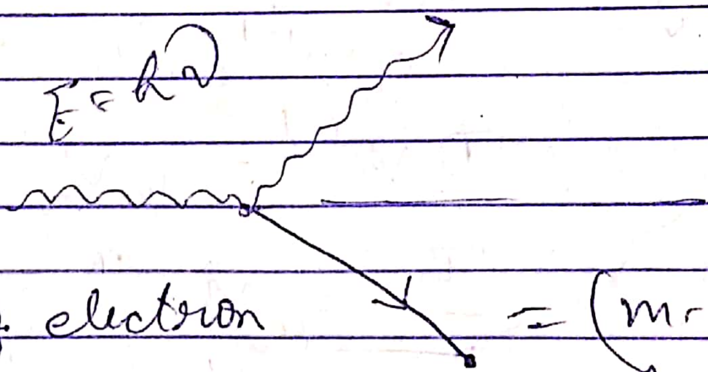
28/09/19

Compton Scattering

Derive an ~~relation~~ expression ~~between~~ for the K.E. in Compton scattering:-

If ν is the frequency of the incident photon and ν' is the frequency of scattered photon. If m_0 is the rest mass of the electron and m is the mass of the electron

$$K.E = (m - m_0)c^2$$
$$= \Delta m c^2.$$



K.E. of electron $= (m - m_0)c^2$
$= \Delta m c^2$

$$h\nu + m_0c^2 = h\nu' + mc^2$$
$$\Rightarrow h\nu - h\nu' = mc^2 - m_0c^2$$
$$\Rightarrow h(\nu - \nu') = (m - m_0)c^2$$

$$\Rightarrow h(\nu - \nu')$$
$$= h\nu\left(1 - \frac{\nu'}{\nu}\right)$$
$$= \frac{hc}{\lambda} - \frac{hc}{\lambda'}$$
$$= hc\left(1 - \frac{\lambda}{\lambda'}\right)$$

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

$$= \frac{hc}{\lambda}\left(\frac{\Delta\lambda}{\lambda'}\right)$$

$$K\cdot E = \frac{hc}{\lambda}\left[\frac{\Delta\lambda}{\Delta\lambda + \lambda}\right] \qquad [\lambda' - \lambda = \Delta\lambda]$$

$$= h\nu\left[\frac{h/m_0c\,(1-\cos\phi)}{h/m_0c\,(1-\cos\phi) + \lambda}\right]$$

$$= h\nu\left[\frac{h/m_0c\lambda\,(1-\cos\phi)}{1 + \frac{h}{m_0c\lambda}(1-\cos\phi)}\right] \qquad \alpha = \frac{h}{m_0c\lambda}$$

$$K.E. \Rightarrow \boxed{= h\nu\left[\frac{\alpha(1-\cos\phi)}{1+\alpha(1-\cos\phi)}\right]} \qquad \boxed{\begin{aligned}\nu\lambda &= c\\ \lambda &= \frac{c}{\nu}\end{aligned}}$$

K.E. of recoil electron $= \boxed{h\nu\left[\frac{\frac{h\nu}{m_0c^2}(1-\cos\phi^\theta)}{1+\frac{h\nu}{m_0c^2}(1-\cos\phi^\theta)}\right]}$

V.V.I.

Case I :- when $\phi^\theta = 0$

$$K\cdot E\cdot = 0.$$

Case II :- when $\phi^\theta = 90'$

$$E = \frac{h\nu\alpha}{1+\alpha}$$

Case III :- when $\phi^\theta = 180'$

$$E = \frac{2h\nu\alpha}{1+2\alpha}$$

H.W.

Find the relation of K.E. of recoil electron in terms of angle of deflection θ.

Proof:

$$K.E. = h\nu\left[\frac{\frac{h\nu}{m_0c^2}(1-\cos\phi)}{1+\frac{h\nu}{m_0c^2}(1-\cos\phi)}\right]$$

$1-\cos\theta = 2\sin^2\theta/2$

$\cos\theta = 1-2\sin^2\theta/2$

$2\sin^2\theta/2 = 1-\cos\theta$

$\sin^2\theta = \frac{\tan^2\theta}{1+\tan^2\theta}$

$$= h\nu\left[\frac{\alpha(2\sin^2\phi/2)}{1+\alpha(2\sin^2\theta/2)}\right]$$

$1-\cos\phi$

$$= h\nu\left[\frac{\alpha(1-\cos\phi)}{1+\alpha(2\sin^2\theta/2)}\right]$$

$\cos 2\phi = \cos^2\phi - \sin^2\phi$

$= 2\cos^2\phi - 1$

$= 1-2\sin^2\phi$

$\therefore \cos 2\phi = 1-2\sin^2\phi$

$$= h\nu\left[\frac{\alpha(1-\cos\phi)}{1}\right] + \frac{\alpha(1-\cos\phi)}{1+\alpha(2\sin^2\theta/2)}$$

$$K.E. = h\nu\left[\frac{\alpha(1-\cos\theta)}{1+\alpha(1-\cos\theta)}\right]$$

$$= h\nu\left[\frac{\alpha(2\sin^2\theta/2)}{1+\alpha(2\sin^2\theta/2)}\right]$$

$$= h\nu\left[\frac{2\alpha\left(\frac{\tan^2\theta/2}{1+\tan^2\theta/2}\right)}{1+2\alpha\left(\frac{\tan^2\theta/2}{1+\tan^2\theta/2}\right)}\right]$$

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$$= h\nu \left[\frac{\dfrac{2\alpha \tan^2 \theta/2}{\cancel{(1+\tan^2\theta/2)}}}{\dfrac{1+\tan^2\theta/2 + 2\alpha \tan^2\theta/2}{\cancel{(1+\tan^2\theta/2)}}} \right]$$

$$= h\nu \left[\frac{2\alpha \tan^2\theta/2}{1+\tan^2\theta/2 + 2\alpha\tan^2\theta/2} \right]$$

$$= h\nu \left[\frac{2\alpha}{\dfrac{1}{\tan^2(\theta/2)} + 1 + 2\alpha} \right]$$

proved.

$$\frac{1}{\tan\theta/2} = (1+\alpha)\tan\phi^{\theta}$$

Now, $E = h\nu \left[\dfrac{2\alpha}{1+2\alpha + (1+\alpha)^2 \tan^2\phi} \right]$

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Wave properties — Wave nature of particles.

De-broglie hypothesis :- $\boxed{\lambda = \frac{h}{mv}}$

By the analogy, with the radiation De-broglie suggested that a wave moving particle can be associated with a wave. the frequency of the wave can be given as, $\nu = \frac{E}{h}$

$$\lambda = \frac{h}{\sqrt{2mKT}}$$

Mass energy relation

$$E = mc^2$$

$$h$$

The wavelength of the wave.

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

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

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

~~De-broglie~~ $\lambda = \frac{h}{\sqrt{2mE_K}}$ $\lambda = \frac{h}{\sqrt{2mqV}}$

Acc. to Kinetic theory of gases,

$$E_K = \frac{1}{2}mv^2 = \frac{3}{2}KT$$

$$\lambda = \frac{h}{\sqrt{3mKT}}$$

Q. A proton and a deuteron have same kinetic energy. which one has longer wavelength.

1.67×10^{-27} kg

sol $E_d = \frac{1}{2}m_d V_d^2 = \cancel{\frac{1}{2}} 2m_p V_d^2$

~~$E_d = \frac{1}{2}m_p V_p^2$~~ $= m_p V_d^2$

$E_p = \frac{1}{2}m_p V_p^2$ $E_p \Rightarrow \frac{1}{2}m_p v_p^2 = m_p V_d^2 \Rightarrow \frac{V_p^2}{2} = V_d^2$

$$\Rightarrow V_d = \frac{V_p}{\sqrt{2}}$$

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$$\frac{\lambda_p}{\lambda_d} = \frac{h/m_p v_p}{h/m_d v_d}$$

$$= \frac{h}{m_p v_p} \cdot \frac{m_d v_d}{h} = \frac{2m_p \cdot \sqrt{2}}{m_p v_p} \times \frac{v_p}{\sqrt{2}}$$

$$\Rightarrow \frac{\lambda_p}{\lambda_d} = \sqrt{2} \Rightarrow \lambda_p = \sqrt{2}\,\lambda_d$$

Q. Calculate the de-broglie wavelength of neutron of energy 1 MeV.

Sol $E = 10^6 \times 1.6 \times 10^{-19}$ J $= 1.6 \times 10^{-13}$ J

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

$= \frac{19.89 \times 10^{-26}}{1.6 \times 10^{-13}}$

$= 12.43 \times 10^{-13}$ m

$= 1.243 \times 10^{-12}$ m

$= 1.243$ pm

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Q. Calculate de-broglie wavelength of neutron of energy 1 MeV.
2.86×10^{-14} m.

Q. Calculate de-broglie wavelength of electron whose K.E is 500 MeV
0.55 Å

Q. A non-relativistic electron has wavelength 2.0 Å. what is its energy?
37.5 eV.

Sol. (1) $E = 1\,MeV = 10^6 \times 1.6\times10^{-19}\,J = 1.6\times10^{-13}\,J$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$= \frac{h}{\sqrt{2\times1.67\times10^{-27}\times1.6\times10^{-13}}}$$

$$= \frac{6.63\times10^{-34}}{\sqrt{5.344\times10^{-40}}}$$

$$= \frac{6.63}{2.31}\times10^{-14}\,m$$

$$= 2.86\times10^{-14}\,m.$$

3.2
20
1.67
× 3.2
334
501×
5.344

−34
+20
−14

$\sqrt{5.344}$

−19
8

2. $E = 500\times10^6\times1.6\times10^{-19}\,J$
$= 8\times10^{-11}\,J$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$= \frac{6.63\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times8\times10^{-11}}}$$

$$= \frac{6.63\times10^{-34}}{\sqrt{145.6\times10^{-42}}}$$

$$= \frac{6.63\times10^{-34}}{12.06\times10^{-21}}$$

$= 0.549\times10^{-13}\,m = 0.55\times10^{-13}\,m$

9.1
×16
546
91×
145.6
14

31
11
2

$\frac{145.6}{22}$

3. $\lambda = \frac{h}{\sqrt{2mE}}$

On squaring both sides,

$\lambda^2 = \frac{h^2}{2mE}$.

$E = \frac{h^2}{2m\lambda^2}$

$= \frac{(6.63\times10^{-34})^2}{2\times9.1\times10^{-31}\times4\times10^{-20}}$

$= \frac{43.95\times10^{-68}}{72.8\times10^{-51}}$

$= 0.603\times10^{-17}$

$= \frac{0.3768\times10^{-17}\times10^{19}}{\cancel{1.6\times10^{-19}}}$

$= 0.3768\times10^{2} = 37.5eV$.

~~08/11/19~~

Problems

Q. Energy in eV. that would be generated through anihilation of 1gm of matter is,

Sol $E = mc^2$

$= 10^{-3} \times 9\times10^{16}$

$1g = 10^{-3}kg$

$E = mc^2$

$= 1\times10^{-3}\times9\times10^{16}$

$= \frac{9\times10^{13}\,J.}{1.6\times10^{-19}}$

$= 5.625\times10^{22}\,eV$