SEM-IV
PHYH-C IX: ELEMENTS OF MODERN PHYSICS

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Solution of mathematical problems L-1, L-2,L-3

Mathematical prob. of L1, L2, L3, L4.

L-1.

Prob. 1.

$$h = 6.627\times10^{-27}\ \text{erg s}$$
$$e = 4.8\times10^{-19}\ \text{esu}$$
$$m = 9.1\times10^{-28}\ \text{g}$$

work function $W_0 = 2.28\ \text{eV} = 2.28\times1.6\times10^{-12}\ \text{ergs}$

$$\therefore \frac{1}{2} m v_{max}^2 = h\nu - h\nu_0$$
$$= h\nu - W_0$$
$$\therefore v_{max}^2 = \frac{2(h\nu - W_0)}{m}$$

we know for u.v ray velocity = velocity of light $= 3\times10^{10}$ cm/s.

$$\therefore c = \nu\lambda$$
$$\nu = \frac{c}{\lambda} = \frac{3\times10^{10}}{3000\times10^{-8}} = 10^{15}\ \text{Hz}$$

$$\therefore v_{max}^2 = \frac{2\times(6.627\times10^{-27}\times10^{+15} - 2.28\times1.6\times10^{-12})}{9.1\times10^{28}}$$

$$v_{max} = \sqrt{\frac{5.958}{9.1}}\times10^{8}$$
$$= 8.1\times10^{7}\ \text{cm s}^{-1}$$
$$v_{max} = 8.1\times10^{5}\ \text{m s}^{-1}$$

[illegible]

L-1
Prob - 2

From Einstein photoelectric equation

$$h\nu_1 = \frac{1}{2} m v_1^2 + W_0 \quad \cdots \quad ①$$

$$h\nu_2 = \frac{1}{2} m v_2^2 + W_0 \quad \cdots \quad ②$$

Substracting ① from ② we get-

$$h(\nu_2 - \nu_1) = \frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2$$

$$= (K.E)_2 - (K.E)_1$$

$$\therefore h = \frac{(K.E)_2 - (K.E)_1}{\nu_2 - \nu_1}$$

$$= \frac{(K.E)_2 - (K.E)_1}{\frac{c}{\lambda_2} - \frac{c}{\lambda_1}} \qquad \because \nu\lambda = c.$$

$$= \frac{(4.0 - 1.8) \times 1.6 \times 10^{-19}}{3 \times 10^8 \left(\frac{1}{700} - \frac{1}{800}\right) \times 10^{10}}$$

$$= 6.57 \times 10^{-34} \text{ JS}$$

L-1
Prob - 3.

We know from Einsteins photoelectric equation

$$h\nu = \frac{1}{2} m v_{max}^2 + W_0$$

$$\therefore W_0 = h\nu - \frac{1}{2} m v_{max}^2$$

$$= (6.62 \times 10^{-27} \times 7.5 \times 10^{14}) - (1.6 \times 10^{-19} \times 10^7)$$

$$= 3.365 \times 10^{-12} \text{ erg.}$$

$$\therefore W_0 = h\nu_0$$

$$\nu_0 = \frac{W_0}{h} = \frac{3.365 \times 10^{-12}}{6.62 \times 10^{-27}} = 5.08 \times 10^{14} \text{ Hz.}$$

L-1.

Prob. 4. From Einstein's photoelectric equation

$$h\nu = h\nu_0 + \frac{1}{2} m v_{max}^2$$

$$\therefore \frac{1}{2} m v_{max}^2 = h\nu - h\nu_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$\therefore hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{2} m v_{max}^2$$

$$\therefore \frac{1}{\lambda} - \frac{1}{\lambda_0} = \frac{1}{2} \cdot m \cdot \frac{v_{max}^2}{hc}$$

$$\therefore \frac{1}{\lambda} - \frac{1}{\lambda_0} = \frac{1}{2} \times \frac{9.11 \times 10^{-31} \times (4 \times 10^5)^2}{(6.626 \times 10^{-34}) \times 3 \times 10^8}$$

$$= 0.0366 \times 10^7$$

$$\therefore \frac{1}{\lambda_0} = \frac{1}{\lambda} - 0.0366 \times 10^7$$

$$\therefore \frac{1}{\lambda_0} = \frac{1}{6000 \times 10^{-10}} - 0.0366 \times 10^7$$

$$= \frac{1}{6} \times 10^7 - 0.0366 \times 10^7$$

$$= 10^7\left(\frac{1}{6} - 0.0366\right)$$

$$= 0.13 \times 10^7$$

$$\therefore \lambda_0 = 7.692 \times 10^{-7}\ m.$$

$$= 7692 \times 10^{-10}\ m$$

$$= 7692\ A^\circ.$$

L-2.

Prob-1. (a) $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c}(1-\cos\phi)$

$$= \frac{6.63\times10^{-34}\,J\cdot s}{9.1\times10^{-31}\times3\times10^{8}}(1-\cos45^\circ)$$

$$= 7.1\times10^{-13}\,m.$$

(b) $\lambda' = \lambda + \Delta\lambda$

$$= (2.426\times10^{-12} + 7.1\times10^{-13})\,m$$

$$= 3.1\times10^{-12}\,m$$

(c) $\phi = \pi/2$ then $\lambda_c = \Delta\lambda = \frac{h}{m_0 c} = 0.024\,A^\circ$

(d) Energy of the incident photon $E_i = \frac{hc}{\lambda}$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{2.426\times10^{-12}}$$

$$= 8.198\times10^{-14}\,J$$

$$= 0.51\times10^{6}\,ev. \quad \left[\because 1ev = 1.6\times10^{-19}J\right]$$

$$= 0.51\,Mev.$$

(e) Energy of the scattered photon:

$$E_s = \frac{hc}{\lambda'}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{3.1\times10^{-12}}$$

$$= 0.40\,Mev.$$

(f) Energy loss by incident photon $= E_i - E_s$

$$= 0.51\,Mev - 0.40\,Mev.$$

$$= 0.11\,Mev.$$

(g) K.E of the recoil electron = energy loss by incident photon

$$E = E_i - E_s$$

$$= \cancel{\quad} = 0.11\,Mev.$$

(h) The direction of emission of the corresponding recoil electron.

$$\tan\theta = \frac{\cot \phi/2}{1+\frac{h\nu}{m_0c^2}} \quad [\phi = 90^\circ]$$

$$= \frac{\cot 45^\circ}{1+\frac{h\nu}{m_0c^2}}$$

$$= \frac{1}{2}$$

$$\therefore \theta = \tan^{-1}\left(\tfrac{1}{2}\right) = 26.56^\circ.$$

(i) The total energy of recoil electron

= K.E of recoil electron + rest mass energy of recoil electron

$$= E + m_0c^2$$

$$= 0.11\ \text{MeV} + \frac{9.1\times10^{-31}\times(3\times10^{8})^2}{1.6\times10^{-19}\times10^{6}}\ \text{MeV}$$

$$= 0.11\ \text{MeV} + 0.51\ \text{MeV}$$

$$= 0.62\ \text{MeV}$$

(j) The fraction of energy loss $= \frac{E_i - E_s}{E_i}$

$$= \frac{0.11\ \text{MeV}}{0.51\ \text{MeV}} = 0.21$$

1-3

(1) In between a photon 100 eV and an electron of 100 eV, which one has shorter wavelength?

A: For photon energy $E = h\nu$

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

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

$$= \frac{6.62\times10^{-34}\times3\times10^{8}}{100\times1.6\times10^{-19}} = 124\ A^{o}.$$

But for an electron like particle de-Broglie wavelength

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

$$= \frac{6.62\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times100\times1.6\times10^{-19}}}$$

$$= 1.2\times10^{-10}\ m$$

$$= 1.2\ A^{o}.$$

Hence de-Broglie wavelength of the electron is much smaller than that of a photon for their same energy.

(2) what is the de-Broglie wavelength of a thermal neutron at 400K.?

we know K.E of a particle at equilibrium absolute temperature T.

$$E = \frac{3}{2}kT$$

$$\therefore \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m\cdot\frac{3}{2}kT}} = \frac{h}{\sqrt{3mkT}}$$

$$\therefore \lambda = \frac{6.62\times10^{-34}}{\sqrt{3\times(1.675\times10^{-27})\times1.38\times10^{-23}\times400}}\ m$$

$$= 1.25\times10^{-10}\ m = 1.25\ A^{o}.$$

(3) If an electron has a wavelength of 1 Å find the energy and momentum.

For a particle of mass m and energy E, the de Broglie wavelength

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

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

$$= \frac{(6.62\times10^{-34})^2}{2\times9.1\times10^{-31}\times(10^{-10})^2}\ \mathrm{J}$$

$$= \frac{(6.62\times10^{-34})^2}{2\times9.1\times10^{-31}\times(10^{-10})^2\times1.6\times10^{-19}}\ \mathrm{eV}$$

$$= 150\ \mathrm{eV}.$$

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

$$= \frac{6.62\times10^{-34}}{10^{-10}}\ \mathrm{kg.m\,s^{-1}}$$

$$= 6.62\times10^{-24}\ \mathrm{kg\,m\,s^{-1}}$$