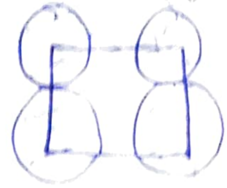
|| Tutorial sheet ||

|| 1 ||

Q.1.) Assuming wave Nature of EM waves, calculate the time required for the emission of photoelectron from a mono atomic layer of 1 cm^2 sodium water upon irradiation of a laser with intensity 10^{-6} W/m^2. The work function of sodium is 2.3 eV and the lattice parameter of two dimensional sodium water are a = b = 4.29 Å and the angle b/w a and b is 90°.



Sol.) 1 atom in $(4.29\,Å)^2$

$(4.29 \times 10^{-10})^2\ m^2$

$18.4041 \times 10^{-20}\ m^2$

We know that for each atom 2.3 eV of energy required to irradiated

Total No. of atoms in 1 cm^2

$$= \frac{1 \times 10^{-4}\ m^2}{18.4041 \times 10^{-20}\ m^2}$$

$\therefore$ $1J = 6.24 \times 10^{18}\ eV$

$= 5.433 \times 10^{+14}$

Total energy Required for 1 cm^2 $= 2.3\ eV\ (5.433 \times 10^{14})$

$= 12.4959 \times 10^{14}\ eV$

So, 10^{-6} W/m^2 Intensity required to Irradicate

$10^{-6}\ W/m^2$ / In

$10^{-6}\ J/s/m^2 \rightarrow 10^{-10}\ J/s/cm^2$

$\rightarrow 6.24 \times 10^{8}\ eV/s$

$$\Rightarrow \frac{12.4959 \times 10^{14}}{6.24 \times 10^{8}}\ s$$

$$\boxed{t = 2.0025 \times 10^{6}\ s}$$

Q.2). Calculate the avg. No. of Photons with energy 2eV inside a black body kept at 500K?

Sol-2) Avg. energy per standing wave with frequency

$\nu \Rightarrow \bar{E} = (\bar{n}_\nu) h\nu$

Probability of finding standing wave with eng. ($h\nu$)

$\boxed{k = 1.381 \times 10^{-23} J/K}$

$\boxed{k = 8.617 \times 10^{-5} eV/K}$

$$\bar{n}_\nu = \frac{1}{e^{\frac{h\nu}{kT}} - 1}$$

$kT = 8.617 \times 10^{-5} \times 500$

$= 4.3085 \times 10^{-2}$

$= 0.043085 \times eV$

$$= \frac{1}{\left(\frac{2}{e^{0.043085}} - 1\right)}$$

$$= \boxed{\frac{1}{10^{20}} \text{ Photons}}$$

~~Q.3) The work fnch of Barium and tungsten are 2.5 eV and 4.2 eV inside a black body kept at 500K.~~

~~Sol~~

Q.3.) The work fnch of Barium and tungsten are 2.5 eV and 4.2 eV respectively. Check wheather these materials are useful in a photocell, which is to be used to detect visible light?

Sol-3) $W_{Barium} = 2.5 eV$, $W_{tung} = 4.2 eV$

$h\nu_B = 2.5 eV$

$$\nu_B = \frac{2.5 \times 1.6 \times 10^{-19} J}{6.626 \times 10^{-34} J} Hz$$

$\boxed{\nu_B = 6.036 \times 10^{14} Hz}$ ✓

$4 \times 10^{14} - 8 \times 10^{14} Hz$

Visible Range

$\therefore 1eV = 1.6 \times 10^{-19} J$

$h = 6.626 \times 10^{-34} J/s$

$$\nu_{Tungsten} = \frac{4.2 \times 1.6 \times 10^{-19}}{6.626 \times 10^{-34}} = 10.14 \times 10^{14} Hz$$

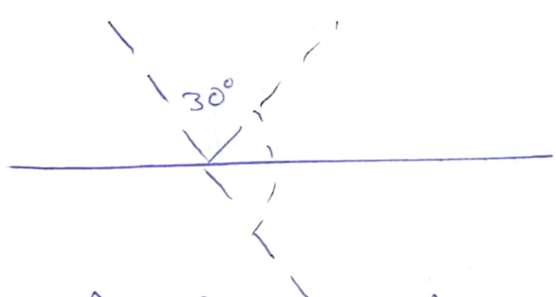
$$\boxed{\nu_{Tungsten} = 10.14 \times 10^{14} Hz}$$

$$\boxed{\frac{hc}{\lambda_0} = 4.2eV}$$

$$\frac{1240 \times eV \cdot nm}{4.2eV} = \lambda_0 \Rightarrow \boxed{\lambda_0 = 295.88 nm}$$

6) A photon of wavelength 40Å strikes an electron at rest and is scattered at an angle of 150° to its orignal direction. Find the wavelength of the photon after collision?

Sol) $\lambda = 40 Å$



$$\lambda' - \lambda = \lambda_c (1 - \cos\theta)$$

$$\lambda' - 40Å = 2.426 \times 10^{-12} (1 - \cos(150°))$$

$$\lambda' - 40 \times 10^{-10} = 2.426 \times 10^{-12} (1 + 0.866)$$

$$= (2.426 \times 10^{-12}) (1.866)$$

$$= 4.852 \times 10^{-12} + 40 \times 10^{-10}$$

$$= ~~0.04852~~$$

$$= 0.04852 \times 10^{-10} + 40 \times 10^{-10}$$

$$\boxed{\lambda' = 40.04885 Å}$$

(7) A change in wavelength of a scattered photon is 2.9×10^{-12} m Calculate the angle of scattered photon if an electron is emitted in the compton Process.

(Sol-7) $\boxed{\lambda' - \lambda = \lambda_c(1-\cos\theta)}$

$$2.9 \times 10^{-12} = 2.426 \times 10^{-12}(1-\cos\theta)$$

~~1.9~~ .

$$1.195 = 1-\cos\theta$$

$$\cos\theta = -0.1953$$

$$\boxed{\theta = 101.26°}$$

(8) If the velocity of photoelectron emitted in a compton Process is 0.5c, calculate the diff. in wavelength of Incident and the scattered photon?

(Sol-8)

$$k.E = (m - m_0)c^2$$

$$k.E = \left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right)$$

$$k.E = e^- = h\nu - h\nu'$$

$$k.E = \frac{hc}{\lambda} - \frac{hc}{\lambda'}$$

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

$$\frac{h}{mc}(1-\cos\phi) = \boxed{\frac{k.E}{hc}(\lambda, \lambda') = \lambda' - \lambda_i}$$

$$k.E\,\lambda_i = \frac{\lambda'}{\lambda' + 1}$$

$$= \frac{1}{\frac{1}{\lambda'} + 1}$$

$$\frac{hc}{k.E\,\lambda_i} = \frac{1}{\lambda'} + 1$$

$$\frac{h\cancel{c}}{\cancel{k.E}\lambda_i} = \cancel{\frac{1}{\lambda'}} + 1$$

$$\frac{hc}{k.E\,\lambda_i} - 1 = \frac{1}{\lambda}$$

$\frac{k.E}{hc} \lambda_i \lambda' + \lambda_i = \lambda'$

$\frac{k.E}{hc} \lambda_i (\lambda' + 1) = \lambda'$

$$\boxed{\lambda' = \frac{\lambda_i}{hc - k.E\lambda_i}}$$

$$\lambda' - \lambda_i = \frac{\lambda_i}{hc - k.E\lambda_i} - \lambda_i$$

(9) What is the minimum energy (Threshold energy) of photon required for an electron-positron creation process?

(Sol9) $E_T = \cancel{k.E} + m_0c^2$
0

$E_T = (m_e + m_{pt})c^2$

$= 2 \times 0.511 \times MeV$

$E_T = \underline{1.022 \times MeV}$

$$\lambda_i = \left(\frac{1}{hc - k.E\lambda_i} - 1\right)$$

$$\lambda' - \lambda_i = \lambda_i \left(\frac{1 - hc - k.E\lambda_i}{hc - k.E\lambda_i}\right)$$

Q.4.) Calculate the mass of Photoelectron emitted from a thin layer of gold upon irradiation of photon of wavelength 50nm. The work fn of gold layer is 5.3eV and the rest mass of electron is 9.1×10^{-31} kg?

Sol (4) $W_{gold} = 5.3eV = \phi$

$m_{elect} = 9.1 \times 10^{-31}$ kg

mass of electron

$k.E = E_{incident} - \phi$

$\phi = h\nu_0 = \frac{hc}{\lambda_0}$

$hc = 1240 eV \cdot nm$

$= \frac{hc}{\lambda_{incident}} - \phi$

$= \frac{1240}{50} - 5.3eV$

$k.E = 19.7 eV$

E_{Total} = k.E + Rest mass Energy of e^-

$m_e c^2 = 19.7 + 0.511 \times 10^6$

$m_e c^2 = 511019.7 eV$

$m_e = 0.5110197 \frac{MeV}{c^2}$

(Q.5) Light of wavelength 2000Å falls on a metallic surface. If the work fnch of the surface is 4.2 eV what is the k.E of the fastest photoelectron emitted? Also calculated the stopping potential and threshold wavelength for the metal?

(sol 5) $\phi = 4.2 eV$

0.511 MeV
↓
Rest Mass energy of electron

$k.E = E - \phi$

$= \frac{hc}{\lambda_m} - \phi$

$hc = 1240 eV \cdot nm$

$= \frac{1240 eV/nm}{200 nm} - 4.2$

$= 6.2 - 4.2 = 2eV$

$\boxed{k.E = 2eV}$

Stopping potential –

$K.E = eV_0$

$2eV = eV_0 \rightarrow \boxed{V_0 = 2V}$

Wave - Particle Duality

Particle

- mass
- velocity
- momentum
- Energy

wave

- Frequency
- wavelength
- wave velocity (Phase)
- Amplitude
- Intensity

Radiation (light)

[visible / I.R (Infrared) / UV / X-ray]
(λ / frequency)

↓ Shows

[Interference / Diffraction / Polarization]

↓ when

[Two waves at the same position at the same time]

↓ conclusion

[The radiation behaves like wave]

(Particle)

[Photon (quanta)]
[$E = h\nu$, $P = h\nu/c$]

↓ shows

[Black Body Radiation Photo electric effect compton effect]

↓ when

[The radiant energy in its interaction with matter in the form of Photon]

↓ conclusion

[The radiation behave like particle]

Wave - Particle duality

On the basis of dual Nature of light in 1924 Louis de-broglie suggested that the dual Nature is not only at light but "each moving material particle has the dual Nature"

"He assumed a wave to be associated with each moving material particle which is called the matter wave and wavelength of this matterwave is given as"

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