Problem 1

Question: Calculate the energy of photon of sodium light of wavelength $5893*10^{-10}$ m in (a) joules and (b) in electron volt. Take $h = 6.62*10^{-34}$ J.s and $c = 3*10^{8}$ m/s.

Solution :

$$(a)\, We\ know\ that$$

$$E = h\nu = hc/\lambda$$

$$E = \frac{(6.62\times10^{-34})\times(3\times10^{8})}{5893\times10^{-10}}$$

$$= 3.375\times10^{-19}\ Joules$$

$$(b)\ As \qquad 1eV = 1.6\times10^{-19}\ Joules$$

$$E = \frac{3.375\times10^{-19}}{1.6\times10^{-19}}eV$$

$$E = 2.11eV$$

Problem 2

Question: What is the threshold wavelength for nickel whose work function is 4.84 eV ?

Solution:

$$Work\ function = 4.84\, eV$$

$$= 4.84 \times (1.6 \times 10^{-19})\ Joules$$

$$The\ work\ function\ W_o = h\nu_o = hc / \lambda_o$$

$$where\ \lambda_o\ is\ the\ threshold\ wavelength$$

$$\lambda_o = \frac{hc}{W_o} = \frac{(6.62 \times 10^{-34}) \times (3 \times 10^{8})}{4.84 \times (1.6 \times 10^{-19})}$$

$$= 3.897 \times 10^{-7}\ meter$$

$$\lambda_o = 3897 \times 10^{-10}\ meter$$

Problem 3

Question: Calculate the work function of sodium if its threshold wavelength 5040 Å.

Solution:

$$We\ know\ that$$

$$W_o = \frac{hc}{\lambda_o}$$

$$W_o = \frac{(6.62\times 10^{-34})\times(3\times 10^{8})}{5040\times 10^{-10}}$$

$$= 3.928\times 10^{-19}\ Joules$$

Problem 4

Question: The work function of sodium is 2.46 eV and its threshold wavelength is 5040 Å. Calculate the value of Planck's constant.

Solution:

$$W_o = \frac{hc}{\lambda_o} \quad or \quad h = (W_o \lambda_o)/c$$

$$h = \frac{(2.46 \times 1.6 \times 10^{-19} \text{ Joule}) \times (5040 \times 10^{-10})}{(3 \times 10^{8}\ m/s)}$$

$$= 6.612 \times 10^{-34}\ J.s$$

Problem 5

Question: The maximum energy of the electrons emitted from a photoelectric surface of work function 2.2 eV illuminated by monochromatic radiation is 0.8 eV What is the wavelength of light incident on the surface?

Solution:

$$According\ to\ Einstein's\ photoelectric\ equation$$

$$h\nu = W_o + K_{\max}$$

$$or \quad \frac{hc}{\lambda} = W_o + K_{\max}$$

$$\lambda = \frac{hc}{W_o + K_{\max}}$$

$$K_{\max} = 0.8\,eV = 0.8 \times (1.6 \times 10^{-19})\ Joules$$

$$W_o = 2.2\,eV \times (1.6 \times 10^{-19})\ Joules$$

$$\lambda = \frac{(6.62 \times 10^{-34}) \times (3 \times 10^{8})}{(2.2 + 0.8)(1.6 \times 10^{-19})} = \frac{(6.62 \times 10^{-34}) \times (3 \times 10^{8})}{(4.8 \times 10^{-19})}$$

$$\lambda = 4.147 \times 10^{-7}\ meter$$

Problem 6

Question: A photon of wavelength 3310 Å falls on a photocathode and ejects an electron of maximum energy $3*10^{-19}$ Joule. Calculate the work function of the cathode material, h = $6.62*10^{-34}$ J.s, c = $3*10^{8}$ m/s.

Solution: when a photon of energy v falls on a photocathode of work function W_o, maximum K.E (K_{max}) of the photo-electron is given by Einstein's photoelectric equation

$$h\nu = W_o + K_{\max}$$

$$W_o = h\nu - K_{\max} = (hc/\lambda) - K_{\max}$$

$$W_o = \frac{(6.62\times10^{-34})(3\times10^{8})}{3310\times10^{-10}} - (3\times10^{-19})$$

$$= (6\times10^{-19}) - (3\times10^{-19}) = 3\times10^{-19}\,Joules$$

$$= \frac{3\times10^{-19}}{1.6\times10^{-19}}\,eV$$

$$= 1..875\ eV$$

Problem 7

Question: The photoelectric work function of potassium surface is 2.2 eV. When ultraviolet light of wavelength 3200 Å falls on potassium surface, calculate the energy of the most energetic photon emitted. What is the threshold frequency for potassium.

Solution: *According to Einstein's photoelectric equation*

$$h\nu = W_o + K_{\max}$$

$$= h\nu - W_o = (hc/\lambda) - W_o$$

$$K_{\max} = \frac{(6.62\times10^{-34})(3\times10^{8})}{3200\times10^{-10}} - (2.2\times(1.6\times10^{-19}))$$

$$= (6.21\times10^{-19} - 2.2\times(1.6\times10^{-19})\ Joules$$

$$= 1.6\times10^{-19}\left[3.886 - 2.22\right] = 1.686\times(1.6\times10^{-19})\ Joules$$

$$= 1.686\, eV$$

The work function W_o and threshold frequency ν_o are related to

$$h\nu_o = W_o \ \ or \ \ \nu_o = \frac{W_o}{h}$$

$$\nu_o = \frac{2.2\times(1.6\times10^{-19})}{6.62\times10^{-34}}$$

$$= 5.309\times10^{14}\ Hz$$

Problem 8

Question: The work function of sodium is 2.3 eV. Does sodium show photoelectric effect for orange light, λ=6800 Å ?. What will be the maximum K.E of the photoelectrons if 2000 Å light falls on a sodium surface ? **Solution:**

$$We\ know\ that$$

$$h\nu_o = W_o = hc / \lambda_o$$

$$\lambda_o = \frac{hc}{W_o} = \frac{(6.62\times10^{-34})(3\times10^{8})}{2.3\times(1.6\times10^{-19})}$$

$$= 5400\times10^{-10}\ meter$$

This is the maximum wavelength which can produce photoelectric emission from sodium surface. Given that the wavelength of orange light is 6800 Å. Hence this wavelength cannot produce photoelectric emission from sodium surface. According to photoelectric equation.

$$h\nu = W_o + K_{\max}$$

$$K_{\max} = h\nu - W_o = (hc / \lambda) - W_o$$

$$K_{\max} = \frac{(6.62\times10^{-34})(3\times10^{8})}{(2000\times10^{-8})\times(1.6\times10^{-19})}eV - 2.3\,eV$$

$$= 6.2\,eV - 2.3\,eV$$

$$= 3.9\,eV$$

Problem 9

Question: The threshold frequency for photoelectric emission in copper is 1.1*10^15 sec^-1. Find the maximum energy of photoelectrons when light of frequency 1.5*10^15 sec^-1 falls on copper surface. Also calculate the retarding potential.

Solution:

$$h\nu = W_o + K_{\max} = h\nu_o + K_{\max}$$

$$K_{\max} = h\nu - h\nu_o = h(\nu - \nu_o)$$

$$= 6.62\times10^{-34}(1.5\times10^{15} - 1.1\times10^{15})$$

$$= 6.62\times10^{-34}\times(0.4\times10^{15})$$

$$= 2.648\times10^{-19}\ Joules$$

$$= \frac{2.648\times10^{-19}}{1.6\times10^{-19}} = 1.655\ eV$$

The retarding potential is the potential which just stop the photoelectrons of maximum K.E. thus,

Stopping potential = 1.655 eV

Problem 10

Question: The work function for sodium is 2.27 eV. What is the velocity of electrons emitted by light of wavelength 4000 Å. Mass of electrons 9.1*10^{-31} kg, h = 6.62*10^{-34} J.s ?

Solution:

$$h\nu = W_o + \frac{1}{2}mv^2$$

$$\frac{hc}{\lambda} = W_o + \frac{1}{2}mv^2$$

$$or \quad \frac{1}{2}mv^2 = \frac{hc}{\lambda} - W_o$$

$$\frac{hc}{\lambda} - W_o = \frac{(6.62\times10^{-34})(3\times10^{8})}{4000\times10^{-10}} - 2.27\times(1.6\times10^{-19})$$

$$= 4.965\times10^{-19} - 3.632\times10^{-19}$$

$$= 1.333\times10^{-19}\ Joule$$

$$Hence, \quad \frac{1}{2}mv^2 = 1.333\times10^{-19}$$

$$v = \sqrt{\frac{(2\times1.333\times10^{-19})}{9.1\times10^{-31}}} = 5.35\times10^{5}\ m/s.$$

Problem 11

Question: Ultraviolet light of wavelength 800 Å and 700 Å when allowed to fall on a certain metal is found to liberate electrons with kinetic energies of 1.8 eV and 4 eV respectively. Find Planck's constant

Solution:

$$h\nu = W_o + \frac{1}{2}mv^2$$

$$\frac{hc}{\lambda} = W_o + \frac{1}{2}mv^2$$

$$Now \quad \frac{hc}{800\times10^{-10}} = W_o + 1.8\,eV$$

$$and \quad \frac{hc}{700\times10^{-10}} = W_o + 4\,eV$$

$$hc\times10^{10}\left[\frac{1}{700}-\frac{1}{800}\right] = 2.2\,eV$$

$$hc\times10^{10}\left[\frac{100}{560}\right] = 2.2(1.6\times10^{-19})$$

$$\frac{h\times(3\times10^{8})\times10^{10}}{56} = 2.2(1.6\times10^{-19})$$

$$h = \frac{2.2(1.6\times10^{-19})56}{(3\times10^{8})\times10^{10}}$$

$$= 6.57\times10^{-34}\ J.s$$

Problem 12

Question: in an experiment tungsten cathode which has a threshold 2300 Å is irradiated by ultraviolet light of wavelength 1800 Å. Calculate (1) maximum energy of emitted photoelectrons and (2) work function tungsten (mention both the results in eV). Given planck's constant h = 6.62*10^{-34} J.s,1 eV = 1.6*10^{-19} joule and velocity of light c = 3*10^{8} m/s.

Solution:

$$E_{\max} = \frac{1}{2}mv^2 = h(\nu - \nu_o)$$

Where v is the frequency of incident radiation and v_o, the threshold frequency. If λ and λ_o are the corresponding wavelengths and c is the velocity of light, then we have

$$E_{\max} = h\left(\frac{c}{\lambda} - \frac{c}{\lambda_o}\right) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right)$$

$$h = 6.62 \times 10^{-34}\ J.s, \lambda = 1800 \times 10^{-10}\ m$$

$$\lambda_o = 2300 \times 10^{-10}\ m, and\ c = 3 \times 10^{8}\ m/s$$

$$E_{\max} = (6.62 \times 10^{-34})(3 \times 10^{8})\left[\frac{1}{1800 \times 10^{-10}} - \frac{1}{2300 \times 10^{-10}}\right]$$

$$= \frac{(6.62\times10^{-34})(3\times10^{8})}{10^{-8}}\left[\frac{1}{18}-\frac{1}{23}\right] = 2.391\times10^{-19}\ J$$

$$= \frac{2.391\times10^{-19}}{1.6\times10^{-19}}eV = 1.485\,eV$$

$$The\ work\ function\ of\ tungsten$$

$$W_o = h\nu_o = hc/\lambda_o$$

$$W_o = \frac{6.6\times10^{-34}\times3\times10^{8}}{2300\times10^{-10}}$$

$$= 8.608\times10^{-19}\ J$$

$$= \frac{8.608\times10^{-19}}{1.6\times10^{-19}} = 5.38\ eV$$

Problem 13

Question: Electrons are emitted with zero velocity from a certain metal surface when it is expose to radiations of λ = 6800 Å. Calculate threshold frequency and work function of metal.

Solution:

Here wavelength 6800 Å represents the long wavelength limit λ_o

$$Now \quad c = \nu_o \lambda_o \qquad or \quad \nu_o = \frac{c}{\lambda_o}$$

$$Threshold \;\; frequency$$

$$\nu_o = \frac{3 \times 10^8}{6800 \times 10^{-10}} = 0.44 \times 10^{15} \; Hz$$

$$The \; work \; function$$

$$W_o = \frac{hc}{\lambda_o} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{6800 \times 10^{-10} \times 1.6 \times 10^{-19}}$$

$$= 1.82 \, eV$$

Problem 14

Question: Calculate the stopping potential for the photoelectrons emitted by gold cathode if the wavelength of the incident radiation is $2*10^{-7}$ m. Given that the work function of gold is 4.80 eV

Solution: The stopping potential V_o is given by

$$eV_o = h\nu - W_o = \frac{hc}{\lambda} - W_o$$

$$or \quad V_o = \frac{hc}{\lambda e} - \frac{W_o}{e}$$

Here, $h = 6.626*10^{-34}$, $c = 3*10^{8}$ m/s, $\lambda = 2*10^{-7}$ m, $W_o = 4.80$ eV $= 4.80*1.602*10^{-19}$ V. Substituting these values, we get

$$V_o = \frac{6.626\times10^{-34}\times3\times10^{8}}{2\times10^{-7}\times1.602\times10^{-19}} - \frac{4.80\times1.602\times10^{-19}}{1.602\times10^{-19}}$$

$$= 6.204 - 4.80$$

$$= 1.404 \ V$$

Problem 15

Question: What potential difference should be applied to stop the fastest photoelectrons emitted by nickel surface under the action of 20 nm ultraviolet light ?. The work function is 5.01 eV.

Solution:

The stopping potential V_o is given by

$$eV_o = hv - W_o = \frac{hc}{\lambda} - W_o$$

$$or \quad V_o = \frac{hc}{\lambda e} - \frac{W_o}{e}$$

Substituting the given values, we get

$$V_o = \frac{6.626\times10^{-34}\times3\times10^{8}}{20\times10^{-9}\times1.6\times10^{-19}} - \frac{5.01\times1.6\times10^{-19}}{1.6\times10^{-19}}$$

$$= 62.15 - 5.01$$

$$= 57.14\ V$$

Problem 16

Question: Light of wavelength λ = 5893 Å is incident on a potassium surface. The stopping potential for the emitted electrons is 0.36 V. Calculate the maximum energy of photoelectron, the work function and threshold frequency.

Solution: $K_{max} = eV_o = 0.36$ eV, The stopping potential V_o is given by

$$eV_o = h\nu - W_o = \frac{hc}{\lambda} - W_o$$

$$W_o = \frac{hc}{\lambda} - eV_o$$

$$= \frac{6.626\times10^{-34}\times3\times10^{8}}{5893\times10^{-10}\times1.6\times10^{-19}} - 0.36\ eV$$

$$= 2.15\ eV - 0.35\ eV = 1.79\ eV$$

$$Work\ function = 1.79\ eV$$

$$Threshold\ frequency = \nu_o = \frac{W_o}{h}$$

$$\nu_o = \frac{(1.79\,eV)(1.6\times10^{-19})\ J/eV}{6.626\times10^{-34}\ J.s}$$

$$= 4.33\times10^{14}\ cycles/\sec.$$

Problem 17

Question: Calculate the maximum velocity of the electrons ejected from a metal surface having work function 5 eV by an incident radiation of 161 nm

Solution:

According to Einstein's photoelectric equation

$$h\nu = W_o + K_{\max} \quad or \quad K_{\max} = h\nu - W_o$$

$$Further \quad K_{\max} = \frac{1}{2} m v_{\max}{}^2$$

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

$$V_o = \frac{6.626\times10^{-34}\times3\times10^{8}}{161\times10^{-9}} - 5\times(1.6\times10^{-19})$$

$$= 12.31\times10^{-19} - 8\times10^{-19} = 4.31\times10^{-19} \quad J$$

$$Now \quad v_{\max}^2 = \frac{2\times(4.31\times10^{-19})}{9.1\times10^{-31}}$$

$$or \quad v_{\max} = \sqrt{\left[\frac{2\times(4.31\times10^{-19})}{9.1\times10^{-31}}\right]} = 9.734\times10^{5} \ m/s$$

Problem 18

Question: Calculate the velocity of a photoelectron, if the work function of target material is 1.24 eV and the wavelength of incident light is 4.36*10^{-7} m. What retarding potential is necessary to stop the emission of these electrons ?

Solution: **we know that**

$$\frac{1}{2}mv^2 = hv - W_o \quad or \quad \frac{1}{2}mv^2 = \frac{hc}{\lambda} - W_o$$

$$Here\, W_o = 1.24\ eV = 1.24 \times 10^{-19}\ J$$

$$= 1.984 \times 10^{-19}\ J$$

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

$$h = 6.6 \times 10^{-31}\ J.s$$

$$Substituting\ these\ values, we\ have$$

$$\frac{1}{2} \times 9.1 \times 10^{-31} = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4.36 \times 10^{-7}} - 1.984 \times (1.6 \times 10^{-19})$$

$$= 4.495 \times 10^{-19} - 1.984 \times 10^{-19} = 2.511 \times 10^{-19}$$

$$v^2 = \frac{2.511 \times 10^{-19} \times 2}{9.1 \times 10^{-31}}$$

$$v = 7.43 \times 10^{5}\ m/s$$

If V_o be the retarding potential required to stop the emission of photoelectrons, we have

$$eV_o = \frac{1}{2}mv^2$$

$$V_o = \frac{\frac{1}{2}mv^2}{e} = \frac{2.511\times 10^{-19}}{1.6\times 10^{-19}}$$

$$= 1.57\, eV$$

Problem 19

Question: If the minimum wavelength recorded in an X-ray spectrum of a 50 kV table is 0.257 Å. Calculate the value of Planck's constant.

Solution:

Maximum energy of X-ray emitted = hv

Maximum energy of electrons in X-ray tube = eV

$$eV = hv$$

$$or \quad h = \frac{eV}{v} = \frac{eV}{c}\lambda$$

Substituting the values of e, V, λ and c, we get

$$V_o = \frac{1.6\times10^{-19}\times50\times10^{3}\times0.257\times10^{-10}}{3\times10^{8}}$$

$$= 6.56\times10^{-34}\ J.s$$

Problem 20

Question: Compute the value of Planck's constant h if photoelectron ejected from the surface of a certain metal by light of frequency 2.2*10^15 Hz are fully retarded by a reverse potential of 6.6 V and those ejected by light of frequency 4.6*10^15 Hz are stopped by reverse potential of 16.5 V.

Solution: **We know that**

$$eV_o = h(v - v_o) \quad ....(1)$$

Substituting the two given values, we have

$$6.6e = h(2.2 \times 10^{15} - v_o)$$

$$and \ 16.5e = h(4.6 \times 10^{15} - v_o) \quad ....(2)$$

Subtracting eqs. (1) from (2), we get

$$h = \frac{9.9 \times 1.602 \times 10^{-19}}{2.4 \times 10^{15}}$$

$$= 6.61 \times 10^{-34} \ J.s$$