17. ELECTRONS AND PHOTONS

1. The energy required to remove elecrton from sodium is 2.3 eV. Does sodium show photoelectric effect for orange light of wavelength 6800 A.U. ?

Given :

$W_0 = 2.3$ eV
$= 2.3 \times 1.6 \times 10^{-19}$ J
$\lambda = 6800$ A.U
$= 6800 \times 10^{-10}$
$= 6.8 \times 10^{-7}$ m

To Find :

Does sodium show photoelectric effect for orange light of wavelength 6800 A.U ?

Formula :

$W_0 = h\nu_0$

Solution :

$$\nu_0 = \frac{W_0}{h}$$

$$\therefore \nu_0 = \frac{2.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$

$\therefore \nu_0 = 5.550 \times 10^{14}$ Hz

Incident frequency,

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{6.8 \times 10^{-7}}$$

$$= \frac{3}{6.8} \times 10^{15}$$

$\therefore \nu = 4.412 \times 10^{14}$ Hz

$\because \nu < \nu_0$

$\therefore$ The sodium light does not show photoelectric effect.

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2. Find the maximum kinetic energy of electrons ejected form a certain material if material's work function is 2.3 eV and the freqeuncy of the incident radiation is 3.0×10^{15} Hz.

Given :

$W_0 = 2.3$ eV
$= 2.3 \times 1.6 \times 10^{-19}$ J
$= 3.68 \times 10^{-19}$ J

To Find :

$K.E_{max} = ?$

Formula :

$K.E_{max} = h\nu - W_0$

Solution :

Form formula

$K.E_{max} = (6.63 \times 10^{-34} \times 3 \times 10^{15}) - 3.68 \times 10^{-19}$
$= 19.89 \times 10^{-19} - 3.68 \times 10^{-19}$
$= (19.89 - 3.68) \times 10^{-19}$

$$= \frac{16.21 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$\therefore K.E_{max} = 10.13$ eV

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3. The work function for potassium and caesium are 2.25 eV and 2.14 eV respectvely. Will the photoelectric emission occur for either of these elements
i) with incident light if wavelength 5650 A.U and
ii) with light of wavelength 5180 A.U ?

Given :

$(W_0)_P = 2.25$ eV
$= 2.25 \times 1.6 \times 10^{-19}$ J
$= 3.6 \times 10^{-19}$ J
$(W_0)_C = 2.14$ eV
$= 2.14 \times 1.6 \times 10^{-19}$ J
$= 3.424 \times 10^{-19}$ J
$\lambda_1 = 5650$ A.U
$= 5.65 \times 10^{-7}$ m
$\lambda_2 = 5180$ A.U
$= 5.18 \times 10^{-7}$ m

To Find :

i) Will the photoelectric effect will occur for either of these elements with $\lambda_1 = ?$
ii) Will the photoelectric effect will occure for either of these elements wilh $\lambda_2 = ?$

Formula :

$W_0 = h\nu_0$

Solution :

Form formula

$(W_0)_P = h(\nu_0)_P$

$\therefore\ (\nu_0)_P = \frac{(W_0)_P}{h}$

$= \frac{3.6\times10^{-19}}{6.63\times10^{-34}}$

$\therefore\ (\nu_0)_P = 5.430 \times 10^{14}$ Hz

Similarly

$\therefore\ (\nu_0)_C = \frac{(W_0)_C}{h}$

$= \frac{3.424\times10^{-19}}{6.63\times10^{-34}}$

$\therefore\ (\nu_0)_C = 5.164 \times 10^{14}$ Hz

i) Also, $\nu_1 = \frac{c}{\lambda_1}$

$= \frac{3\times10^{8}}{5.65\times10^{-7}}$

$= \frac{3.000}{5.65} \times 10^{15}$

$= 5.310 \times 10^{14}$ Hz

But $(\nu_0)_P = 5.430 \times 10^{14}$ Hz

$\because\ 5.310 \times 10^{14} < 5.430 \times 10^{14}$

i.e. $\nu c < (\nu_0)_P$

$\therefore$ There is no photoelectric emission for Potassium when λ_1 wavelength is incident on it.

For Caesium,

5.164×10^{14} Hz $< 5.310 \times 10^{14}$ Hz

i.e. $\nu_1 > (\nu_0)_C$

$\therefore$ Photoelectric effect will occure when λ_1 wavelength is incident on it.

$\therefore$ Only caesium exhibits photoelectric effect for λ_1= 5650 AU.

ii) With λ_2, the corresponding frequency is given by

$\nu_2 = \frac{c}{\lambda_2}$

$= \frac{3\times10^{8}}{5.18\times10^{-7}}$

$= \frac{3}{5.18} \times 10^{15}$

$\nu_2 = 5.792 \times 10^{14}$

For potassium

5.792×10^{14} Hz $> 5.430 \times 10^{14}$ Hz

i.e. $\nu_2 > (\nu_0)_P$

$\therefore$ Photoelectric emission will take place when λ_2 wavelength is incident on it

For caesium

5.792×10^{14} Hz $> 5.16 \times 10^{14}$ Hz

i.e. $\nu_2 > (\nu_0)_C$

$\therefore$ Photoelectric emission will take place when λ_2 wavelength is incident on it.

For λ_2 wavelength, both potassium and caesium will exhibit photoelectric emission.

$\therefore$ Potassium and caesium both exhibit photoelectric effect.

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4. The work function of tugsten is 4.50 eV. Calculate the speed of fastest electron ejected when light whose photon energy is 5.80 eV shines on the surface.

Given :

$W_0 = 4.50$ eV

$h\nu = 5.8$ eV

To Find :

$V_{max} = ?$

Formula :

$K.E_{max} = \frac{1}{2}mv_{max}^2$

Solution :

Since

$K.E_{max} = h\nu - W_0$

$K.E_{max} = (5.8 - 4.5)$ eV

$= 1.3$ eV

$K.E_{max} = 1.3 \times 1.6 \times 10^{-19}$ J

From formula

$\therefore\ V_{max} = \sqrt{\frac{2K.E_{max}}{m}}$

$\therefore \quad V_{max} = \sqrt{\dfrac{2\times1.3\times1.6\times10^{-19}}{9.1\times10^{-31}}}$

$\therefore \quad V_{max} = \sqrt{\dfrac{2\times1.6}{9.1}\times10^{12}}$

$= 0.676 \times 10^6$ m/s

$V_{max} = 676$ km/s

5. **If the work function for certain metal is 1.8 eV,**
   i) What is the stopping potential for electrons ejected from metal when light of 4000 A.U shines on the metal ?
   ii) What is the maximum speed of the ejected electrons ?

Given :

$W_0 = 1.8$ eV

$= 1.8 \times 1.6 \times 10^{-19}$ J

$\lambda_1 = 4000$ A.U $= 4 \times 10^{-7}$ m

To Find :

i) $V_0 = ?$

ii) $v_{max} = ?$

Formula :

i) $K.E_{max} = eV_0$

ii) $K.E_{max} = \frac{1}{2}mv^2_{max}$

Solution :

Since,

$K.E_{max} = h\nu - W_0$

$= \dfrac{hc}{\lambda} - W_0$

$= \dfrac{6.63\times10^{-34}\times3\times10^8}{4\times10^{-7}} - 1.8 \times 1.6 \times 10^{-19}$

$= \dfrac{19.89}{4} \times 10^{-19} - 2.88 \times 10^{-19}$

$= 4.972 \times 10^{-19} - 2.88 \times 10^{-19}$

$= (4.972 - 2.88) \times 10^{-19}$

$\therefore \quad K.E_{max} = 2.092 \times 10^{-19}$ J

From formula (i)

$\therefore \quad V_0 = \dfrac{K.E_{max}}{e}$

$= \dfrac{2.092\times10^{-19}}{1.6\times10^{-19}}$

$\therefore \quad V_0 =$ **1.31 V**

From formula (ii)

$\therefore \quad v^2_{max} = \dfrac{2K.E_{max}}{m}$

$\therefore \quad v_{max} = \sqrt{\dfrac{2\times2.092\times10^{-19}}{9.1\times10^{-31}}}$

$= \sqrt{\dfrac{4.184\times10^{12}}{9.1}}$

$= 0.678 \times 10^6$ m/s

$\therefore \quad v_{max} = 678$ km/s

6. **The work function of caesium is 2.14 eV. Find**
   i) the threshold frequency for caesium and
   ii) photocurrent wavelength of incident light if photocurrent is brought to zero by stopping potential of 0.60 V.

Given :

$W_0 = 2.14$ eV

$= 2.14 \times 1.6 \times 10^{-19}$ J

$= 3.424 \times 10^{-19}$ J

$V_0 =$ stopping potential $= 0.60$ V

To Find :

i) $(\nu_0)_C = ?$

ii) $\lambda = ?$

Formula :

i) $W_0 = h\nu_0$

ii) $eV_0 = h\nu - W_0$

Solution :

From formula (i)

$(\nu_0)_C = \dfrac{W_0}{h}$

$$= \frac{3.424\times10^{-19}}{6.63\times10^{-34}}$$

$$= \frac{3.424}{6.63} \times 10^{15}$$

$\therefore \quad (\nu_0)_C = 5.164 \times 10^{14}$ Hz

From formula (ii)

$$eV_0 = \frac{hc}{\lambda} - W_0$$

$$\therefore \quad \frac{hc}{\lambda} = eV_0 + W_0$$

$$= 0.96 \times 10^{-19} + 3.424 \times 10^{-19}$$

$$\frac{hc}{\lambda} = 4.384 \times 10^{-19}$$

$$\therefore \quad \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.384\times10^{-19}}$$

$\therefore \quad \lambda = 4.537 \times 10^{-7}$

$\therefore \quad \lambda = 4537$ A.U

7. When a surface is irradiated with light of wavelength 4950 Å, a photocurrent appears which vanishes of a retarding potential greater than 0.6 V is applied across the phototube. When different source of light is used, it is found that the critical retarding potential is changed to 1.1 V. Find the work function of the emitting surface and the wavelength of the second source.

Given :

$\lambda_1 = 4950$ Å

$= 4.95 \times 10^{-7}$ m

$e = 1.6 \times 10^{-19}$ C

$V_{01} = 0.6$ V

$h = 6.63 \times 10^{-34}$ Js

$V_{01} = 0.6$ V

$V_{02} = 1.1$ V

To Find :

$W_0 = ?$

$\lambda_2 = ?$

Formula :

i) $\nu = \dfrac{c}{\lambda}$

ii) $eV_0 = h\nu - W_0$

Solution :

From formula (i)

$$\nu_1 = \frac{3\times10^{8}}{4.95\times10^{-7}}$$

$\nu_1 = 6.06 \times 10^{14}$ Hz

From formula (ii)

$W_0 = h\nu_1 - eV_{01}$

$W_0 = 6.63 \times 10^{-34} \times 6.06 \times 10^{14} - 1.6 \times 10^{-19} \times 0.6$

$= 4.17 \times 10^{-19} - 0.96 \times 10^{-19}$

$W_0 = 4.17 \times 10^{-19}$ J

$$\therefore \quad W_0 = \frac{3.058\times10^{-19}}{1.6\times10^{-19}}$$

$\therefore \quad W_0 = 1.911$ eV

Also, $\dfrac{hc}{\lambda_2} = eV_{02} + W_0 \qquad \left[\because \nu = \dfrac{c}{\lambda}\right]$

$$\therefore \quad \lambda_2 = \frac{hc}{eV_{02} + W_0}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{\left(1.6\times10^{-19}\times1.1+1.911\times1.6\times10^{-19}\right)}$$

$$= \frac{6.63\times3\times10^{-26}}{(1.1+1.911)\times1.6\times10^{-19}}$$

$$= \frac{6.63\times3\times10^{-7}}{3.011\times1.6}$$

$\therefore \quad \lambda_2 = 4.128 \times 10^{-7}$

$\therefore \quad \lambda_2 = 4128$ Å

8. **The work function for the surface of aluminium is 4.2 eV. How much potential difference will be required to stop the emission of maximum energy electrons emitted by light of 2000 Å wavelngth ? What will the wavelength of that incident light for which stopping potential will be zero ?**

Given :

$W_{01} = 4.2 \text{ eV}$
$= 4.2 \times 1.6 \times 10^{-19}$ J

$\lambda = 2000$ Å
$= 2 \times 10^{-7}$ m

$e = 1.6 \times 10^{-19}$ J

$h = 6.63 \times 10^{-34}$ J s

$c = 3 \times 10^{8}$ m/s

To Find :

$V_0 = ?$

$\lambda = ?$ at

$V_0 = 0$

Formula :

$eV_0 = h\nu - W_0$

Solution :

Since,

$$\nu = \frac{c}{\lambda}$$

$$= \frac{3\times10^{8}}{2\times10^{-7}}$$

$\nu = 1.5 \times 10^{15}$ Hz

From formula

$$V_0 = \frac{h\nu - W_0}{e}$$

$$= \frac{h\nu}{e} - \frac{W_0}{e}$$

$$= \frac{6.63\times10^{-34}\times1.5\times10^{15}}{1.6\times10^{-19}} - 4.2$$

$$= \frac{6.63\times1.5\times10^{-19}}{1.6\times10^{-19}} - 4.2$$

$= 6.216 - 4.2$

$\therefore V_0 = 2.016$ V

When stopping potential is zero i.e

$V_0 = 0$

$\therefore h\nu = W_0$

$$\frac{hc}{\lambda} = W_0$$

$$\therefore \lambda = \frac{hc}{W_0}$$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{4.2\times1.6\times10^{-19}}$$

$$\therefore \lambda = \frac{19.89\times10^{-26}}{6.72\times10^{-19}}$$

$= 2.959 \times 10^{-7}$ m

$\therefore \lambda = 2959$ **Å**