Unit 2: Particles and Waves

Photoelectric Emission

(1) a) $5.46 \times 10^{-7}\ m$

b) (i) $f = \frac{v}{\lambda}$

$= \frac{3 \times 10^{8}}{5.46 \times 10^{-7}}$

$= \underline{5.49 \times 10^{14}\ Hz}$

(ii) $T = \frac{1}{f}$

$= \frac{1}{5.49 \times 10^{14}}$

$= \underline{1.82 \times 10^{-15}\ s}$

(2) a) $\lambda = \frac{v}{f}$

$= \frac{3 \times 10^{8}}{2 \times 10^{15}}$

$= \underline{1.5 \times 10^{-7}\ m}$

b) $T = \frac{1}{f}$

$= \frac{1}{2 \times 10^{15}}$

$= \underline{5 \times 10^{-16}\ s}$

Photoelectric Emission

(3) (a) The gold leaf falls.
This is because the ultraviolet light has a frequency greater than the threshold frequency (f_0) therefore electrons are ejected from the plate.

b
(i) The leaf would fall quicker, more photons hitting Zinc plate per second.
(ii) Leaf would take longer to fall, less photons hitting Zinc plate per second.
(iii) The red light does not have a frequency greater than the threshold frequency therefore the golf leaf would not fall.
(iv) The gold leaf would not fall. This is because the threshold frequency of tin is higher than the frequency of the radiation incident on the surface.
(v) If the electroscope is positively charged the UV Lamp would not discharge it, therefore the gold leaf would remain up.

(4) (a) $E = hf$
$E = 6.63 \times 10^{-34} \times 4.28 \times 10^{14}$
$= 2.84 \times 10^{-19}$ J

(b) $E = hf$

$E = 6.63\times10^{-34} \times 7.5\times10^{14}$

$= 4.97\times10^{-19}\,J.$

(c) $E = hf$

$= 6.63\times10^{-34} \times 5\times10^{14}$

$= 3.32\times10^{-19}\,J.$

(5) (a) $f = V/\lambda$

$f = \frac{3\times10^{8}}{700\times10^{-9}}$

$f = 4.29\times10^{14}\,Hz.$

$E = hf$

$E = 6.63\times10^{-34} \times 4.29\times10^{14}$

$\underline{E = 2.84\times10^{-19}\,J.}$

(b) $f = V/\lambda$

$f = \frac{3\times10^{8}}{400\times10^{-9}}$

$f = 7.5\times10^{14}\,Hz.$

$E = hf$

$E = 6.63\times10^{-34} \times 7.5\times10^{14}$

$\underline{E = 4.97\times10^{-19}\,J.}$

(c) $f = \frac{V}{\lambda}$

$f = \frac{3\times10^{8}}{60\times10^{-9}}$

$f = 5\times10^{15}\,Hz.$

$E = hf$

$E = 6.63\times10^{-34} \times 5\times10^{15}$

$\underline{E = 3.32\times10^{-18}\,J.}$

(6) (a) $f = \frac{E}{h}$

$f = \frac{5.3\times10^{-20}}{6.63\times10^{-34}}$

$\underline{f = 7.99\times10^{13}\,Hz.}$

(b) $f = \frac{E}{h}$

$f = \frac{2.8\times10^{-19}}{6.63\times10^{-34}}$

$\underline{f = 4.2\times10^{14}\,Hz.}$

Photoelectric Effect Cont.

(6) (c) $f = \frac{E}{h}$.

$f = \frac{9.65 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 1.46 \times 10^{15}$ Hz.

(7) (a) $f = \frac{E}{h}$

$f = \frac{1.66 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 2.5 \times 10^{14}$ Hz.

$\lambda = v/f$.

$\lambda = \frac{3 \times 10^{8}}{2.5 \times 10^{14}}$

$\lambda = 1.2 \times 10^{-6}$ m.

(b) $f = \frac{E}{h}$.

$f = \frac{3.62 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 5.46 \times 10^{14}$ Hz

$\lambda = v/f$.

$\lambda = \frac{3 \times 10^{8}}{5.46 \times 10^{14}}$

$\lambda = 5.49 \times 10^{-7}$ m (549 nm)

(c) $f = \frac{E}{h}$

$f = \frac{7.96 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 1.2 \times 10^{15}$ Hz.

$\lambda = v/f$.

$\lambda = \frac{3 \times 10^{8}}{1.2 \times 10^{15}}$.

$\lambda = 2.5 \times 10^{-7}$ m (250 nm)

(8) In question 14 the only photon that is visible light is in part b (549 nm)

(9) a) Photoelectric emission is the release of electrons when they absorb the energy of photons incident upon the metal.

b) Threshold frequency

c) When the irradiance of the radiation increases more photons are incident upon the metal. This releases more electrons which increases the current in the circuit.

(10) (a) Threshold frequency.

(b) If frequency is below f_0, the threshold frequency, this means that the photons do not have enough energy to eject electrons as the work function (W) equals hf_0.

$$f_0 = \frac{W}{h}$$

$$= \frac{2.65 \times 10^{-18}}{6.63 \times 10^{-34}}$$

$$f_0 = 4 \times 10^{15} \text{ Hz}$$

(11)

$$f_0 = \frac{2.65 \times 10^{-18}}{6.63 \times 10^{-34}}$$

$$= \underline{\underline{4.0 \times 10^{15} \text{ Hz}}}$$

(12) $f_0 = 1.25 \times 10^{16}$

$W = hf_0$

$W = 6.63 \times 10^{-34} \times 1.25 \times 10^{16}$

$W = 8.3 \times 10^{-18}$ J.

$E = hf$

$= 6.63 \times 10^{-34} \times 1.25 \times 10^{16}$

$= 8.3 \times 10^{-18}$ J.

$K.E = hf - hf_0$.

$K.E = 8.3 \times 10^{-18} - 8.3 \times 10^{-18}$

$K.E = 0$ J.

(13) (a) The Work Function

(b) $f_0 = \frac{W}{h}$

$f_0 = \frac{6.1 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f_0 = 9.2 \times 10^{14}$ Hz.

(c)

(i) $E = hf$

$E = 6.63 \times 10^{-34} \times 1.2 \times 10^{15}$

$E = 7.97 \times 10^{-19}$ J.

"Extra Energy" $= 7.97 \times 10^{-19} - 6.1 \times 10^{-19} = 1.87 \times 10^{-19}$ J

(ii) This "extra energy" will be in the form of kinetic energy.

Work Function Continued.

(14) (a) $f_o = \frac{W}{h}$

$f_o = \frac{3.3 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f_o = 4.98 \times 10^{14}$ Hz.

(b)(i) No, frequency of 4×10^{14} Hz is lower than threshold frequency (f_o)

(ii) $f = \frac{V}{\lambda}$

$f = \frac{3 \times 10^8}{5 \times 10^{-7}}$

$f = 6 \times 10^{14}$ Hz since greater than f_o, photoemission will take place.

(15) (a) $E = hf$

$E = 6.63 \times 10^{-34} \times 5.0 \times 10^{14}$

$E = 3.32 \times 10^{-19}$ J.

(b) hf_o (Work Function) $= E - K.E$.

$= 3.32 \times 10^{-19} - 7.0 \times 10^{-20}$

$= 2.62 \times 10^{-19}$ J.

(16) $E = hf$

$E = 6.63 \times 10^{-34} \times 5 \times 10^{14}$.

$E = 3.315 \times 10^{-19}$ J.

$K.E = E - W = 3.315 \times 10^{-19} - 2.9 \times 10^{-19} = 4.15 \times 10^{-20}$ J

(17) $K.E = 2.0 \times 10^{-20} J$.

$f_0 = 8.7 \times 10^{14} Hz$.

$W = hf_0$

$W = 6.63 \times 10^{-34} \times 8.7 \times 10^{14}$

$W = 5.77 \times 10^{-19} J$.

$E = K.E + W$

$E = 2 \times 10^{-20} + 5.77 \times 10^{-19}$

$E = 5.97 \times 10^{-19} J$.

$f = \frac{E}{h}$

$f = \frac{5.97 \times 10^{-19}}{6.63 \times 10^{-34}}$

$\underline{f = 9 \times 10^{14} Hz}$

$\lambda = \frac{V}{f}$

$\lambda = \frac{3 \times 10^{8}}{9 \times 10^{14}}$

$\underline{\lambda = 333 nm.}$

Work Function Continued

(18) (a) $f_0 = \frac{W}{h}$ $\qquad \lambda = V/f$

$f_0 = \frac{6.95 \times 10^{-19}}{6.63 \times 10^{-34}}$ $\qquad \lambda = \frac{3 \times 10^8}{1.05 \times 10^{15}}$

$f_0 = 1.05 \times 10^{15}\ Hz$. $\qquad \underline{\lambda = 286\ nm}$

(b) $\lambda = 255\ nm$

$f = \frac{V}{\lambda}$ $\qquad E = hf$.

$f = \frac{3 \times 10^8}{255 \times 10^{-9}}$ $\qquad E = 6.63 \times 10^{-34} \times 1.18 \times 10^{15}$

$f = 1.18 \times 10^{15}\ Hz$. $\qquad \underline{E = 7.82 \times 10^{-19}\ J}$.

max $K.E = E - W$

$= 7.82 \times 10^{-19} - 6.95 \times 10^{-19}$

$= \underline{8.73 \times 10^{-20}\ J}$.

(19) (a) $W = 3.04 \times 10^{-19}\ J$.

$\lambda = 5 \times 10^{-7}\ m$

$E = ?$

$f = \frac{V}{\lambda}$

$f = \frac{3 \times 10^8}{5 \times 10^{-7}}$

$\underline{f = 6 \times 10^{14}\ Hz}$

(19) a) continued,

$$E = hf$$

$$E = 6.63 \times 10^{-34} \times 6 \times 10^{14}$$

$$E = 3.98 \times 10^{-19} \text{ J}.$$

$$K.E = E - W$$

$$K.E = 3.98 \times 10^{-19} - 3.04 \times 10^{-19}$$

$$\underline{K.E = 9.4 \times 10^{-20} \text{ J}.}$$

(b) $m = 9.1 \times 10^{-31} \text{ kg}$

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

$$9.4 \times 10^{-20} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$$

$$v^2 = 2.07 \times 10^{11}$$

$$\underline{v = 4.55 \times 10^5 \text{ ms}^{-1}}$$

(20) a) $E = P \times t$

$= 8 \times 5$

$= \underline{\underline{40\ J}}$

b) $f = \frac{v}{\lambda}$

$= \frac{3 \times 10^8}{4.9 \times 10^{-7}}$

$= 6.12 \times 10^{14}\ Hz$

$E = hf$

$= 6.63 \times 10^{-34} \times 6.12 \times 10^{14}$

$= 4.06 \times 10^{-19}\ J$

Number of photons $= \frac{40}{4.06 \times 10^{-19}}$

$= \underline{\underline{9.85 \times 10^{19}}}$