

Homework #12

$$(39-1) \text{ Power} = \frac{\text{energy}}{\text{sec}} = \frac{\text{energy}}{\text{photon}} \frac{\text{photons}}{\text{sec}}$$

$$= \frac{hc}{\lambda} \left(\frac{\text{photons}}{\text{sec}} \right)$$

$$\text{So Power} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{sec}) (3 \times 10^8 \frac{\text{m}}{\text{sec}})}{550 \times 10^{-9} \text{ m}} \left(100 \frac{1}{\text{sec}} \right)$$

$$= \boxed{3.62 \times 10^{-17} \text{ watts}}$$

(39-2) From the photoelectric equation

$$hf = K_{\max} + \Phi$$

with $K_{\max} = 0$ for cutoff and $f = \frac{c}{\lambda}$,

$$\frac{hc}{\lambda_c} = \Phi \quad (\lambda_c = \text{cutoff wavelength})$$

$$\lambda_c = \frac{hc}{\Phi} = \frac{1240 \text{ eV}\cdot\text{nm}}{\Phi}$$

The photoelectric effect will occur only if $\lambda < \lambda_c$.

For potassium, $\Phi = 2.25 \text{ eV}$

$$\Rightarrow \lambda_c = \frac{1240 \text{ eV}\cdot\text{nm}}{2.25 \text{ eV}} = 551 \text{ nm}$$

For cesium, $\Phi = 2.14 \text{ eV}$

$$\Rightarrow \lambda_c = \frac{1240 \text{ eV}\cdot\text{nm}}{2.14 \text{ eV}} = 579 \text{ nm}$$

- a) If $\lambda = 565 \text{ nm}$, the photoelectric effect will occur for ^{cesium} effect
- b) If $\lambda = 518 \text{ nm}$, the photoelectric will occur for both

$$\begin{aligned}
 (39-3) \quad K_{\max} &= hf - \Phi \\
 &= (4.14 \times 10^{-15} \text{ eV} \cdot \text{sec}) (3 \times 10^{15} \frac{1}{\text{sec}}) - 2.3 \text{ eV} \\
 &= \boxed{10.1 \text{ eV}}
 \end{aligned}$$

$$(39-4) \text{ a) } hf = K_{\max} + \Phi$$

Set $f = \frac{c}{\lambda}$ and $K_{\max} = eV_{\text{stop}}$ to get

$$\begin{aligned}
 \frac{hc}{\lambda} &= eV_{\text{stop}} + \Phi \\
 \text{or } V_{\text{stop}} &= \frac{hc/\lambda - \Phi}{e} \\
 &= \frac{1240 \text{ eV} \cdot \text{nm}}{400 \text{ nm}} - 1.8 \text{ eV} \\
 &\quad \text{1 elementary charge} \\
 &= \boxed{1.30 \text{ V}}
 \end{aligned}$$

$$\text{b) } K_{\max} = \frac{1}{2} m_e v_{\max}^2 = eV_{\text{stop}}$$

$$\begin{aligned}
 \text{So } v_{\max} &= \sqrt{\frac{2eV_{\text{stop}}}{m_e}} \\
 &= \sqrt{\frac{2(1.6 \times 10^{-19} \text{ C})(1.30 \text{ V})}{9.11 \times 10^{-31} \text{ kg}}} \\
 &= \boxed{6.76 \times 10^5 \frac{\text{m}}{\text{sec}}}
 \end{aligned}$$

$$(39-5) \text{ a) } f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/sec}}{35 \times 10^{-12} \text{ m}} = \boxed{8.57 \times 10^{18} \text{ Hz}}$$

$$\text{b) } E = hf = (4.14 \times 10^{-15} \text{ eV} \cdot \text{sec}) (8.57 \times 10^{18} \frac{1}{\text{sec}}) = \boxed{3.55 \times 10^4 \text{ eV}}$$

$$\begin{aligned}
 \text{c) } p &= \frac{E}{c} = \frac{(3.55 \times 10^4 \text{ eV}) (\frac{1.6 \times 10^{-19} \text{ J}}{\text{eV}})}{3 \times 10^8 \text{ m/sec}} \\
 &= \boxed{1.89 \times 10^{-23} \text{ kg} \cdot \text{m/sec}}
 \end{aligned}$$

$$(39-6) a) \Delta\lambda = \lambda_f - \lambda_i = \frac{h}{m_e c} (1 - \cos\phi) = \frac{hc}{m_e c^2} (1 - \cos\phi)$$

$$\text{So } \Delta\lambda = \frac{1240 \text{ eV} \cdot \text{nm}}{511 \times 10^3 \text{ eV}} (1 - \cos 30^\circ)$$

$$= 2.43 \times 10^{-3} \text{ nm} (1 - \cos 30^\circ)$$

$$\lambda_f - \lambda_i = 3.25 \times 10^{-4} \text{ nm} = 0.325 \text{ pm}$$

$$\text{Thus } \lambda_f = \lambda_i + 0.325 \text{ pm}$$

$$= 2.4 \text{ pm} + 0.325 \text{ pm}$$

$$= \boxed{2.73 \text{ pm}}$$

$$b) \lambda_f - \lambda_i = (2.43 \times 10^{-3} \text{ nm}) (1 - \cos 120^\circ)$$

$$= 3.65 \times 10^{-3} \text{ nm} = 3.65 \text{ pm}$$

$$\text{So } \lambda_f = \lambda_i + 3.65 \text{ pm}$$

$$= 2.4 \text{ pm} + 3.65 \text{ pm}$$

$$= \boxed{6.05 \text{ pm}}$$

$$(39-7) \lambda = \frac{h}{p} \text{ and } K = \frac{p^2}{2m_e} \text{ and } K = 25 \text{ keV}$$

Let's use a factor of c to make the calculation easier

$$\lambda = \frac{hc}{pc} \text{ and } K = \frac{(pc)^2}{2m_e c^2} \text{ and } K = 25 \text{ keV}$$

$$\text{So } pc = \sqrt{2m_e c^2 K}$$

$$\text{and thus } \lambda = \frac{hc}{\sqrt{2m_e c^2 K}}$$

$$\lambda = \frac{1240 \text{ eV}\cdot\text{nm}}{\sqrt{2(511 \times 10^3 \text{ eV})(25 \times 10^3 \text{ eV})}}$$

$$= 7.76 \times 10^{-3} \text{ nm} = \boxed{7.76 \text{ pm}}$$

$$(39-8) \quad \Delta p \approx \frac{\hbar}{\Delta x} = \frac{h}{2\pi \Delta x} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{sec}}{2\pi (50 \times 10^{-12} \text{ m})}$$

$$= \boxed{2.11 \times 10^{-24} \text{ Kg}\cdot\text{m/sec}}$$

$$(40-9) \quad E = \frac{h^2}{8m_e L^2} n^2 \quad \text{with } n=1$$

$$\text{a) So } E = \frac{(hc)^2}{8m_e c^2 L^2} \quad \text{for the electron}$$

$$= \frac{(1240 \text{ eV}\cdot\text{nm})^2}{8(511 \times 10^3 \text{ eV})(0.1 \text{ nm})^2}$$

$$= \boxed{37.6 \text{ eV}}$$

$$\text{b) } E = \frac{(hc)^2}{8m_p c^2 L^2} \quad \text{for the proton}$$

$$= \frac{(1240 \text{ eV}\cdot\text{nm})^2}{8(938 \times 10^6 \text{ eV})(0.1 \text{ nm})^2}$$

$$= \boxed{2.05 \times 10^{-2} \text{ eV}}$$

$$(40-10) \quad E = \frac{(hc)^2}{8m_e c^2 L^2} n^2 \quad \text{with } n=1$$

$$= \frac{(1240 \text{ eV}\cdot\text{nm})^2}{8(511 \times 10^3 \text{ eV})(1.4 \times 10^{-5} \text{ nm})^2}$$

$$= 1.92 \times 10^9 \text{ eV} = \boxed{1.92 \text{ GeV}}$$

The atomic nucleus could not confine an electron with this much energy! There are no electrons in the nucleus.

(40-11) a) The energies of the hydrogen atom's quantum states are

$$E_n = -13.6 \text{ eV} \frac{1}{n^2}$$

When an atom absorbs or emits a photon, the photon's energy is

$$\begin{aligned} E_{\text{photon}} &= E_{\text{high}} - E_{\text{low}} \\ &= 13.6 \text{ eV} \left(\frac{1}{n_{\text{low}}^2} - \frac{1}{n_{\text{high}}^2} \right) \\ &= 13.6 \text{ eV} \left(\frac{1}{1^2} - \frac{1}{3^2} \right) \\ &= \boxed{12.1 \text{ eV}} \end{aligned}$$

$$b) p = \frac{E}{c} = \frac{(12.1 \text{ eV}) \left(\frac{1.6 \times 10^{-19} \text{ J}}{1 \text{ eV}} \right)}{3 \times 10^8 \text{ m/sec}}$$

$$= \boxed{6.45 \times 10^{-27} \text{ kg} \cdot \text{m/sec}}$$

$$c) \lambda = \frac{hc}{E} = \frac{1240 \text{ eV} \cdot \text{nm}}{12.1 \text{ eV}} = \boxed{102 \text{ nm}}$$

$$(40-12) a) E_{\text{absorbed}} = 13.6 \text{ eV} \left(\frac{1}{n_{\text{low}}^2} - \frac{1}{n_{\text{high}}^2} \right)$$

$$= 13.6 \text{ eV} \left(\frac{1}{1^2} - \frac{1}{4^2} \right)$$

$$= \boxed{12.8 \text{ eV}}$$

b) How can the electron get from $n=4$ to $n=1$?

$4 \rightarrow 1$ one step

$4 \rightarrow 3 \rightarrow 1$ or $4 \rightarrow 2 \rightarrow 1$ two steps

$4 \rightarrow 3 \rightarrow 2 \rightarrow 1$ three steps

The six transitions involved are

$4 \rightarrow 3$, $4 \rightarrow 2$, $4 \rightarrow 1$, $3 \rightarrow 2$, $3 \rightarrow 1$, $2 \rightarrow 1$

The energies are:

$$4 \rightarrow 3: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{3^2} - \frac{1}{4^2} \right) = 0.661 \text{ eV}$$

$$4 \rightarrow 2: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{2^2} - \frac{1}{4^2} \right) = 2.55 \text{ eV}$$

$$4 \rightarrow 1: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{1^2} - \frac{1}{4^2} \right) = 12.8 \text{ eV}$$

$$3 \rightarrow 2: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{2^2} - \frac{1}{3^2} \right) = 1.89 \text{ eV}$$

$$3 \rightarrow 1: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{1^2} - \frac{1}{3^2} \right) = 12.1 \text{ eV}$$

$$2 \rightarrow 1: E_{\text{photon}} = 13.6 \text{ eV} \left(\frac{1}{1^2} - \frac{1}{2^2} \right) = 10.2 \text{ eV}$$

