Name____

Physics 111 Quiz #7, November 12, 2021

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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A certain metal is first illuminated with light of wavelength $\lambda_1 = 350nm$ and then by light with wavelength $\lambda_2 = 540nm$. In both cases, electrons are ejected from the metal's surface and the speed of the ejected electrons differs by a factor of 2 in the two cases.

1. What is the ratio of the kinetic energies K_1 and K_2?

   The energy of the photon is inversely proportional to the wavelength. The larger wavelength has the smaller kinetic energy and thus the smaller speed. We have:

   $$K_2 = \tfrac{1}{2}mv_2^2 = \tfrac{1}{2}mv^2$$

   $$K_1 = \tfrac{1}{2}mv_1^2 = \tfrac{1}{2}m(2v)^2 = 4\left(\tfrac{1}{2}mv^2\right) = 4K_2$$

   $$\frac{K_1}{K_2} = 4$$

2. What is the work function of the metal in eV?

   $$K_1 = 4K_2 \rightarrow \tfrac{hc}{\lambda_1} - \phi = 4\left(\tfrac{hc}{\lambda_2} - \phi\right) \rightarrow \tfrac{4hc}{\lambda_2} - \tfrac{hc}{\lambda_1} = 3\phi \rightarrow \phi = \tfrac{hc}{3}\left(\tfrac{1}{\lambda_2} - \tfrac{1}{\lambda_1}\right)$$

   $$\phi = \left\{\frac{6.63 \times 10^{-34}Js \times 3 \times 10^8\frac{m}{s}}{3}\left(\frac{4}{540 \times 10^{-9}m} - \frac{1}{350 \times 10^{-9}m}\right)\right\} \times \frac{1eV}{1.6 \times 10^{-19}J} = 1.88eV$$

3. What is the maximum wavelength (in nm) that will produce photoelectrons?

   $$K = \frac{hc}{\lambda_{max}} - \phi = 0 \rightarrow \lambda_{max} = \frac{hc}{\phi} = \frac{6.63 \times 10^{-34}Js \times 3 \times 10^8\frac{m}{s}}{1.88eV \times \frac{1.6\times10^{-19}J}{1eV}} = 6.61 \times 10^{-9}m = 661nm$$

4. Suppose tungsten x-rays are used in a Compton effect experiment with an energy 69.3182keV. Electrons are observed to recoil with a speed of $v = 0.2c$. What is the energy of the scattered x-rays?

$$K = (\gamma - 1)mc^2 = \left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right)mc^2 = \left(\frac{1}{\sqrt{1-\frac{(0.2c)^2}{c^2}}} - 1\right) \times 511\frac{keV}{c^2} \times c^2 = 10.5372keV$$

$$E = E' + K \rightarrow E' = E - K = 69.3182keV - 10.5372keV = 58.781keV$$

5. At what angle (with respect to the direction of the incident x-rays) was the x-ray detector placed to detect the scattered x-rays?

$$\frac{1}{E'} = \frac{1}{E} + \frac{(1-\cos\phi)}{E_{rest}} \rightarrow \cos\phi = 1 - E_{rest}\left(\frac{1}{E'} - \frac{1}{E}\right)$$

$$\cos\phi = 1 - 511\frac{keV}{c^2}\left(\frac{1}{58.781keV} - \frac{1}{69.3182keV}\right) = -0.3283 \rightarrow \phi = 109.2^0$$