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When a laser is pointed at a zinc metal surface ($\Phi = 7.85 \times 10^{-13}$ μJ), an electron is ejected with a velocity of 1.44×10^5 mm/ms. What is the wavelength of light that is emitted by the laser? Report your answer in nm.

Ok, let's think about this problem in pieces:

1. Consider the equation $E_{photon} = \Phi + E_k$
   a. Which variable is explicitly told to you in the problem? Is it in SI units? If not, convert it.

$$7.85 \times 10^{-13}\,\mu J \left| \frac{10^{-6}\,J}{1\,\mu J} \right. = 7.85 \times 10^{-19}\,J$$

   b. Can you determine either of the other variables from the information you are given and the extra info below? If so, calculate that value. Make sure you are careful with units (when in doubt, use SI units).

$E_{photon} = h\nu = \frac{hc}{\lambda}$ $\qquad h = 6.626\ x\ 10^{-3}\ \ Js$ $\qquad c = 2.998\ x\ 10^8\ ms^{-1}$

$E_k = \frac{1}{2}mv^2$ $\qquad m_{electron} = 9.109\ x\ 10^{-31}kg$ $\qquad c = \lambda\nu$

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2}(9.109 \times 10^{-31}\,kg)(1.44 \times 10^5\,\tfrac{m}{s})^2 = 9.44 \times 10^{-21}\,J$$

$$v = 1.44 \times 10^5\,\frac{mm}{ms} \left| \frac{10^{-3}\,m}{1\,mm} \right| \frac{1\,ms}{10^{-3}\,s} = 1.44 \times 10^5\,m/s$$

   c. Now put it all together and solve for the 3rd term in the equation $E_{photon} = \Phi + E_k$

$$E_{photon} = 7.85 \times 10^{-19}\,J + 9.44 \times 10^{-21}\,J$$

$$E_{photon} = 7.94 \times 10^{-19}\,J$$

   d. Is this the answer that you need? If not, use the information given above to solve for the variable that you want. Make sure to note that the problem is asking for the answer in a specific unit.

$$E = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34}\,Js)(2.998 \times 10^8\,\frac{m}{s})}{7.94 \times 10^{-19}\,J}$$

$$\lambda = 2.5 \times 10^{-7}\,m \left| \frac{1\,nm}{10^{-9}\,m} \right. = 250\,nm$$

2. Now try it yourself. Determine the velocity of an electron that is ejected from a Uranium surface when 145 nm light is directed at that surface. The threshold energy of Uranium is 3.6 eV (note that 1 eV = 1.602×10^{-19} J).

$$3.6\ eV \left| \frac{1.602 \times 10^{-19} J}{1\ eV} \right. = 5.77 \times 10^{-19} J = \phi$$

$$\lambda = 145 nm \left| \frac{10^{-9} m}{1 nm} \right. = 1.45 \times 10^{-7} m \qquad E_{photon} = \frac{hc}{\lambda}$$

$$E_{photon} = \frac{(6.626 \times 10^{-34} Js)(2.998 \times 10^{8} m/s)}{1.45 \times 10^{-7} m} = 1.37 \times 10^{-18} J$$

$$E_K = E_{photon} - \phi = 1.37 \times 10^{-18} J - 5.77 \times 10^{-19} J = 7.93 \times 10^{-19} J$$

$$E_K = \frac{1}{2} m v^2 \qquad v = \left(\frac{2 E_K}{m}\right)^{1/2} = \left(\frac{2(7.93 \times 10^{-19} J)}{9.109 \times 10^{-31} kg}\right)^{1/2} = 1.32 \times 10^{5} \frac{m}{s}$$

3. The threshold energy of carbon is 4.81 eV while aluminum is 4.08 eV. Using your understanding of Coulomb's Law, explain why it takes less energy to release and electron from aluminum.

$$E_p = c\frac{q_1 q_2}{r} \text{ where c is a constant}$$

Carbon: $Z = 6$ $\quad E_p = \frac{(+6)(-1)}{r} = \frac{-6}{r}$

Al $\quad Z = 13$ $\quad E_p = \frac{(+13)(-1)}{r} = \frac{-13}{r}$

So, If the radii were the same, the Al e^- would be held more tightly... but this is not the case. Al $n=3$ + C $n=2$, so $r_{Al} > r_C$ making the attractive energy lower.

4. Determine the frequency of a photon required to release an electron from carbon.

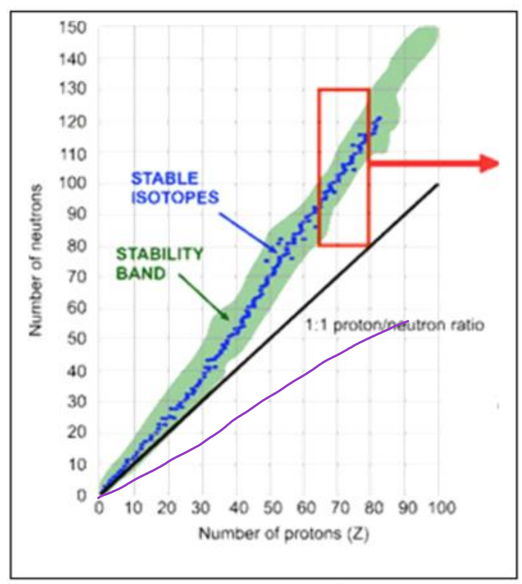
$$\frac{4.81\,eV \mid 1.602\times10^{-19}\,J}{\mid 1\,eV} = 7.706\times10^{-19}\,J$$

In this case, we are not told that the e^- has any kinetic energy, so $E_K = \emptyset$

$$E_{photon} = \phi = 7.706\times10^{-19}\,J$$

$$E_{photon} = h\nu \qquad \nu = \frac{h}{E} = \frac{6.626\times10^{-34}\,Js}{7.706\times10^{-19}\,J} = 8.6\times10^{-16}\,s^{-1}$$

5. The image to the right shows the relationship between the number of neutrons and protons for stable nuclei.



   a. As stable nuclei get larger, do the number of protons increase more quickly or slowly than the number of neutrons?

      What would the graph look like if the opposite were true?

      purple line

   b. Using your understanding of Coulomb's law, propose a reason that one subatomic particle needs to be more abundant than the other as nuclei get larger.

protons (positive charges) are forced to pack into a very small area. The proximity of these charges is very unfavorable. Neutrons serve as buffers that prevent the protons from bumping into each other. As the Z increases, more buffer (neutrons) is needed for stability.

6. Two stable isotopes of lithium exist. Lithium-6 has an exact mass of 6.015 amu and lithium-7 has an exact mass of 7.016 amu.

   a. What is the average mass of lithium? 6.94 amu

   b. Is this number closer to the mass of ^{6}Li or ^{7}Li? Based on this, which isotope do you think is more abundant?

      ^{7}Li

   c. Calculate the natural abundance of each isotope.

$x = {}^{6}Li$

$y = {}^{7}Li$

$x + y = 1$

$y = 1 - x$

$6.94 = 6.015x + 7.016y$

$6.94 = 6.015x + 7.016(1-x)$

$6.94 = 6.015x + 7.016 - 7.016x$

combine like terms

$-0.076 = -1.001x$

$x = 0.076 \Rightarrow 7.6\%$

^{6}Li

$y = 1 - x = 1 - 0.076$

$x = 0.924$

92.4%

^{7}Li