*Name*__________________________

PIXE Homework #2 - Physics 100

Union College Fall 2024

1. Describe the PIXE process using words and/or diagrams. If you use a diagram, please explain what the diagram is about.

   PIXE stands for proton induced x-ray emission spectroscopy. This is a technique whereby a high-energy proton interacts with a target nucleus ejecting an electron from an inner atomic orbital of the target atom. An electron from a higher atomic orbital de-excites to the vacancy in the lower atomic orbital with an emission of an x-ray photon. The energy of the photon is characteristic of the atomic nucleus.

2. What are the K_α and K_β transition energies for the following elements: ${}^{40}_{20}Ca$, ${}^{59}_{27}Co$, and ${}^{197}_{79}Au$? (Please use the equations given in the lecture and not the table of x-ray energies to do the calculation.)

   The x-ray energies are given by $\Delta E = -Z^2 \frac{me^4}{2(4\pi\varepsilon_0)^2 \hbar^2}\left(\frac{1}{n_l^2} - \frac{1}{n_u^2}\right)$*, where for the* α*-transition we have* $n_u = 2 \rightarrow n_l = 1$ *and for a* β*-transition* $n_u = 3 \rightarrow n_l = 1$*. Thus, for a* K_α *transition (evaluating the constants) we have*

$$\Delta E_\alpha = -Z^2 \frac{me^4}{2(4\pi\varepsilon_0)^2 \hbar^2}\left(\frac{1}{n_l^2} - \frac{1}{n_u^2}\right) = -Z^2\left[\frac{9.11\times10^{-31}kg\times\left(1.6\times10^{-19}C\right)^4}{32\pi^2\left(8.85\times10^{-12}\,\frac{C^2}{Nm^2}\right)^2\left(\frac{6.63\times10^{-34}Js}{2\pi}\right)^2}\right]\left(\frac{1}{1} - \frac{1}{4}\right)$$

$$\Delta E_\alpha = \left(1.626\times10^{-18}J\right)Z^2 = (10.16)Z^2$$

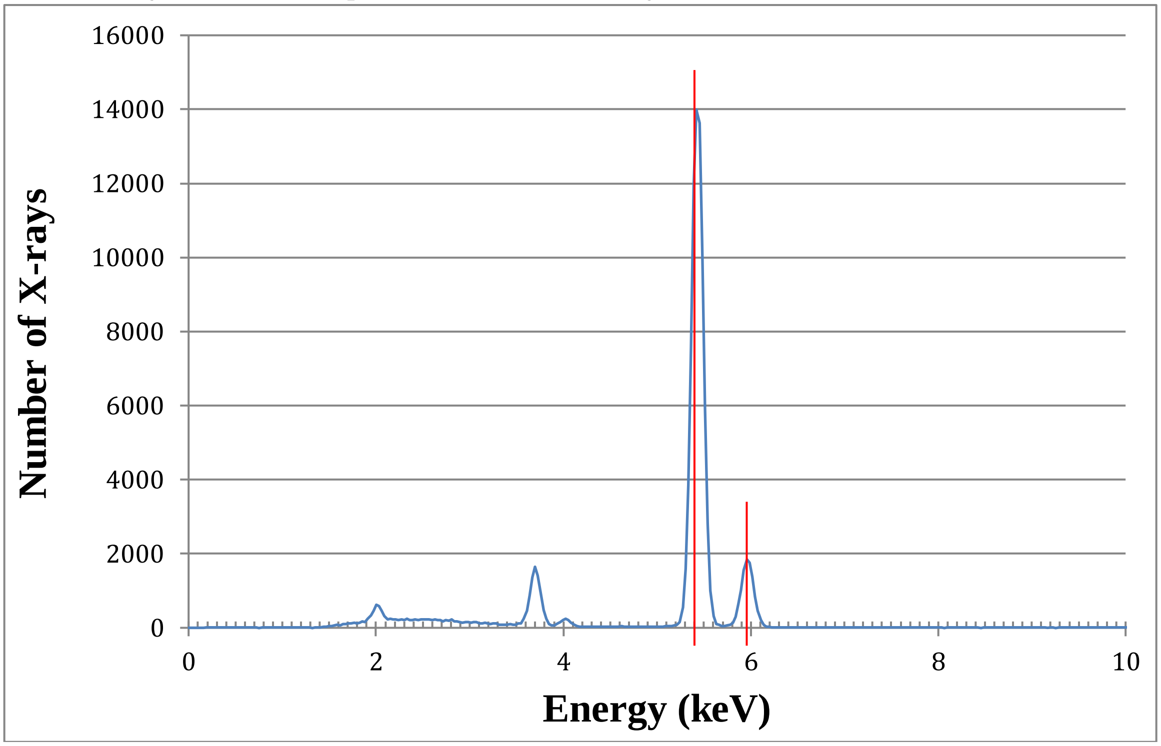
, while for a K_β *transition*

$$\Delta E_\beta = -Z^2 \frac{me^4}{2(4\pi\varepsilon_0)^2 \hbar^2}\left(\frac{1}{n_l^2} - \frac{1}{n_u^2}\right) = -Z^2\left[\frac{9.11\times10^{-31}kg\times\left(1.6\times10^{-19}C\right)^4}{32\pi^2\left(8.85\times10^{-12}\,\frac{C^2}{Nm^2}\right)^2\left(\frac{6.63\times10^{-34}Js}{2\pi}\right)^2}\right]\left(\frac{1}{1} - \frac{1}{9}\right)$$

$$\Delta E_\beta = \left(1.927\times10^{-18}J\right)Z^2 = (12.04eV)Z^2$$

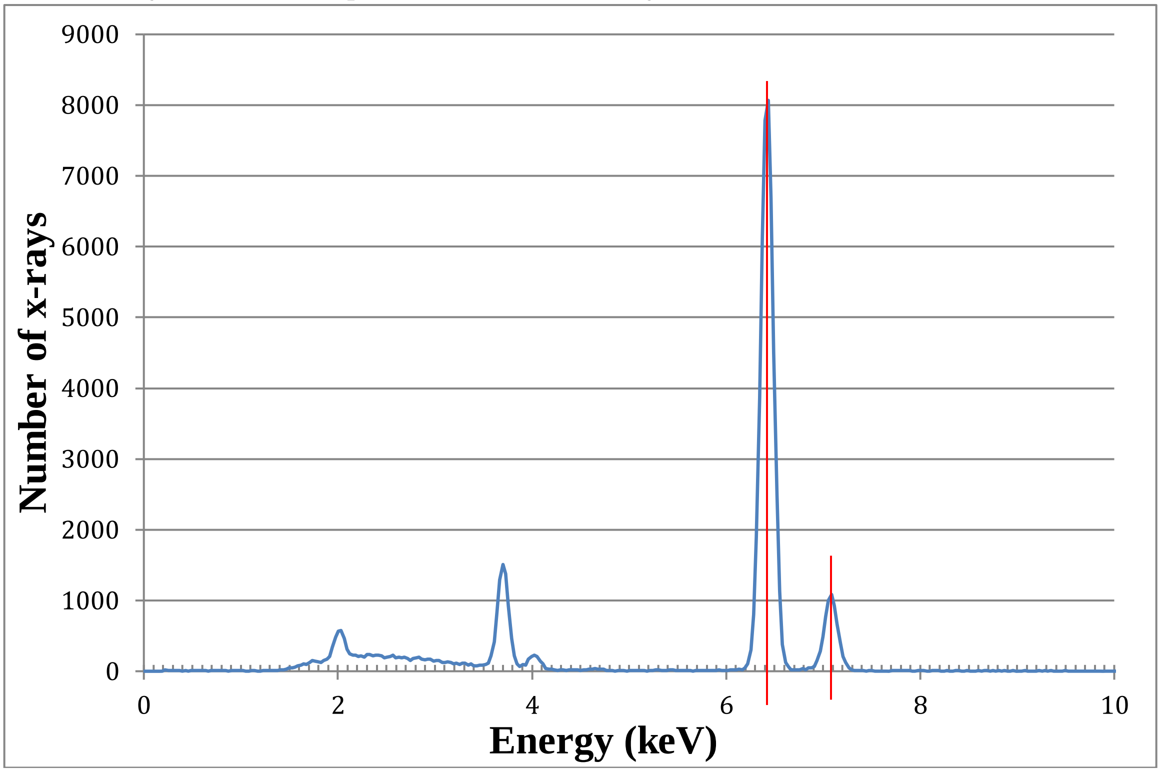
Element	ΔE_α (keV)	ΔE_α (J)	ΔE_β (keV)	ΔE_β (J)
${}^{40}_{20}Ca$	4.064	6.5×10^{-16}	4.816	7.7×10^{-16}
${}^{59}_{27}Co$	7.407	1.19×10^{-15}	8.78	1.4×10^{-15}
${}^{197}_{79}Au$	63.41	1.02×10^{-14}	75.14	1.2×10^{-14}

3. Given the *PIXE* spectrum of a single element standard shown below, what is the element indicated by the red lines? Hint: Approximate the energy of the peaks and use the unmodified energy equations to determine the atomic number of the element. You may need to use a periodic table to identify the element.



The energy of the K_a *peak is approximately* $5.4keV$*, while the* K_a *peak is* $6.0keV$. *Using the formula from problem #2 we can calculate the atomic number of the unknown element. Using the* K_a *energy, we have* $\Delta E_a = 5.4keV = (10.16eV)Z^2 \rightarrow Z = 22.5$ *and thus the element could be either Ti (* $Z = 22$ *) or V (* $Z = 23$*). From the* K_b *energy, we have* $\Delta E_b = 6.0keV = (12.04eV)Z^2 \rightarrow Z = 22.4$ *and thus the element could be either Ti (* $Z = 22$ *) or V (* $Z = 23$*). Most likely we'd choose titanium.*

4. Given the *PIXE* spectrum of a single element standard shown below, what is the element indicated by the red lines? Hint: Approximate the energy of the peaks and use the unmodified energy equations to determine the atomic number of the element. You may need to use a periodic table to identify the element.



The energy of the K_a *peak is approximately* $6.4 keV$, *while the* K_a *peak is* $7.1 keV$. *Using the formula from problem #2 we can calculate the atomic number of the unknown element. Using the* K_a *energy, we have* $\Delta E_a = 6.4 keV = (10.16 eV) Z^2 \rightarrow Z = 25$ *and thus the element could be Mn (* $Z = 25$ *). From the* K_b *energy, we have* $\Delta E_b = 7.1 keV = (12.04 eV) Z^2 \rightarrow Z = 24.3$ *and thus the element could be either Cr (* $Z = 24$ *) or Mn (* $Z = 25$ *). We'd most likely choose chromium.*