Name___________________________
PIXE Homework #2 - Physics 100
Union College Fall 2016

1. Describe the PIXE process.

   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: ${}^{19}_{9}F$, ${}^{59}_{27}Co$, 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*

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

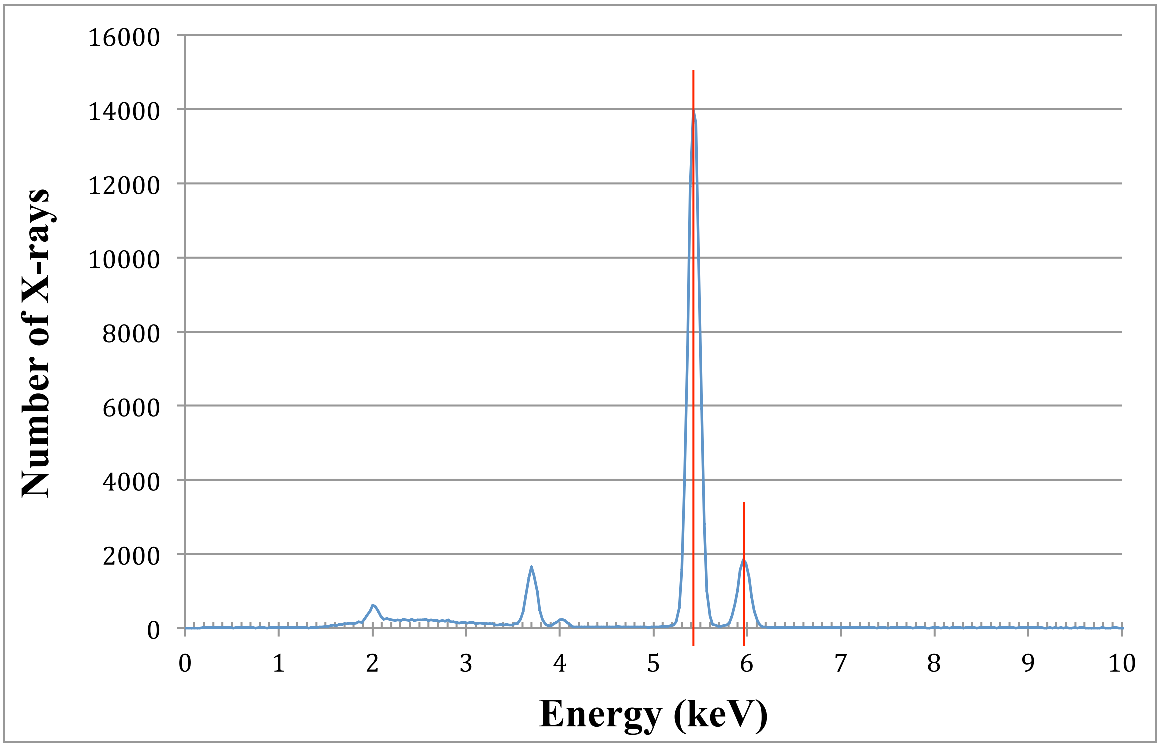
$$\Delta E_\beta = \left(1.927\times10^{-18}J\right)Z^2 = (12.04eV)Z^2$$

Element	ΔE_α (keV)	ΔE_α (J)	ΔE_β (keV)	ΔE_β (J)
${}^{19}_{9}F$	0.822	1.31×10^{-16}	0	0
${}^{59}_{27}Co$	7.407	1.19×10^{-15}	8.78	1.40×10^{-15}
${}^{197}_{79}Au$	63.41	1.02×10^{-14}	75.14	1.20×10^{-14}

3. What is the ratio of the K_α energies of ${}^{238}_{92}U$ to ${}^{12}_{6}C$?

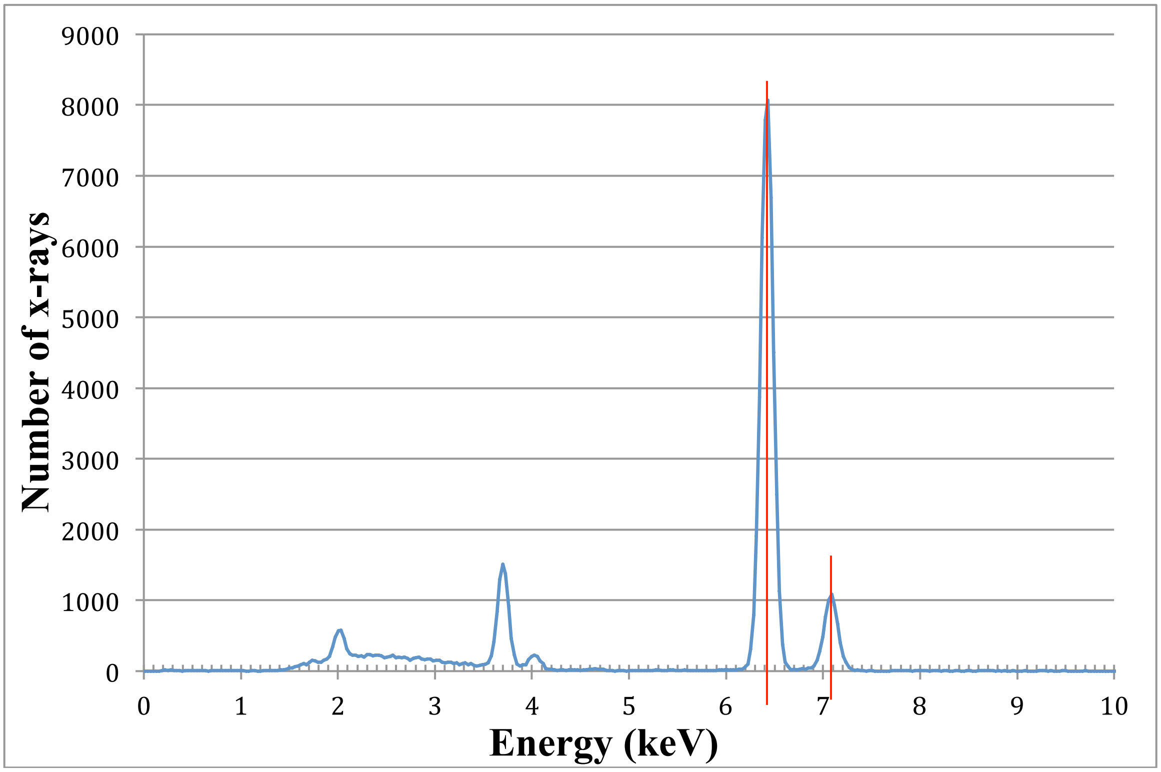
Using the formula above: $\frac{U_{K_\alpha}}{C_{K_\alpha}} = \frac{(92)^2}{(6)^2} = 235$ *where all of the constants cancel by taking the ratio.*

4. Given the *PIXE* spectrum of a single element standard shown below, what are the elements?



The energy of the K_α *peak is approximately* $5.4keV$, *while the* K_α *peak is* $6.0keV$. *Using the formula from problem #2 we can calculate the atomic number of the unknown element. Using the* K_α *energy, we have* $\Delta E_\alpha = 5.4keV = (10.16eV)Z^2 \rightarrow Z = 22.5$ *and thus the element could be either Ti (*$Z = 22$*) or V (*$Z = 23$*). From the* K_β *energy, we have* $\Delta E_\beta = 6.0keV = (12.04eV)Z^2 \rightarrow Z = 22.4$ *and thus the element could be either Ti (*$Z = 22$*) or V (*$Z = 23$*).*

5. Given the *PIXE* spectrum of a single element standard shown below, what are the elements?



The energy of the K_α *peak is approximately* $6.4keV$*, while the* K_α *peak is* $7.1keV$*. Using the formula from problem #2 we can calculate the atomic number of the unknown element. Using the* K_α *energy, we have* $\Delta E_\alpha = 6.4keV = (10.16eV)Z^2 \rightarrow Z = 25$ *and thus the element could be Mn (*$Z = 25$*). From the* K_β *energy, we have* $\Delta E_\beta = 7.1keV = (12.04eV)Z^2 \rightarrow Z = 24.3$ *and thus the element could be either Cr (*$Z = 24$*) or Mn (*$Z = 25$*).*