*Name*__________________________

PIXE Homework #3 - Physics 100

Union College Fall 2016

1. Suppose that your x-ray detector had an energy resolution of $\Delta E = 0.5keV$, would it be able to separate the K_α lines for platinum($^{195}_{78}Pt$) and gold($^{197}_{79}Au$)? An energy resolution means that anything smaller than this value, and I won't be able to distinguish the lines from each other – the lines will overlap. In other words on an x-ray energy spectrum (a graph of the intensity of x-rays versus their energy, as was shown in homework 2) would you be able to tell the K_α line of platinum from the K_α line of gold?

   $\Delta E = 0.5keV$ *corresponds to* $\Delta E = 500eV$. *I need to determine the* K_α *energies for platinum and gold. They are* $61813eV$ *and* $63409eV$ *respectively. The difference in their energies is* $1596eV$ *and thus since they are separated by more than* $\Delta E = 500eV$ *I'd see them as separate peaks.*

2. What are the two shortest wavelengths for a molybdenum($^{96}_{42}Mo$) atom?

   The two shortest wavelengths are given from the energies. The energies are calculated using

$$\Delta E_\alpha = E_2 - E_1 = -13.6eV(Z-1)^2\left[\frac{1}{4}-1\right] = 17.15keV = 2.74\times10^{-15}J$$

$$\Delta E_\beta = E_3 - E_1 = -13.6eV(Z-1)^2\left[\frac{1}{9}-1\right] = 20.32keV = 3.25\times10^{-15}J$$

   and the wavelengths are given respectively as:

$$\lambda = \frac{hc}{E}$$

$$\lambda_\alpha = \frac{6.63\times10^{-34}Js\times3\times10^8\,\frac{m}{s}}{2.74\times10^{-15}J} = 7.26\times10^{-11}m$$

$$\lambda_\beta = \frac{6.63\times10^{-34}Js\times3\times10^8\,\frac{m}{s}}{3.25\times10^{-15}J} = 6.11\times10^{-11}m$$

3. An unknown single element target is used in a PIXE experiment and characteristic x-rays are produced with wavelengths of $1.55\times10^{-10}m$ and $1.31\times10^{-10}m$. What is most likely the elemental make up of the target?

   Using $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}Js\times\frac{1eV}{1.6\times10^{-19}J}\times3\times10^8\,\frac{m}{s}}{1.55\times10^{-10}m} = 8.02keV$ *and*

   $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}Js\times\frac{1eV}{1.6\times10^{-19}J}\times3\times10^8\,\frac{m}{s}}{1.31\times10^{-10}m} = 9.49keV$, *the element could be Copper* *using the table of x-ray energies, or it could be Zinc. The actual element is copper because the K_α energy is exact.*

4. Show that the Moseley's law for K_α radiation may be expressed as $\sqrt{f} = \sqrt{\frac{3}{4}\left(\frac{13.6eV}{h}\right)}(Z-1)$ where *f* is the x-ray frequency.

$$E_n = -13.6eV(Z-1)^2\left[\frac{1}{n_{upper}^2} - \frac{1}{n_{lower}^2}\right] = hf \rightarrow f = -\frac{13.6eV(Z-1)^2}{h}\left[\frac{1}{n_{upper}^2} - \frac{1}{n_{lower}^2}\right] \rightarrow$$

$$f = \frac{-13.6eV(Z-1)^2}{h} \times \left(\frac{1}{2^2} - \frac{1}{1^2}\right) = \frac{3}{4} \times \frac{13.6eV(Z-1)^2}{h}$$

$$\sqrt{f} = \sqrt{\frac{3}{4} \times \frac{13.6eV}{h}}(Z-1)$$

5. Suppose that you did not have a source of protons in which to perform a PIXE experiment. Rather, you had a source of alpha particles (or helium nuclei.) Describe how you could use the alpha particles to do materials identification of an unknown target material. In particular describe the HIXE (which stands for Helium Induced X-ray Emission spectroscopy) process and what the energy formula for the emitted x-rays might look like.

   HIXE stands for helium induced x-ray emission spectroscopy. This is a technique whereby a high-energy helium nucleus (an alpha particle) 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. The process of using alpha particles would be identical to using protons in the process. As for the "energy formula" the energy formula that we developed in class we obtained by adding together the kinetic and potential energies of an electron in a given orbit. The formula only involves a electron transitioning between two atomic orbitals. It does not reference the incident particle that created the vacancy in the inner atomic orbital. Therefore the energy formula will be exactly the same for HIXE as for PIXE.