X-Ray Spectroscopy

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Conceptual Questions:

1. In this experiment we considered the x-ray spectra of various elements to identify and classify unknown sources. The two processes that produced x-rays in our lab were photoionization and internal conversion. Photoionization, as the name suggests, occurs when an electron vacates an inner-shell due to a high-energy photon. Internal conversion is the process in which an electron vacates an inner-shell due to the transfer of energy of the decaying nucleus to the electron. In our experiment, the x-rays filled vacancies in the K shell, classifying them as "K x-rays".

2. In order to create a highly accurate calibration curve that would allow us to convert channel number to energy value we used samples whose K_α and K_β transitions created high intensity peaks and ignored samples that had low intensity peaks (less than 20 percent intensity). This conversion changed the Counts vs Channel number data returned by the MCA into Counts vs Energy plots, which revealed the x-ray fluorescence spectra of a particular source.

3. The experiment was limited in the fact that the $K_{\alpha 1}$ and $K_{\alpha 2}$ emissions were too close to resolve, and so the value used to plot the calibration curve was the average between the two. The same followed for both K_β emissions.

   Another limitation was that our investigation only considered K x-rays, so emissions landing in other shells (L and M) were not considered.

4. The regime in which our experiment was set up allowed for positive identification of the presence of an element. If the peak was detected at a channel, the channel was converted

to an energy and compared to the expected energy values of known elements.

Results:

1. Figure 1 and 2 display our calibration curves to convert channel number to energy value for both K_α and K_β emissions. In order to obtain the curve, we picked samples with high intensity photopeaks so as to achieve a low uncertainty in the value for where the energy resided in relation to the channel number the peak appeared at. Using the known values for samples' energies we plotted Energy vs Channel from the values given by Iron, Copper, Nickel, Zinc, Zirconium, and Molybdenum. We used these in particular in order to get data for both lighter and heavier elements to span a larger range than if we had only considered light elements or only heavy.

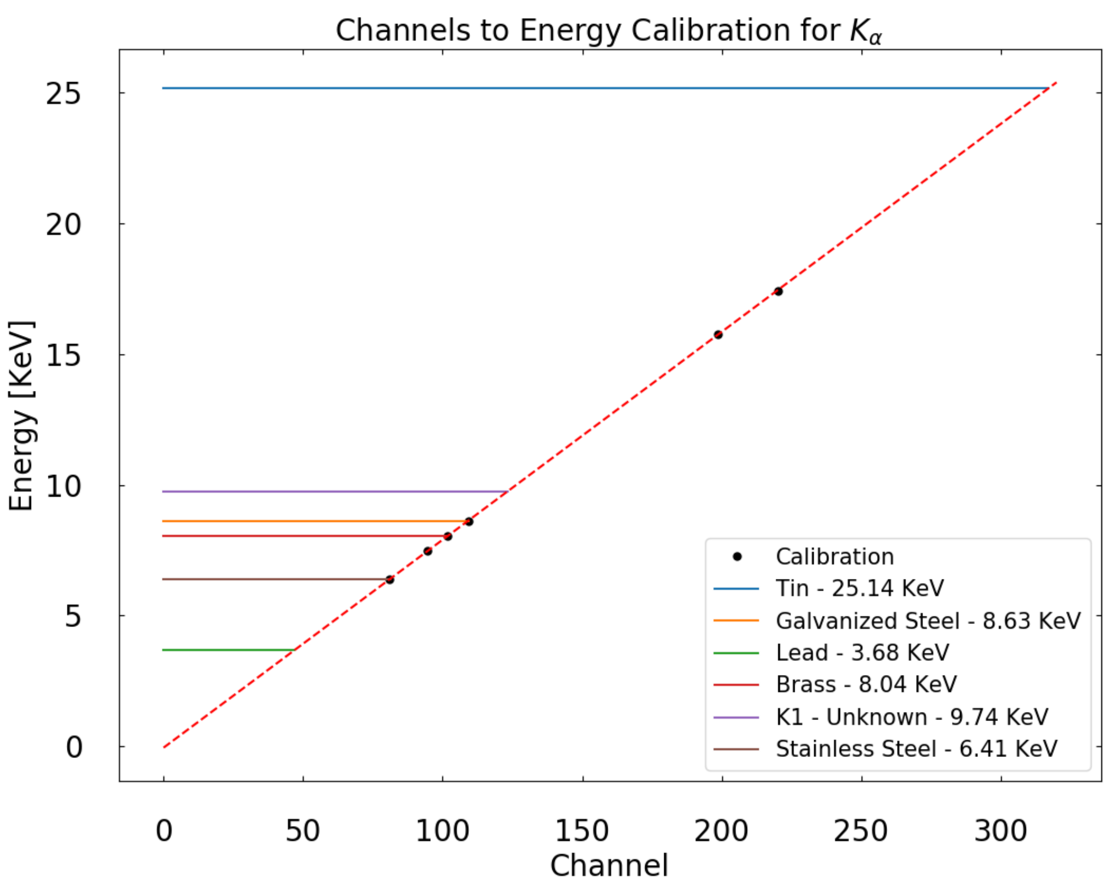

Figure 1: Linear Regression Calibration for K_α emission with analyzed element energies for classification

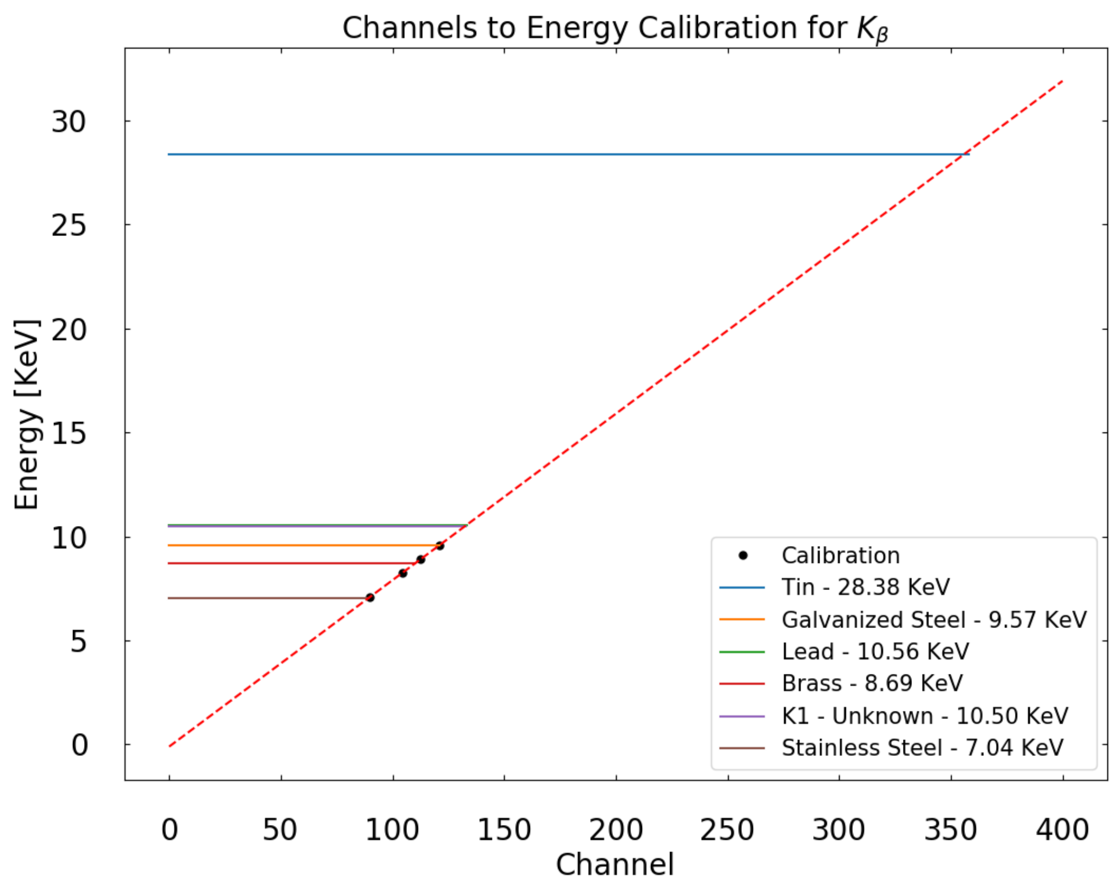

Figure 2: Linear Regression Calibration for K_β emission with analyzed element energies for classification

2. Below are each of the plots of the analyzed samples, note that many samples feature a 30 keV peak that we could not identify. Note that Galvanized Steel was analyzed and shown to include peaks corresponding to Iron and Zinc, which is consistent with the idea that galvanization is the process in which a material is protected with a Zinc layer. However the data file for Galvanized Steel was not saved.

3. Figure 8 displays our fit of $E^{1/2}$ of the K_α x-rays to $a(Z-b)$ to test Moseley's law. We experimentally determined a to be $(103.03 \pm 0.13) \times 10^{-3}\ keV^{1/2}$, which is in agreement with the accepted value of $101 \times 10^{-3} keV^{1/2}$ in terms of the order of magnitude, but not within the uncertainty. We also experimentally determined b to be 1.48 ± 0.05, which is in good agreement with the specified acceptable value of roughly 1 because the deviation is said to be accounted for due to the screening of the nuclear charge.

References

[1] http://www.xrfresearch.com/xrf-spectrum-lead/.

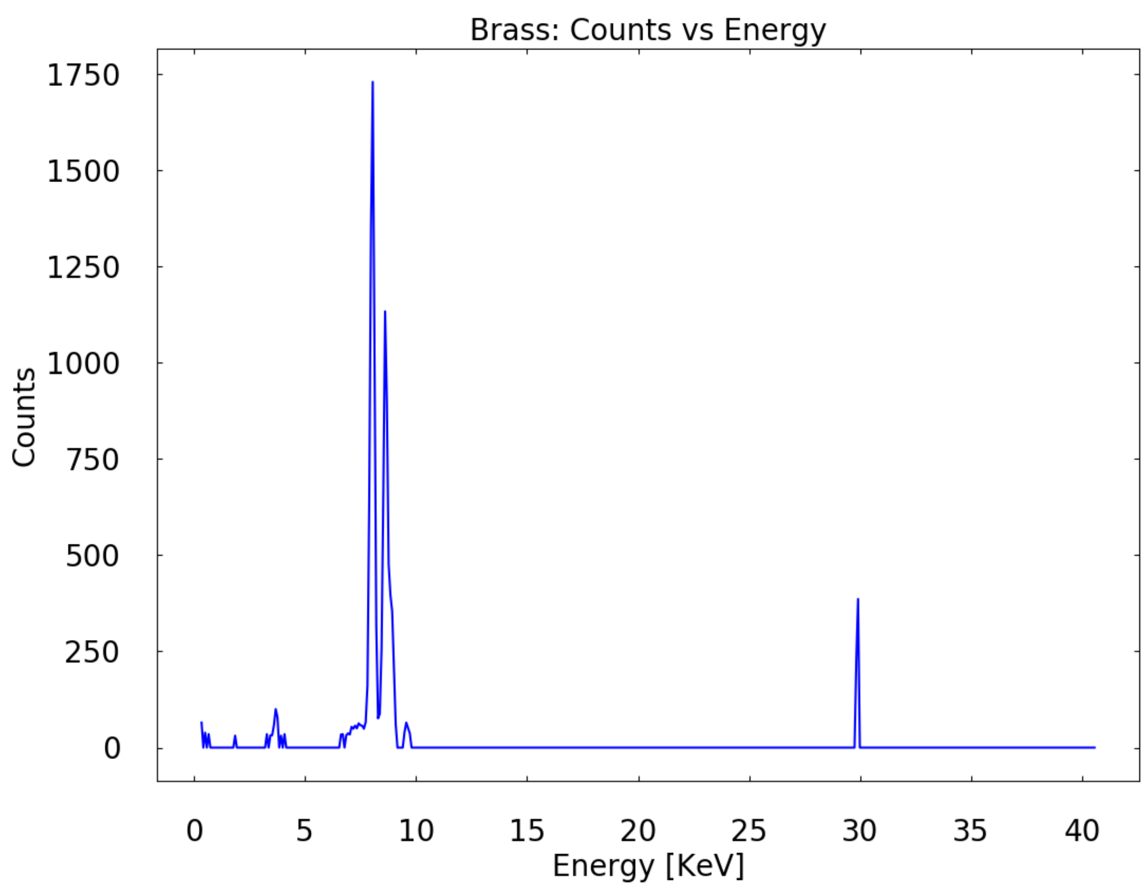

Figure 3: X-ray fluorescence spectrum for Brass. Important features: K_α peaks at 8 and 8.6 keV, consistent with the fact that brass is an alloy of Copper and Zinc.

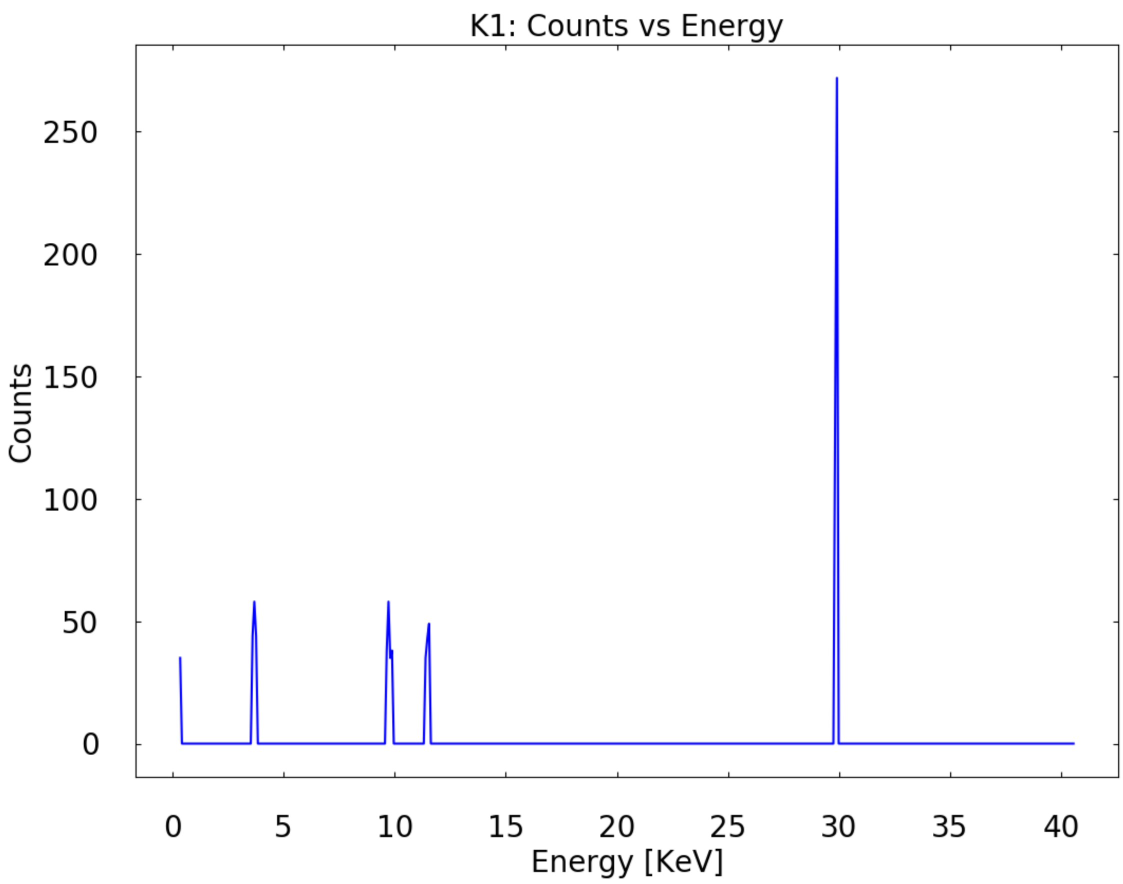

Figure 4: X-ray fluorescence spectrum for Unknown - K1. Important features: Peaks at 10 and 12 keV, 10 keV possibly corresponding to Zinc's K_β emission and 12 keV most likely corresponding to Lead

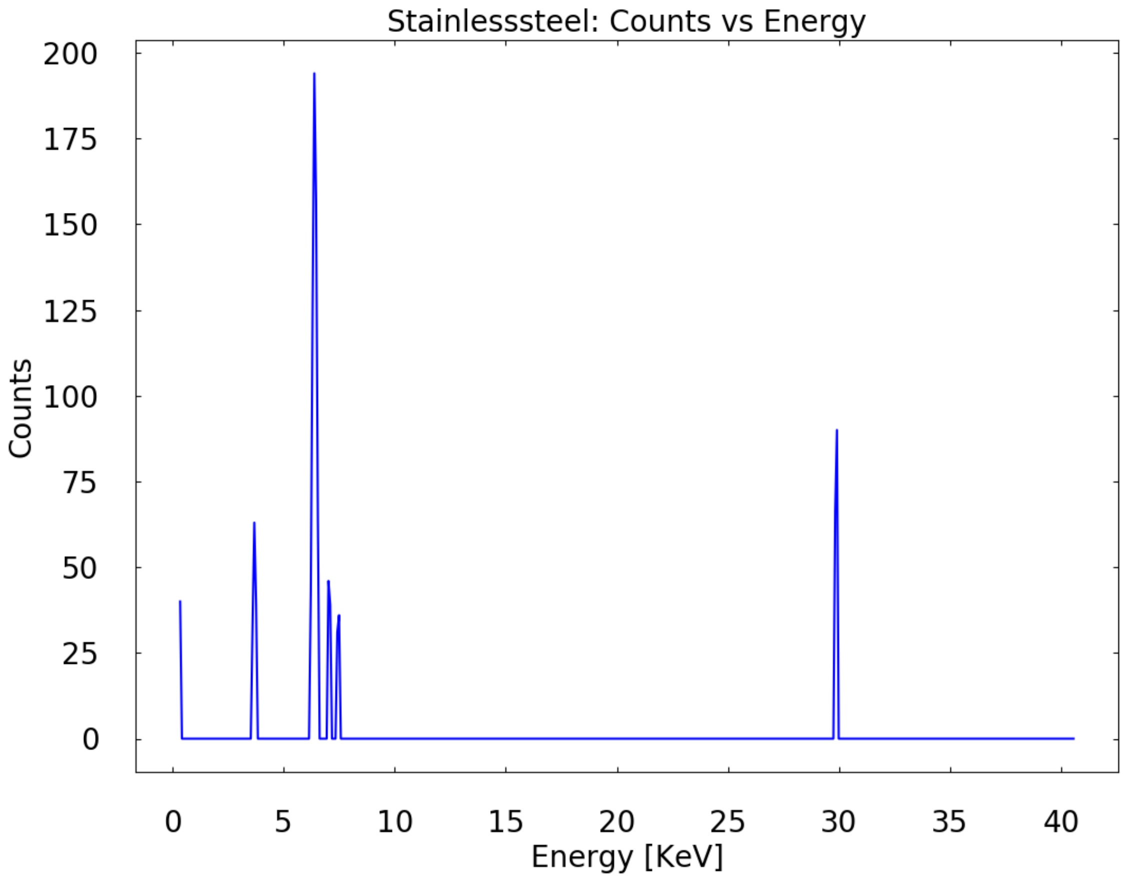

Figure 5: X-ray fluorescence spectrum for Stainless Steel. Important features: Peaks at 6.4, 7, and 7.5 keV, corresponding to Iron's K_α, Iron's K_β, and Nickel's K_β values respectively.

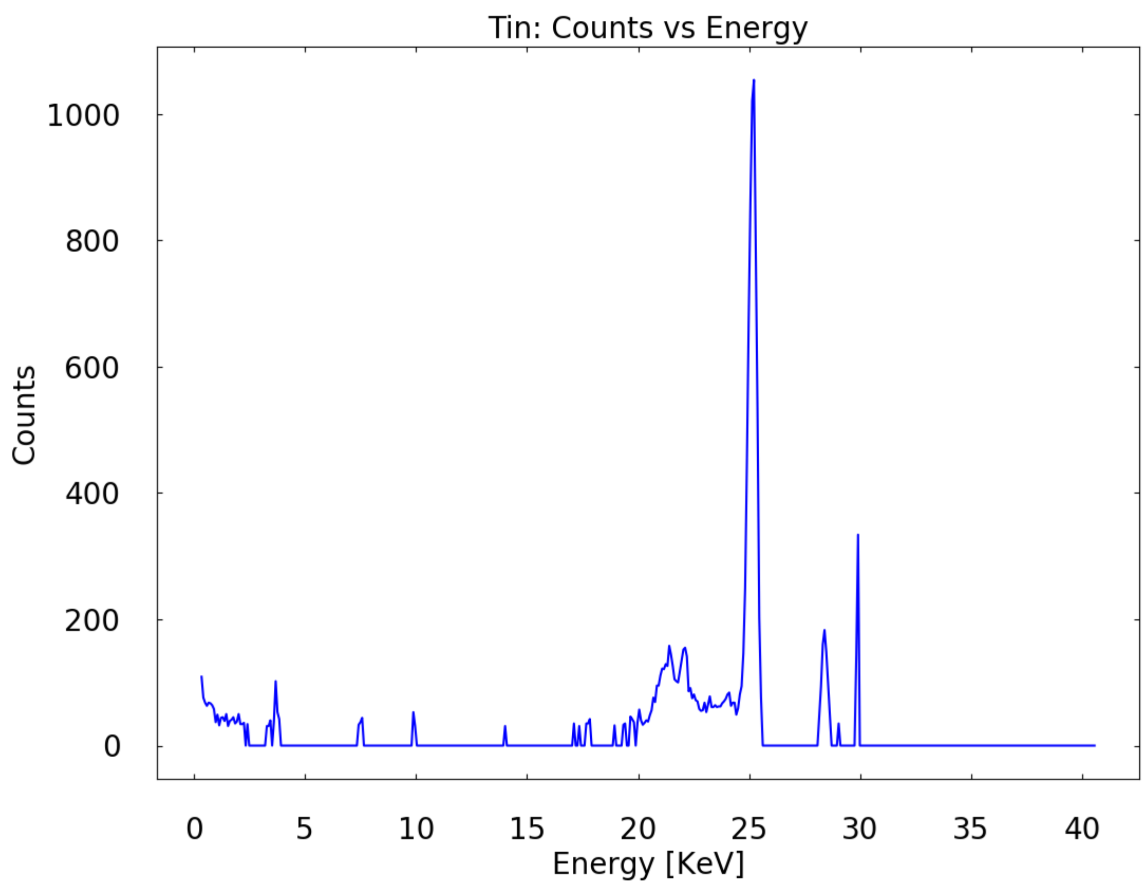

Figure 6: X-ray fluorescence spectrum for Tin. Important features: Most prominent peaks at 25 and 28 keV, where the structures at different points come from Neptunium

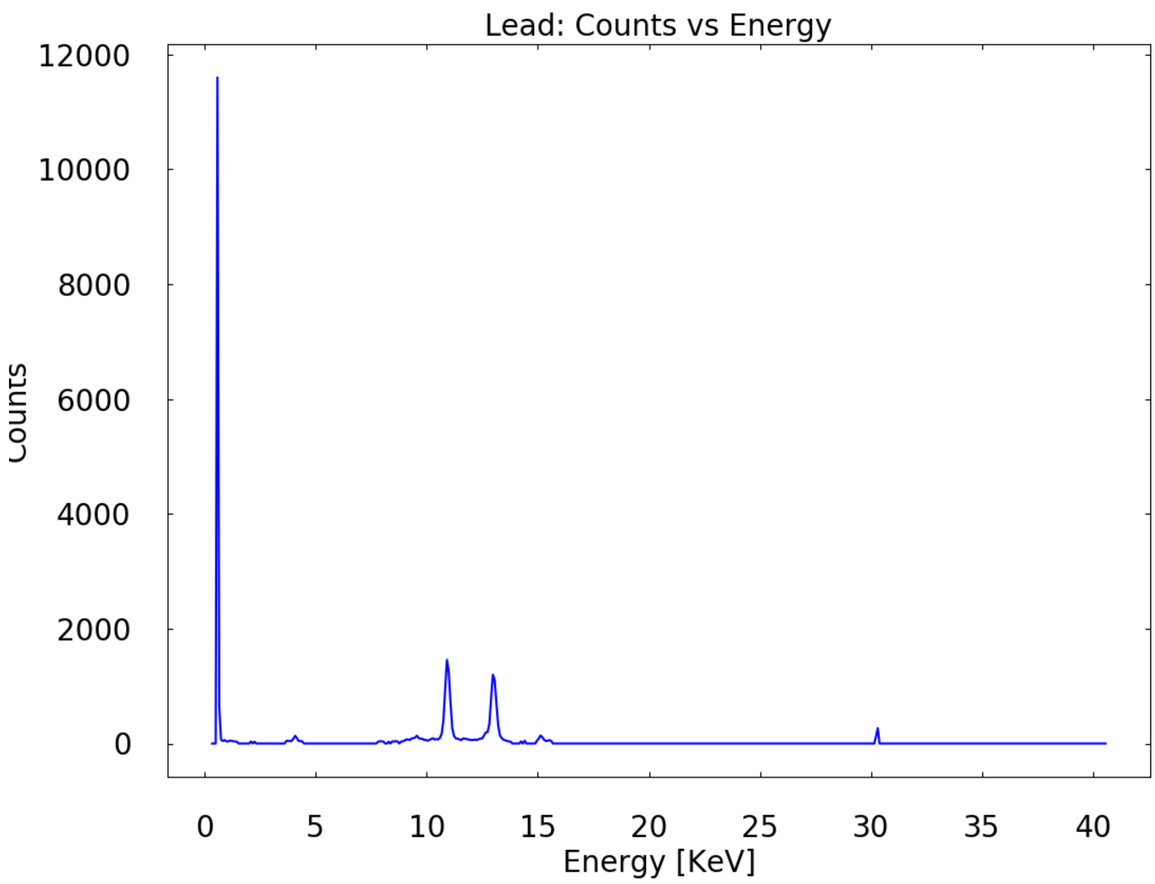

Figure 7: X-ray fluorescence spectrum for Lead. Important features: Most prominent peaks at 11.0, and 13.5 keV. Since these two are the most prominent, we stipulated that 11.0 was most likely K_α and 13.5 was most likely K_β. The other very small peaks are made smaller by the fact that the lead shielding produces the very large peak closest to zero, but the small peaks exist at 15.2, and 4 keV. We suspect that since the source is able to produce L x-rays that these peaks may be the result. There also seems to be a small peak at around 9 keV, but the surrounding structure makes it difficult to differentiate between it and Neptunium. We compared these found peaks to another group's investigation of Lead's fluorescence spectrum and found decent agreement. [1]