X-Ray Studies

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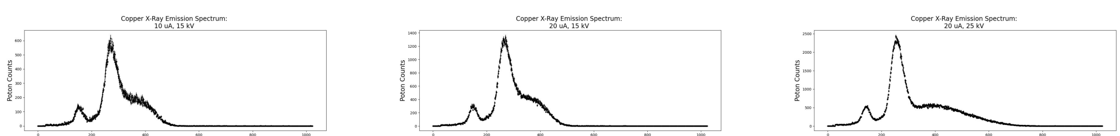
Abstract

X-rays are electromagnetic waves that occupy energies in the range of 0.1 to 100 keV. When x-rays hit a target material, two types of x-rays can be observed: characteristic radiation or bremsstrahlung radiation.[1] Characteristic radiation is unique to each element, proving a reliable way for classifying unknown elements either for medical or experimental research purposes. The specific relationship between an elements atomic number (Z) and the corresponding characteristic radiation (Kalpha) was modeled by Henry Mosely in 1914 and is known as Mosely's Law. [2] This report first tests Mosely's law experimentally and second, creates a full x-ray emission spectrum for Copper using x-ray crystal diffraction.

1 Methods

Our set-up consisted of a Tel-X-Ometer that produced the x-rays by accelerating electrons in the x-ray tube. The x-rays can then be observed using the proportional counter in which ionized electrons with high voltage will further ionize in a cumulative effect. When an electron is ionized, it will strike the central wire, causing a voltage dip proportional to the energy. Therefore, the proportional counter detects x-ray energies via the linear relationship of voltage to energy. We used the method of the proprtional counter in testing Mosely's law. However, the proportional counter was not able to resolve K alpha and K beta characteristic lines. We used the method of Braggs Scattering to achieve higher resolution of the characteristic energy peaks in the second part of creating a full x-ray spectrum for copper. In this method, x-rays in the Tel-X-Ometer were diffracted through a Lithium crystal lattice. The intensity is observed as constructively interfering waves that hit the detector when their wavelengths are in phase according to the Bragg's scattering equation $n\Lambda = 2dsin\theta$.

Using these methods we studied characteristic radiation and bremsstrahlung radiation. Characteristic radiation occurs when electrons with high enough energy eject the inner most shell of the electron known as the K-shell. Subsequently, electrons from higher shells producing quantized characteristic x-rays that depend on the binding energy of the shells as determined by the atomic number (Z). In contrast, bremsstrahlung radiation occurs when the attracctive force between the negatively charged accelerated electron and the positvely charged nucleus alter the trajectory of the electron such that it slows down and loses kinetic energy. Crucially, the electron cannot give off more energy than it has, which easily determins the bremsstrahlung cutoff as directly proportional the voltage applied (Fig. 1).



(a) (b) (c)

Figure 1: The characteristic radiation, or two the peaks, remain the same in a,b, and c, because it is dependent on the atomic number which remains constant. The bremsstrahlung cutoff increases in c) because of the direct proportionality of increased voltage. The photon count increases as a result of increases in b) as a result of of increasing the current, or the amount of electrons to be accelerated.

1

2

1.1 Testing Mosley's Law

In order to test the relationship of atomic number and energy, we first performed a calibration between the channel number and energy. (Fig.2) After calibrating for the energy, we recorded the energy of the K-alpha characteristic line for seven different elements with z-values bewteen 23-30: Vanadium (23), Chromium (24), Manganese (25), Iron (26), Nickel (28), Copper (29), Zinc (30). (Fig. 2)

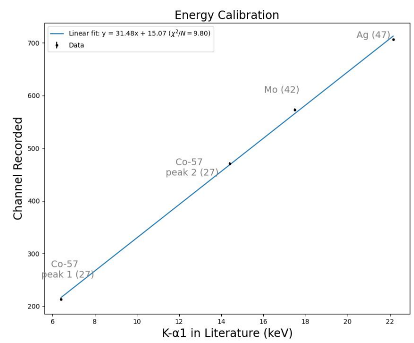


Figure 2: The calibration plot relating the channels of observed peak and literature value peaks for Cs-37, Mo, and Ag.

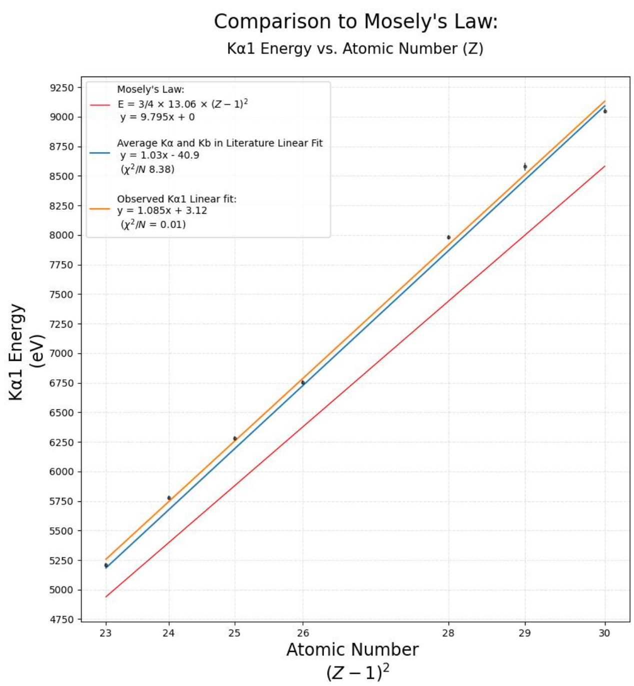
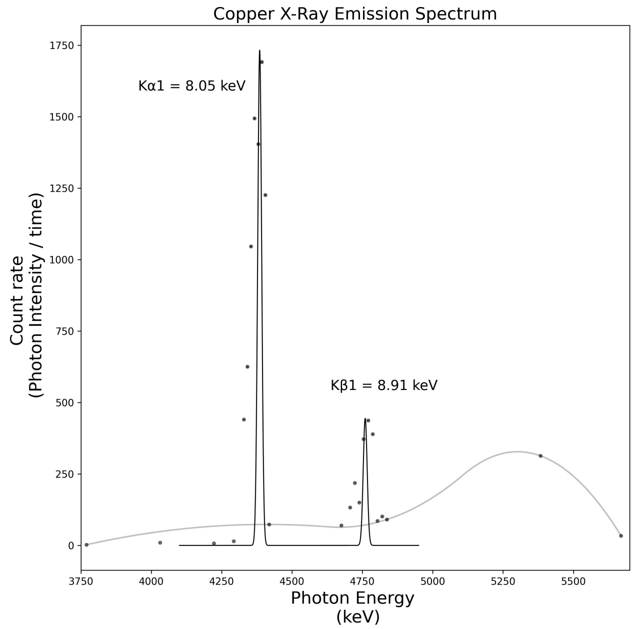


Figure 3: The comparison of observed K-alpha energies and atomic number to Mosely's law as well as the average of K-alpha K-beta lines recorded in literature. Note that while the energies differ in terms of magnitude between the observed values and Mosely's law, the correlation is similar as evident by their slopes. Higher correlation is seen between the observed values and the averaged literature values.



(a)

Item	Quantity
Widgets	42
Gadgets	13

Table 1: An example table.

1.2 How to add Tables

1.3 How to write Mathematics

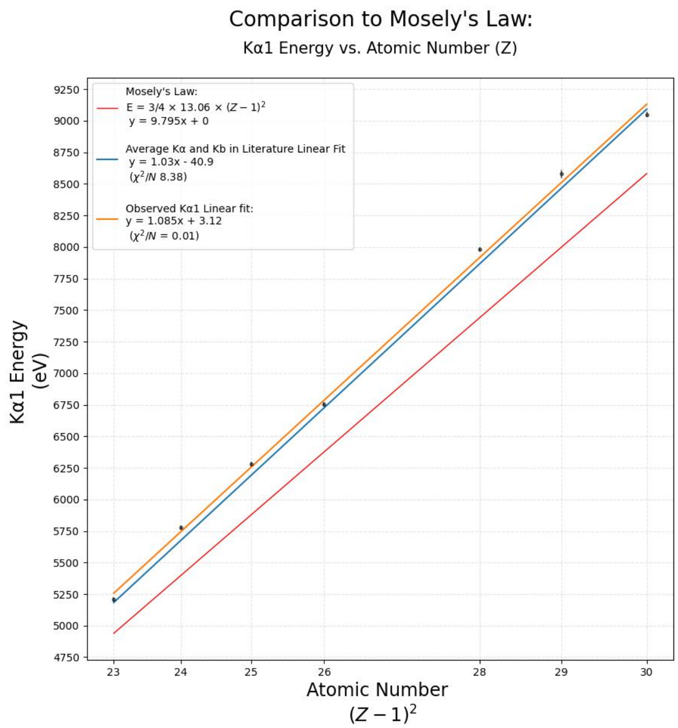
LaTeX is great at typesetting mathematics. Let $X_1, X_2, \ldots, X_n$ be a sequence of independent and identically distributed random variables with $\mathrm{E}[X_i] = \mu$ and $\mathrm{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \cdots + X_n}{n} = \frac{1}{n} \sum_{i}^{n} X_i$$

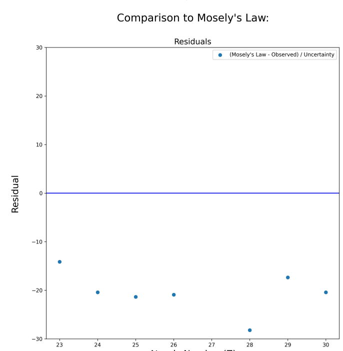
denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.

References

https://www.ncbi.nlm.nih.gov/books/NBK546155/: :text=Note
https://www.britannica.com/science/Moseleys-law



a



b

Figure 4: (a) blah (b) blah