

Lab 0: HPGe Spectroscopic Calibration

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Introduction

Gamma rays are quantized electromagnetic radiation produced by nuclear transitions. These uncharged particles cannot directly ionize or excite atoms in material it traverses through, making them difficult to be detected directly. Therefore, it is necessary that some fraction of the incident photon's energy to be transferred to an electron in the absorbing material. These fast electrons can then induce excitations or ionization which provide valuable information about the nature of the incident gamma rays.

The sensitive volume of a radiation detector serves as a gamma-ray spectrometer, measuring the intensity and energy of incident gamma rays. It is advantageous for this region to be composed of solid material, to increase the probability of a photon interacting inside of it. High purity germanium detectors, a common type of semi-conductor detector, employ a highly absorptive germanium crystal, in addition to being compact, and offering fast timing characteristics [1].

These devices must be calibrated so that the signal produced corresponds to the correct incident radiation energy. Most calibration procedures involve using a known gamma ray source to assign the output voltage of the detector with the corresponding known gamma ray energy. Once a detector is properly calibrated it is capable of measuring unknown sources to better understand a radiation field of interest.

Methods

In this lab, raw (uncalibrated) data was collected from five different radiation sources: ^{241}Am , ^{133}Ba , ^{60}Co , ^{137}Cs , and ^{152}Eu . The measurements were performed using a coaxial HPGe detector and a 13-bit resolution MCA, yielding 8192-bin spectra. It is assumed that each of these measurements

were taken with each source at the same location and distance from the detector. All raw data collected is plotted in Figure 1.

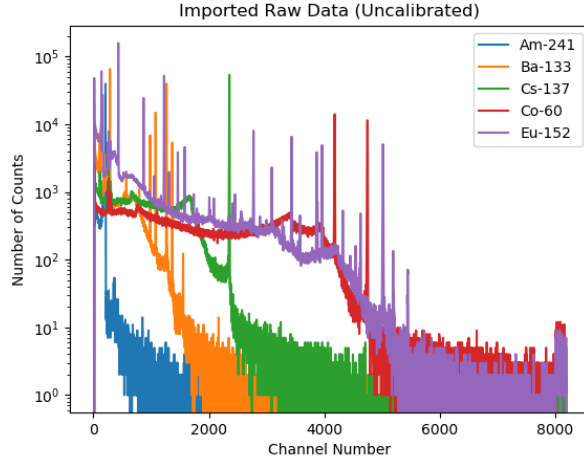


Figure 1: Calibrated Americium and Cesium Spectrum

The gamma energies of interest are given in Table 1, were primarily chosen based on their branching ratios, as those with the highest branching ratios tend to be the most visible within a spectrum.

| Source | E_γ (keV) | Branching Ratio (%) |
|-------------------|------------------|---------------------|
| ^{241}Am | 59.541 | 35.9(4) |
| ^{133}Ba | 80.997 | 36.68 |
| | 356.017 | 62.05(19) |
| ^{60}Co | 1173.237 | 99.973(7) |
| | 1332.501 | 99.98(6) |
| ^{137}Cs | 661.657 | 85.1(2) |
| ^{152}Eu | 121.781 | 28.67(2) |
| | 1408.006 | 21.07(1) |

Table 1: Gamma-ray lines used in the calibration

A simple linear calibration method can be employed two different energy peaks and the channels in the raw data where these peaks are believed to correspond to.

$$m = \frac{E_2 - E_1}{chan_2 - chan_1} \quad (1)$$

where m is the slope of the linear regression line, and E_1 and $chan_1$ are a single gamma energy and corresponding channel number.

The general equation of the linear regression line is:

$$Energy - E_1 = m(channel - chan_1) \quad (2)$$

Results

The equation of the linear regression line for this data using the 59.541 keV peak of ^{241}Am and the 661.657 keV peak from ^{137}Cs .

$$Energy = 0.280576(channel) + 1.181092 \quad (3)$$

This model is then used to calibrate both ^{241}Am and ^{137}Cs data, and is displayed in Figure 2.

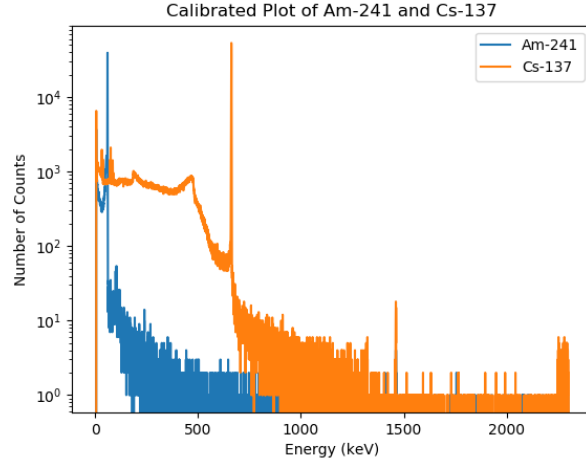


Figure 2: Calibrated Americium and Cesium Spectrum

Comparing the calibrated pulse height spectrum of ^{133}Ba to its true values as specified in the nuclear data literature we find that the model is sufficiently accurate. The full comparison is displayed in the table below.

| Actual Energy (KeV) | Calibrated Energy (KeV) | Percent Difference (%) |
|---------------------|-------------------------|------------------------|
| 80.9979 | 81.1453 | $1.8192 \cdot 10^{-3}$ |
| 276.3989 | 276.7067 | $1.1137 \cdot 10^{-3}$ |
| 302.8508 | 303.0809 | $7.5968 \cdot 10^{-4}$ |
| 356.0129 | 356.3903 | $1.0601 \cdot 10^{-3}$ |
| 383.8485 | 384.1673 | $8.3062 \cdot 10^{-4}$ |

Discussion

Calibrating a gamma ray spectrum is vital for observing and measuring any gamma radiation field. From the data provided, a simple linear fit between 59.541 keV and 661.657 keV has shown to be sufficiently accurate.

For future work and improvement upon this energy calibration, more than two peaks could have been used to determine the parameters of linear calibration, or a higher order polynomial regression method.

References

- [1] G.F. Knoll. *Radiation Detection and Measurement*. John Wiley & Sons, 2010.