Lab 0: HPGe Spectroscopic Calibration

Grey Batie

September 17, 2018

just "to detect"

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.

This is true, and a nice reference, but it would be more relevant to focus on HPGe as a spectroscopic instrument

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

Good, but how do we measure the distribution of these voltages? Pulse height spectrum!

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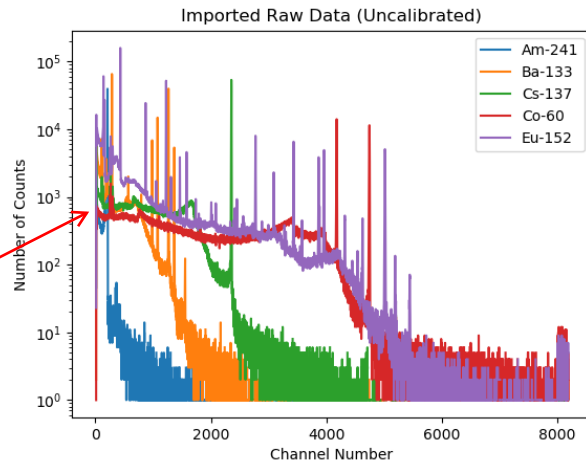
Figure 1: Calibrated Americium and Cesium Spectrum

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.

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

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.

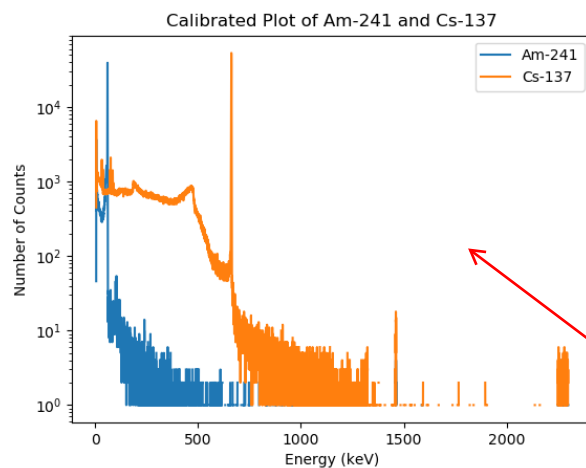The general equation of the linear regression line is:

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

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.

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

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

Too many sig figs: you do not have this degree of precision

Okay, but plot does not convey any new quantitative information... consider replacing with a plot of the residuals for your validation step next

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.

For what purpose? This statement is too vague... we want the results and discussion to convey concrete information, for example: analysis of the energy calibration yielded an accuracy of roughly 0.001%, corresponding to an accuracy of the energy determination on the order of 100 eV.

Cite the specific source

3

This photopeak is not appropriate for evaluating the calibration due to the bias from the doublet features

More meaningful to present this information in relevant units, i.e. residuals in keV

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.