Energy Calibration

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Not quite, there are plenty of non-spectroscopic instruments. It IS important for all spectroscopic instruments though

Introduction

Energy calibration is a necessary step for every radiation detector. Calibration ensures the accuracy and the quality of the results. Without proper calibration, there is no way to tell how the channel numbers from a multi-channel analyzer correlate to energy. This paper shows a simple linear calibration using Am-241 and Cs-137 and validates the calibration by applying it to Ba-133 and Eu-152.

model

radionuclides

Methods

To do the calibration, elements were picked which had well-defined single energy peaks. Using the spectra from those elements, each peak was fit with a Gaussian distribution. The centroids of those Gaussians, given in channel number, were fit to the known energies of the peaks using a linear regression. This calibration was done using Am-241 and Cs-137.

To validate the calibration, the calibration was applied to two other elements which each had several energy peaks, Ba-133 and Eu-152. Again, the peaks in the spectra were fit using a Gaussian distribution and the centroids taken as the peak energy value. The true peak energy was compared with the calculated peak energy by calculating the percent error.

Consider a citation

Results

The calibration was done with Am-241 and Cs-137. For each spectrum, the main peak was found and fit with a Gaussian using scipy.optimize.curve_fit. Fig. 1 shows the two spectra; Fig. 2 and Fig. 3 show the Gaussian fit for each peak. The fits were used to find the centroid of each peak. On an 8192-channel scale, the Am-241 peak centroid was at channel 207.73 and

It's not quite regression since the number of data points and the number of free parameters in the model are equivalent in the two-point case

the Cs-137 peak centroid was at channel 2353.97. A linear regression was done using the centroid values and the true peak energy values, 59.5412 keV and 661.657 keV. [1] The calculated calibration for this detector was

Good citation for nuclear data

$$Energy \text{ (keV)} = 0.2805 \, (Channel \ Number) + 1.2639 \tag{1}$$

Significant figures slightly oversell the precision of the measurement given the precision of the centroid determination

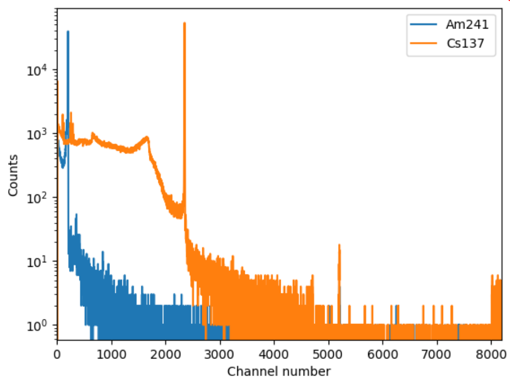


Figure 1: The calibration spectra on a semi-log plot.

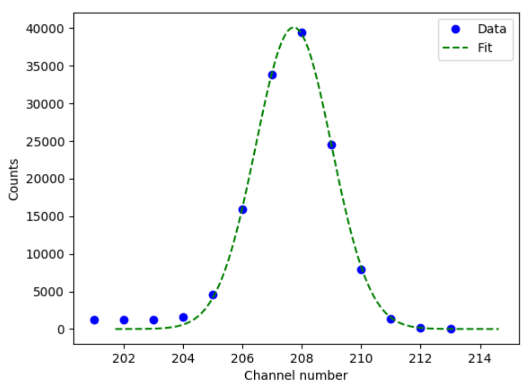
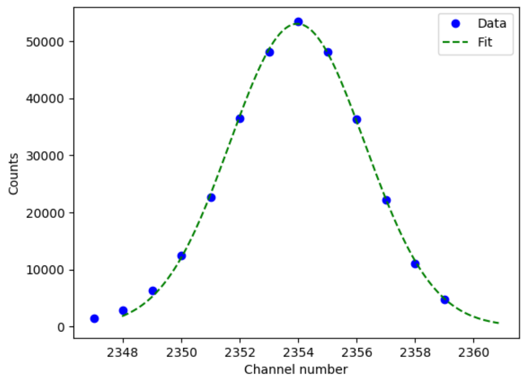


Figure 2: A Gaussian fit to the peak in the Am-241 spectrum.



This peak (and the neighboring 79.6 keV peak) are typically avoided for the purposes of calibration and validation due to the nature of the doublet peak. Error is more reflective of poor model for this peak rather than the energy calibration itself

Figure 3: A Gaussian fit to the peak in the Cs-137 spectrum.

Validation of the calibration was done by applying eq. 1 to spectra for Ba-133 and Eu-152. As in the intial calibration, a Gaussian fit was applied to the energy peaks and the centroid taken as the peak value. The centroid value in channels was converted to keV using the calibration calculated above. Results for the two validation sources are presented in Table 1 and Table 2 with the true peak energy value, the measured value with this calibration, and the percent different at each energy.

Table 1: Comparison of true peak energy and calibrated peak energy for Ba-133.

True Peak Energy [1]	Calibration Peak Energy	Percent Error
80.898	81.020	0.150
276.398	276.452	0.020
302.853	302.894	0.013
356.017	356.044	0.008
383.851	383.876	0.006

Table 2: Comparison of true peak energy and calibrated peak energy for Eu-152.

True Peak Energy [1]	Calibration Peak Energy	Percent Error
121.782	121.777	0.004
244.697	244.712	0.006
344.279	344.261	0.005
411.116	411.075	0.010
778.904	778.933	0.004
867.373	867.416	0.005
964.079	964.113	0.004
1085.869	1085.943	0.007
1112.069	1112.172	0.009
1212.948	1213.034	0.007
1299.140	1299.258	0.009
1408.006	1408.174	0.012

A keen observation supported by your analysis, but (as mentioned above) there are external factors that explain this. Nevertheless, it is a good hypothesis in that it is supported by your results!

Discussion

Based on the low percent error in the validation peak fitting, the nonlinearity is small and a simple linear calibration is suitable for this energy range. For energies below about 100 keV, a higher order polynomial might be needed for more accuracy; the percent error is higher for the 80.9 keV line from Ba-133 than the other validation peaks. Knoll [2] suggests fitting using a polynomial of the form

$$E_i = \sum_{n-0}^{N} a_n D_i^n. \tag{2}$$

A higher order polynomial fitting would need more calibration peaks than the two used in this paper. There is a trade off between the accuracy of a calibration and the time required to run it.

References

[1] S.Y.F. Chu, L.P. Ekstrom, and R. B. Firestone. The Lund/LBNL nuclear data search, v. 2.0. `http://nucleardata.nuclear.lu.se/toi/`, 1999. Accessed: 2018-01-30.

[2] Glenn F Knoll. *Radiation detection and measurement*. John Wiley & Sons, 2010.