

Experiment 2

This experiment consists of three parts: Identifying the different features of the NaI gamma spectrum, measuring the resolution of the NaI detector, and an energy calibration of the detector. For the energy calibration, you will determine the energies (and the uncertainties of your measurements) of the photopeaks of Bi^{207} .

Identifying the features of the NaI gamma spectrum

In the introduction to this experiment, we discussed the different parts of the NaI gamma spectrum. You will be given a printout of three different gamma spectra taken with one of the NaI detectors in the laboratory. You are to identify all the different features of each of the spectra. If the following features are present, be sure to indicate them on the graphs:

- a) photopeak(s)
- b) Compton Region(s)
- c) Compton Edge(s)
- d) Backscattering peak(s)
- e) Characteristic X-rays

Resolution of the NaI Detector

In the introduction to this experiment, we discussed what is meant by the resolution of the detector and how to measure it. You are to determine the resolution of the photopeak for Cs^{137} . To do this, you need to first record a spectra for Cs^{137} . Then, using the fitting program developed by previous Cal Poly Physics students find the channel number of the peak center, C_0 , and the width parameter σ . As discussed in the introduction, the **F**ull **W**idth at **H**alf **M**aximum (FWHM) is related to σ by:

$$FWHM = 2\sqrt{\ln(2)}\frac{\sigma}{C_0} \quad (1)$$

Show your data and calculations for the FWHM for the Cs^{137} photopeak. Note: the manufacturer of the detector claims the FWHM should be between 6% and 8%.

Energy Calibration of the MCA

In this part you will first calibrate energy of the Multichannel- Analyzer, then determine the energies of the two gamma rays of the ^{207}Bi decay and the uncertainty of your values. As calibration standards, you will be given ^{22}Na , ^{137}Cs , and ^{54}Mn . The CRC lists the energies of the primary gamma rays of these sources to be:

^{137}Cs : 661.64 KeV
^{22}Na : 511.0034 and 1274.5 KeV
^{54}Mn : 834.827 KeV

Use these standards to estimate how the channel number of the photopeak is related to the energy of the gamma, $E(C)$. Once you have determined your best estimate for $E(C)$, then determine the energies of the two photopeaks of Bi^{207} . There are a number of things to consider in calibrating the MCA. Some important properties are:

- a) The detection system is not exactly linear.
At some level of accuracy the function $E(C)$ is not linear.
- b) There is an offset, $E(0)$ is not necessarily zero energy. For example, channel number 10 might correspond to the zero of energy.
- c) The amplifier gain can drift in time.

Suggestions for Calibrating the MCA

1. For some of the amplifiers in the lab, the drift in gain is quite significant. To correct for this problem, you can measure two samples at the same time. For example, you can collect data with both Na^{22} and Cs^{137} together, Na^{22} and Mn^{54} together, as well as Mn^{54} and Bi^{207} together. In these combinations, the photopeaks of the two isotopes don't overlap each other. With proper scaling, you can account for amplifier drift. In your writup, explain how you corrected for amplifier drift.
2. You can try different expressions for $E(C)$, the energy of the photopeak as a function of channel number. Each computer has EXCEL installed on it. You can use EXCEL (or another spreadsheet) to try linear and/or quadratic fits of the standards. Try various fits and see how much your predictions of the Bi^{207} photopeak energies vary to estimate your uncertainty of these energies.
3. Find the channel number of the Compton edge for Cs^{137} . After you have calibrated the MCA, determine the energy of the Cs^{137} Compton edge. You will use this value in one of the questions.

Laboratory Writeup for Experiment 2

Your lab writeup will consist of the following:

- 1) (2 points) Identify the isotopes of the three spectra passed out in class. For each one, point out the different features (photopeak, compton edge, etc.).
- 2) (1 point) Show your measurements and calculations for determining the FWHM for the Cs^{137} photopeak.
- 3) (6 points) Determine the energy and uncertainty of the main photopeaks of ^{207}Bi . Discuss

in detail how you corrected for amplifier gain and the type of fit you used to obtain your values. Show all your data.

4) (1 points) Measure the channel number and determine the energy of the Compton edge for ^{137}Cs . You will use this value in the question below.

5) (2 points) The "Compton Edge" corresponds to the maximum transfer of energy from photon to free electron. This occurs when a "head on" collision takes place between photon and electron. The incident photon ($E = h\nu$) is backscattered (180 degrees scattering angle) and emerges with energy $E' = h\nu'$ where $\nu' < \nu$. Use conservation of energy and momentum to show that the kinetic energy of the electron at the Compton Edge is

$$E_{electron} = \frac{2(h\nu)^2}{2h\nu + m_0c^2}$$

where m_0c^2 is the rest energy of the electron. What is the energy for the Cs^{137} 662KeV gamma ray? Does it correspond to the energy of your Compton edge?