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 ^{207}Bi.

Identifying the features of the NaI gamma spectrum

In the introduction to this experment, 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 ^{137}Cs. To do this, you need to first record a spectra for ^{137}Cs. 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:

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

Show your data and calculations for the FWHM for the ^{137}Cs 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 the 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 ^{60}Co. The literature lists the energys of the primary gamma rays of these sources to be:

^{137}Cs: 661.64 KeV
^{22}Na: 511.0034 and 1274.5 KeV
^{60}Co: 1173.237 and 1332.501 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 (and uncertainties) 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. That is, 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.

<u>Suggestions for estimating the energies and uncertainties of ^{207}Bi</u>

1. You should take and tabulate the following data for each gamma of the standards and ^{207}Bi: the time you took the measurement, the channel number of the center of the peak, and the width parameter σ of the peak. You should have this information for 5 gammas from the standards and 2 gammas from Bi.

2. You should also take a second measurement of one of the standards at a different time than the first measurement. By seeing how much the channel number of the center changed, you can estimate how much the amplifier gain might change during the measurements. You might need to take a second measurement of all the isotopes.

3. 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 in the fit for these energies.

4. To get an idea of the uncertainty of the energy calibration, you can examine the residues of the standards from the fit. That is, use the function E(C) to predict the energies of the standards. The difference of these predicted energies with the known values of the standards will give you an estimate of the uncertainty in calibrating the energy of the Bi photopeaks.

As a final measurement, find the channel number of the Compton edge for ^{137}Cs. After you have calibrated the MCA, determine the energy of the ^{137}Cs 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. Identify the isotopes of the three spectra passed out in class. For each one, point out all the different features (photopeak(s), compton edge(s), etc.).

2. Show your measurements and calculations for determining the FWHM for the ^{137}Cs photopeak.

3. Determine the energy and uncertainty of the main photopeaks of ^{207}Bi. Discuss in detail the type of fit you used to obtain your values, and how you estimated the uncertainties in the ^{207}Bi energies. **Show all your data, graphs, and calculations**.

4. 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. The "Compton Edge" corresponds to the maximum transfer of energy from a photon to a "free" electron initially at rest. This occurs when a "head on" collision takes place between the photon and electron. The incident photon is backscattered (180 degrees scattering angle) and the electron is scattered forward with energy E_e. Start with the equations for the conservation of energy and momentum and **derive** the following relationship for the **kinetic energy of the scattered electron** at the Compton Edge:

$$K = \frac{2E_0^2}{2E_0 + m_0c^2} \tag{2}$$

   where E_0 is the energy of the incoming gamma, m_0c^2 is the rest energy of the electron, and $K = E_e - m_0c^2$ is the kinetic energy of the scattered electron. What is the energy K for an incident ^{137}Cs ($E_0 = 662$ KeV) gamma ray? Does it correspond to the energy that you measured for your Compton edge?