LAB 5 Friday

Gamma Spectroscopy with HPGe Detector

Germanium

I. Introduction:

The Ge(Li) and HPGe gamma-ray detectors have revolutionized many operations in the nuclear industry. The operations which were once carried out by tedious radiochemistry techniques are now completed using instrumental methods. In the case of reactor effluent characterization, for example, radiological determinations are necessary to establish compliance of the installation with NRC regulation; likewise, fission product concentrations in reactor fuel rods are useful monitors of fuel burnup.

In the first part of this experiment, you will calibrate an MCA system (both energy and efficiency) and measure the gamma-ray spectrum associated with an unknown radioactive source. Using the energy spectrum you should be able to determine the identity of the radionuclide(s) present. Furthermore, by using the efficiency curve that you develop for your detector, you should be able to estimate the activity of the radionuclide(s) present.

II. Energy Calibration

Procedure:

1. Check with the instructor prior to beginning the lab exercise; the HPGe detection system should be ready to go, but you'll need to trace all cables to confirm their proper connection.

2. Run the Gamma Vision software. Assure that the "0003 DSPE-381" DSPEC unit is selected in the spectrum source field (top, center pull-down menu). The DSPEC unit is on the floor underneath the desk.

3. Access the HV bias switch through the "Acquire" pull-down menu and "MCB Properties". It should be set to **+4,500 V** and switched **ON**.

4. Also, check "Presets", "Amplifier" and "ADC" settings in the MCB Properties menu (a conversion gain of 8192 channels works well).

5. The gamma sources for this experiment can be found in the lead shield on the floor in the SE corner of the room. You'll use the gamma standard (Marnelli beaker), the check sources in the red box, and the mixed-nuclide source in the small case.

6. Stack seven of the check sources (pick the activity) on top/center of the HPGe detector (these are the sources from the red box, minus the "unknown" source). Be careful with the lead shielding of the HPGe, it is very heavy and has quite a bit of momentum once you get it going. If the tracks are out of line, readjust them before sliding open the lid.

7. Accumulate counts (~ 2 minutes) in the analyzer until you have an appropriate

(Print - on computer)

number of counts per channel in the various full-energy peaks. You should see ~~15~~ 13 full-energy peaks from the 7 check sources.

8. Using the Gamma Vision software, erase the current energy calibration (by deleting, one at a time, the photons in the file) and create your own new calibration (with the 15 full-energy peaks that you just collected). In your report, you'll need to detail how you did this step to show me that you did indeed create your own calibration.

9. Save your spectrum (to a location that you can also access later) as both a spectrum file (SPC) and an ASCII file.

10. Plot energy vs. channel number and develop a calibration equation for your system.

III. Energy Resolution (peak info) (Spreadsheet info)

The energy resolution of a gamma-ray spectrometer is a measure of its ability to resolve (or separate) adjacent peaks in a gamma-ray spectrum. Formally, we can define energy resolution, R, as

$$R = \frac{FWHM}{H_0} x100\% \tag{1}$$

where R is energy resolution (in %), *FWHM* is the full width of a given photopeak at half the maximum number of counts in the peak channel, measured in number of channels; and H_0 is the peak energy expressed as the channel number of the peak mid-point.

Procedure:

Spreadsheet

1. Using the gamma-ray spectrum you collected above, and using Eq. 1, calculate the resolution at each of the 15 γ-ray energies and tabulate your data.
2. Plot the resolution vs. gamma ~~energy~~ w/ increase (on a separate graph, R vs. E_γ.) Is the general shape of the curve what you expected? Why or why not? expected it to go down w/ energies

IV. Efficiency Calibration

The efficiency of gamma-ray detection with a spectrometer is a complex function of many quantities. For our purposes, we will calculate the absolute efficiency for a given geometry; that geometry will take the form of a stack of the seven check sources (in random sequence) placed directly in the middle of the HPGe detector. Ideally, we would like a calibration source that has many different photon emissions and is distributed uniformly throughout the source medium. Since the calibration source that we are creating with the stacked check sources is not uniform, a precise measure of efficiency is not possible. For this exercise however, we will make the assumption that the stacked sources result in a uniformly distributed calibration source. Further, when we estimate the activity of our unknown

source(s) later in the lab, we will assume that the geometry of the unknown is the same as the geometry of the check sources. We know this not to be the case, and additional errors will exist because of the assumption. Absolute efficiency is calculated using,

radpro calculator

$$\varepsilon_{abs}\left[\frac{cts}{\gamma}\right] = \frac{count\ rate}{emission\ rate} = \frac{CR[{}^{cts}/_{s}]}{A[{}^{dis}/_{s}]\cdot y[{}^{\gamma}/_{dis}]} \qquad (2)$$

where CR is the count rate (counts/sec) in the photopeak area, A is the check-source activity (disintegrations/sec), and y is the fraction of disintegrations giving rise to a γ-ray (the gamma yield). In this experiment, we shall determine the absolute detection efficiency and its dependence on γ-ray energy.

Procedure:

use netarea!!

— rad pro Calculator decay

1. For this exercise you want to obtain the net count rate in each full-energy peak; therefore, it is necessary to subtract the background counts from your source spectrum. You may need to transfer your data to Excel to do this. Select about 5 channels on either side on the photopeak (to establish an estimate of background count rate) and find the area of the trapezoid created by those channels.

2. Determine the full-energy peak area for each of the 15 calibration peaks and record the results. Using equation (2) and calculating the gamma-ray emission rate of the sources, calculate the absolute efficiency at each gamma-ray energy.

3. Plot ε_{abs} vs. E_{γ} as a log-log plot. Real cal. #2 w/efficiency table interpolation to do

4. Fit a curve to the plot to get an efficiency function for the HPGe detector. Explain the physics behind the curve-fit that you chose. Compare your results to the plot on page 449 of Knoll. Efficiency Energy not exactly w/data

5 minute count time.

5. Remove the calibration source and erase the calibration spectrum. Obtain the Marinelli source and place it on the HPGe (the data sheet for the Marinelli source can be found in the desk drawer). Accumulate counts for an appropriate amount of time in order to estimate, using the efficiency calibration that you just developed, the activity of the three nuclides that are still present in the Marinelli source. Co60 + Cs137 — everything else decayed

activity — calc. later

V. Use of Escape Peaks in γ-Ray Spectroscopy c

The interaction of high energy γ-radiation (>1.02 MeV) with the detector can result in pair production events. The positron produced in the initial pair production event will most likely annihilate in the detector producing two 0.511 MeV photons. Thereafter, three things can happen to these 0.511 MeV photons, including:

— Abstract
— Introduction
— method

a) the energy of both photons is absorbed in the detector, giving rise to a count in the full energy peak;

b) the energy of one 0.511 MeV photon is absorbed in the detector, while the second photon escapes without interaction, giving rise to a count at a location in the energy spectrum that is 0.511 MeV less than the photopeak (the single escape peak); or

c) the energy of both 0.511 MeV photons escapes the detector, giving rise to a count at a location in the energy spectrum that is 1.022 MeV less than the photopeak (the double escape peak).

Since HPGe detectors have such low detection efficiency, which is also energy dependent, the phenomenon of escape peaks is quite important in γ-ray spectroscopy when using germanium. High-energy γ-rays could also be detected by measuring the escape peaks rather than their full energy peaks.

Procedure: 2min count time

Single escape — Energy 1275 KeV
less than 1.022 — double escape 511 KeV
full 1789 KeV
Sodium main energy

511
stopped in source
Source w/ limit 2.511
positron

1. Collect a ^{22}Na spectrum. Locate the full-energy peaks and the single- and double-escape peaks.
2. How are the energies of these peaks related to the rest energy of an electron?
3. Describe what causes an annihilation peak and at what energy is it located?
   in order for that to happen — rate is small - so don't see single double
4. Describe what is happening in or out of the detector that causes these peaks to appear in the spectrum.
5. Can you see 1,022 keV peak in your energy spectrum? If not, explain why? NO. Because we don't see double escape or single escape
   Sum peak 1789 — Annihilation - 511 KeV — full peak 1275 — don't see double escape
   Picture → escape peaks

VI. Identification of an unknown radionuclide.

2 minute count time - Zinc 65 - Cesium

1. Obtain the unknown button source and place it in a similar position, with respect to the detector, as you placed the sources when calibrating the detector's efficiency (ideally, we're trying to repeat the geometry so that the absolute efficiency calibration holds true). Count the unknown long enough to have distinguishable peaks with enough counts to estimate the activity of the source.

2. Using the full-energy peaks, identify the radionuclide(s) present. CS + ZN

3. Apply the efficiency calibration to your collected spectrum and calculate the activity of the unknown source.

   list of natural Activity — 10 min count
   Gamma vision per GV software

4. Obtain the environmental source (rock) and ~~examine~~ its gamma spectrum. What radioactive sources do you see in the rock sample? Estimate their activity.
   • K-40 Potassium
   • B 214

VII. Background collection: google search - gamma rays that are prominent natural bkgd.

1. Collect a 24-hour background spectrum (this has been done for you; you should see the spectrum saved on the desktop).

2. Determine the energies and identify all prominent peaks (as many as possible).

3. Discuss the origin of these peaks. If any are caused by specific reactions, identify those reactions. Lead 214 from detector —

4. Place all sources back in the lead shield (SE corner of room, on the floor). The system can be left on when you're finished.

Peak	Energy
1 BA 133	81 keV
2	
3 BA 133	303 keV
4 BA 133	356 keV
5	
6 ~~Ba 133~~	~~81~~ ~~511 keV~~
7 CS-137	662 keV
8 CO60	1.33 MeV
9 NA 22	~~511 + 1275 keV~~ 511 + 1275 keV
10 CO60	1.33 MeV
11	
12	
13	
14	
15	

MN54 833 keV

8 peaks

energy Calibration equation only 1st part

Barium 133 - 5~~17.~~

Cd-109 - ~~214.24 keV~~ 22 keV
Bust won't see

Co-57 - ~~835.9~~ 122 keV

~~60~~ 1.17

Cobalt 60 - 1.33 MeV + 1.17

Cs 137 - 662 keV

MN 54 - 835 keV (100)

NA 22 - 511 keV + 1275 keV

Zn 65 - unknown -

~~Po 210 - 5.33 MeV alpha~~

CO 57 + CD 109
→ decayed out
removed