LAB4 - Thursday

NaI and Gamma Spectroscopy Laboratory
NE/RHP 536

Purpose

The purpose of this laboratory exercise is:

(1) to characterize a sodium iodide (NaI) detector by determining its
   a. operating voltage,
   b. energy calibration,
   c. resolution,
   d. absolute efficiency,
   e. dead time; and

(2) to learn basic techniques of using a multichannel analyzer (MCA) to identify and quantify an unknown radionuclide.

Materials and Methods

The NaI system to be used in this laboratory consists of a NaI crystal with an integrated photomultiplier tube and attached pre-amplifier, a high voltage source, an amplifier, an SCA, and a multichannel analyzer (MCA). You will need to use one of the four lab stations (east wall) that has a Canberra Multiport II in the NIM bin. The Multiport contains the MCA card which then feeds a digital signal to the computer via USB connection. You'll also need to have a ^{60}Co, a ^{137}Cs, and an 'unknown' check source on hand.

Assemble the NaI system: three cables originate in the preamplifier (preamp power, detector bias, and PMT signal); connect bias supply; signal and preamp power to the amplifier; amp output to the SCA (or MCA); and SCA to the counter/timer. For this experiment, begin by setting the amplifier gain to 100/0.60, the shaping time to 2 μsec, and set the Lower Level (E) to 2.0 V with a window (ΔE) of 10.0 V on the SCA.

Procedure

resting against detector 1st counts.

detector
source

I. High Voltage Plateau

GAin = 100 x 0.6 = 60

1. Utilizing the SCA, determine the HV counting plateau starting at about 700 V to no more than 1400 V. Plot net counts vs. applied voltage. Comment on your graph and determine the optimal applied voltage. Describe, completely, how you accomplished this task.

2. Using the oscilloscope, capture an image of the NaI pulse as it leaves the preamplifier. Also, capture an image of the occurrence of pulse pile-up and describe what is occurring.

3. Set the high voltage to your determined operating voltage for the rest of the experiments.

4. Once the operating voltage is established, count a ^{137}Cs check source, a ^{60}Co check source, and background for an appropriate amount of time (to determine absolute efficiency with some degree of confidence). — to wood taped block

ε = Activity · Gamma yield

$\boxed{\Gamma = S\,\Omega\,\varepsilon\,F}$

* Platen is 1200-1400 Volts ⇒ 1300 V = is 50% of plateau

30sec counts
Cs137 - 85%
Co60 - 100%
100%

5. Estimate the net count rate from the ^{137}Cs and ^{60}Co sources (counted individually), and determine the counting error of each.

6. Determine the absolute efficiency for each source given a reproducible geometry. What geometry did you use and what assumptions did you make in this determination of absolute efficiency?

II. Dead Time Cs 137 - 1μCi 3/5 Dec 20.. - Co^{60} Feb 2012 1μCi

1. Using the SCA and counter/timer, determine a reproducible geometry that is suitable for using the split source (or two disk sources) method.

1 2. Place source #1 on/near the detector. Record counts (C_1) for a specific preset time. 119333

1+2 3. Place source #2 on/near the detector without removing source #1 and record counts (C_{12}). 188627

2 4. Remove source #1 from the detector. Record counts (C_2). 88144

5. Remove source #2 from the detector and record an appropriate background count (C_B). 131 1st

6. Repeat steps 1 through 5 two more times. 107 2nd 103 3rd

7. For the three set of counts, calculate dead time (3 estimates). Determine the error for each of the three dead-time calculations. - use wood blocks

8. Comment on the dead time and explain why your times are consistent, or not.

III. Develop Differential and Integral Pulse Height Spectra Using the SCA

1st point - Electrical noise

1. Using the oscilloscope and a ^{137}Cs source, adjust the appropriate settings such that a majority of pulses have an amplitude of about 5-7 Volts. 5 to 7 ✓ if you set gain too large, peak w/ cutoff; small - No good spectrum

gain Coarse = 30 x Fine = 0.8 = 24 Gain

2. Using the SCA and a ^{137}Cs source, record the differential pulse height spectrum by selecting a small energy window (e.g., $\Delta E = 0.5$ V) and adjusting the lower level (E) through its entire range at increments equal to 0.5 V (when using $E = 0.0$, recall that a large number of "pulses" will be collected, but that they are the result of electronic noise and not radiation detection); collect counts for an appropriate time period at each setting of E. Plot your results. How would your plot change if you had used increments of E less than 0.5 V, or greater than 0.5 V? SCA ΔE @ 0.5 E = 0.0 ← graph would look more smooth w/ more points

Should be a mirror of just flipped.

3. Now record the integral pulse height spectrum by fully opening the energy window (ΔE = 10 V) and initially setting the lower level (E) to zero. Increase E through its entire range at increments of 0.5 V (or any appropriate increment of your choosing) and collect counts for an appropriate time period at each setting of E. Plot your results.

IV. MCA Energy Calibration

To Start the MCA:

940V
300 course
0.4 fine = 120 Gain

- Using the ^{137}Cs and ^{60}Co sources together, connect the amplifier output to the Multiport II input (MCA #1)
- On the PC, open the "Gamma Acquisition and Analysis" program (there should be a shortcut on the desktop)
- In the new window, select "File"
- Select "Open Datasource"
- In that window, click the "Detector" button
- Then choose "MP2-MCA1" (MP2-MCA2 selects the 2nd MCA in the NIM bin)
- Click the "Clear" button, then click the "Start" button to ensure data collection (and that the data collected are associated with radioactive decay of the check sources)
- If data are not collected, check for the "Acquire" light on the Multiport II and make sure the signal input is connected to the MCA that is acquiring
- If data are collected, adjust the system gain such that the ^{137}Cs full-energy peak appears at about 50% of the scale (and the ^{60}Co peaks appear at about 80% of the scale); the MCA is ready

Channel: 2206
Cs - 264.5keV
Co1 -
Co2 -

1. Using the MCA, determine the calibration of Channel vs. Energy. Count the ^{137}Cs and ^{60}Co sources together. Record the peak energy channel for each of the three peaks.

2. Plot your results and determine the calibration equation. This plot will demonstrate (to a small degree) the linearity of the amplifier. - Screenshot

3. Enter your own calibration data in the table provided in the software (go to "Calibrate" and then "Energy Only Calibration"). View ("Calibrate" and then "Energy Show") your calibration curve and record the equation describing the energy/channel relationship.
   Y= 0.317 - 33.67   y= 0.317x - 33.67 = energy channel ratio
   keV/ch   keV

4. Comment on your energy calibration graph and how it relates to your expectations.

Set the gain switch

V. Resolution

1. Preset (in "MCA" and then "Acquire Setup") the "real" counting time of the MCA to an appropriate value and take a count of the ^{137}Cs source. After setting a region of interest (ROI) around each peak, determine the FWHM (keV) and peak energy (keV) either manually or by using the computer software. Calculate the resolution of each of the three peaks as a % of the peak energy.

   compton edge

   Max energy transferred to electrons
   $\theta = 180$

2. At what energy does the ^{137}Cs Compton edge occur in your spectrum? Calculate E_C for 662 keV photons to confirm the placement of the Compton edge.

3. Repeat steps 1 and 2 for the 2nd ^{60}Co peak (1.332 MeV).

4. Comment on how your resolution changes with gamma-ray energy, and why.

VI. Absolute Efficiency

Higher energy peaks are wider - ~~rates~~ FWHM

Absolute efficiency.

- trys to take out dead time - doesn't necessarily mean software

1. Collect a "live" count using both sources. Using the computer software (or manually), determine the net photopeak area and standard deviation in each of the three peaks. For your "live" time, what was the corresponding "real" time?

2. Noting activity and calibration date on the sources, calculate absolute efficiency for both ^{137}Cs and ^{60}Co.

3. What is the difference between "real" and "live" counting? Compton edge 450 keV

4. Comment on the absolute efficiency as it relates to the gamma-ray energy, geometry, intrinsic efficiency, etc.

VII. Dead Time 45.38%

1. Most software packages have "real time" and "live time" counts. The software should show you the percentage of dead time, as well. Using the configuration of both samples on the detector, take a live-time count and record the results.

2. Compare the dead time percentage from the MCA to your estimate using the SCA method (Section II). Discuss how they do or don't compare.

VIII. Determination of an unknown gamma emitter.

1. The instructor will provide you with an unknown gamma-emitting radionuclide. Count the unknown for a few minutes on the MCA in the same geometry as was used in Section VI.

2. Determine the mean energy of all peaks and the gross and net counts in each peak. Determine which radioisotopes are present in the unknown and estimate the activity of each unknown.