OPERATION AND CHARACTERISTICS OF A SEMICONDUCTOR RADIATION DETECTOR II: THE GE(LI) DETECTOR

The Ge(Li) detector is one member of a class of semiconductor radiation detectors called lithium drifted detectors. These detectors feature large depletion depths achieved by drifting Li into a p-type crystal to form a "chemically compensated" region in the crystal. In the depletion region there is no excess of either type of charge carrier, n or p. (See Chapter 8 for a detailed discussion of the construction and operation of Ge(Li) detectors.) Because of its high atomic number and large depletion depth, the Ge(Li) detector is ideally suited for γ-ray detection and this is its principle use.

In this experiment, we will explore some of the characteristics of the Ge(Li) detector used as a part of a γ-ray spectrometer. We shall do this by repeating many of the measurements we used to define the characteristics of a NaI(Tl) γ-ray spectrometer in Experiment VI. We shall continually contrast our results for the Ge(Li) detector with those obtained for the NaI(Tl) detector. In addition, we shall make some additional measurements that relate to special characteristics of the Ge(Li) detector.

A. Energy Resolution

Procedure:

1. Setup (or have your instructor setup) the electronic apparatus shown in Figure VIII-1.* The multichannel analyzer used

* As in Experiments VII and VIII, we are assuming that the reader is familiar with the operation of a multichannel analyzer. If not, the instructor should operate the analyzer during the experiment.

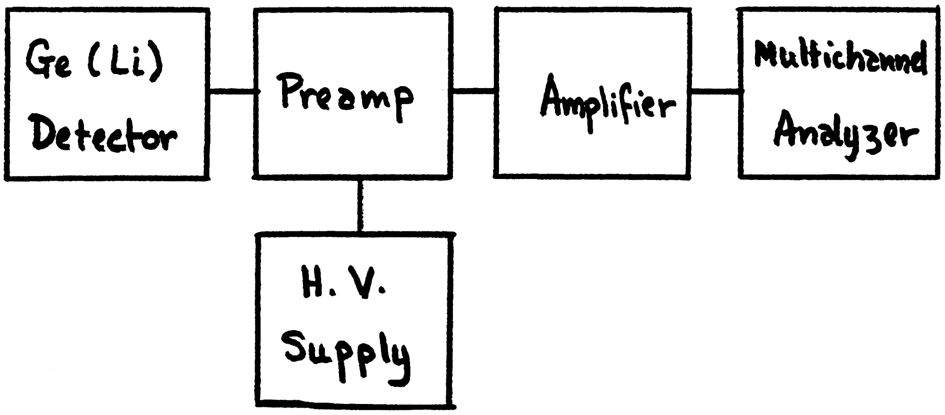

Figure VIII-1. Electronic Block Diagram for Ge(Li) Gamma Ray Spectrometer.

should have at least a 1024 channel memory. The voltage applied to the detector should be that recommended by the manufacturer. Set the preamp, amplifier, and multichannel analyzer controls to the positions indicated by your instructor.

2. Repeat the energy calibration procedure outlined in Section I, Experiment VI using this spectrometer. Determine the constants m and b that describe the energy calibration for your spectrometer, using the equation

E_γ (KeV) = m (channel number) + b

m = ________________keV/channel

b = ________________keV

3. Determine the energy resolution of <u>your spectrometer system</u> using the procedure outlined in Section IV, Experiment VI. Use γ-ray sources of ^{57}Co, ^{137}Cs, ^{54}Mn and ^{60}Co. Enter your results in Table VIII-1. For a Ge(Li) detector, the theoretical lower limit for the energy resolution of the detector is given by:

$$R(\%) \simeq \frac{0.144}{\sqrt{E_\gamma}} \qquad \text{VIII-1}$$

where E_γ is the γ-ray energy in MeV.

4. Plot the resolution R vs $\frac{1}{\sqrt{E_\gamma}}$ and verify the form of equation VIII-1. How does your <u>system</u> resolution compare with the theoretical lower limit for the detector alone?

5. Enter the resolution values for a NaI(Tl) spectrometer obtained in Experiment VI into Table VIII-1. Make a plot

TABLE VIII-1

Peak Assignment	Channel Number	Peak Energy	Ge(Li) Resolution (%)	Resolution of NaI (%) (Expt. VI)

of the ratio of $\frac{\text{NaI (Tl) resolution (\%)}}{\text{Ge(Li) resolution (\%)}}$ vs E_γ. You should find that the Ge(Li) detector resolution is at least a factor of 25 better than the NaI(Tl) resolution)

B. <u>Detection Efficiency</u>

<u>Procedure</u>:

1. Determine the detection efficiency of your Ge(Li) γ-ray spectrometer, E_{Ge}, using the procedure outlined in Section V, Experiment VI. Record the results in Table VIII-2.
2. Enter the values of the efficiency ε_{NaI} calculated for a NaI detector from Expt. VI in Table VIII-2. Plot on the same graph (a) log ε_{Ge} vs log E_γ and (b) log ε_{NaI} vs log E_γ using log-log paper. In both cases, you should obtain straight line plots. You should also see the large enhancement in detection efficiency obtained with NaI detectors compared to the Ge(Li) detectors.

C. <u>Use of Escape Peaks in Ge(Li) γ-ray Spectroscopy</u>

In Chapter 7, we discussed the interaction of higher energy γ-radiation with matter via pair production. We pointed out that the positron produced in the initial pair production event will annihilate in the detector producing two 0.511 MeV γ-rays. Three things can happen to these 0.511 MeV γ-rays. They are:

1. Both γ-rays will be stopped in the detector giving rise to a full energy peak in the γ-ray spectrum.
2. One γ-ray may be stopped in the detector while the second γ-ray escapes the detector without interaction giving rise to a peak in the γ-ray spectrum at the γ-ray energy -0.511 MeV (<u>the single escape peak</u>).

3. Both γ-rays may escape the detector giving rise to a peak at E_γ -1.02 MeV (the double escape peak).

Examples of these phenomena are seen in Figure 7-6. Since a Ge(Li) detector has such a low detection efficiency which is so energy dependent, the phenomenon of escape peaks is quite important in γ-ray spectroscopy. Many high energy γ-rays are detected by detecting and measuring the escape peaks rather than the full energy peaks.

Procedure:

1. Using the same experimental setup as in Section B, measure the γ-ray spectrum of ^{228}Th (or any other high energy γ-ray emitter). Plot the spectrum on semilog paper and identify all peaks, especially escape peaks. Record this information in Table VIII-3.
2. Calculate the peak area for each escape peak and full energy peak. Compute the ratio of full energy peak area/ single escape peak area/ double escape peak area below

   Full energy peak/Single escape/Double escape =

   _____:______:_____

   You should now see how important escape peaks are in Ge(Li) γ-ray spectroscopy.

TABLE VIII-2

Source	Source Strength (γ pm)	Net Photo-peak Counts	Counting Time	Net Photo-peak Area (cpm)	ϵ_{Ge}	ϵ_{NaI}

TABLE VIII-3

Peak Channel	Peak Energy	Peak Assignment	Net Peak Area