Advanced Laboratory: Nuclear Experiment

I. Measure the Spectrum of Several Sources.

1. Measure the spectrum of gamma rays emitted from Cs-137, Co-60, Co-57 and Na-22. Calibrate the system using the two gamma rays emitted from Na-22 and use that as your reference. Remember that if you change the gain after you calibrate the system you will need to re-calibrate it.
2. Compare the spectra to those given in the lab manual.
3. Do the Compton edges and the backscattered peaks occur where you expect them to occur? It may be harder to do this for the sodium and cobalt because they have two peaks, so you only need to measure these for Cs-137.

   I want to see the spectra (the files saved on disk and a print out) and your calculation of the energies lost by the gamma rays in Compton scattering through 180 degrees.

II. Measure the Range of 0.662 MeV Gamma Rays

1. Measure the attenuation coefficient (range) of the 0.662 MeV gamma ray emitted by Cs-137 in lead and aluminum. I suggest that you only count the events in the photopeak. Also you will want to count for long enough to get about 10,000 counts in the photopeak with no absorber present. (Once you put the absorber in, you may have to count longer to get the 5,000 to 10,000 counts necessary to limit your uncertainties. Remember the uncertainty in the count is equal to the square root of the count.) It is the count rate that is important. The count rate as a function of thickness, x, should depend on the thickness according to

   $$Rate = R_0 \exp\left(-x/L\right)$$

   Where R_0 is the count rate for no material between the sample and detector and L is the range of the gamma ray in that material. You should plot Ln(count rate) vs thickness. The slope is related to the range. (How is L related to the slope?) You should also find the uncertainty in the range. You will want to record both the net and gross count rates and compare the L's for each one.
2. Compare the ranges in lead and aluminum to those quoted in Melissinos and the lab manual.

Key Concepts and Measuring Equipment

You should understand the processes or devices listed below. Know how they work and affect your measurements. Be prepared to explain them **if** I ask about them! (You don't need to include them in your write up.

1. Photoelectric Effect
2. Compton Scattering
3. Scintillator (NaI crystal doped with thallium)
4. Photomultiplier Tube
5. Nuclear decay modes, i.e. β and β+ decay and alpha decay. (Look these up in your Modern Physics book.)

You Might want to make a table like the one below for the attenuation length or range, but with more rows. This should be done in Excel. Note that you should record the time and both the gross and net counts.

Thickness (cm)	Time	Count (net)	Rate (net)	Ln(rate)	Count (gross)	Rate (gross)	Ln(rate)

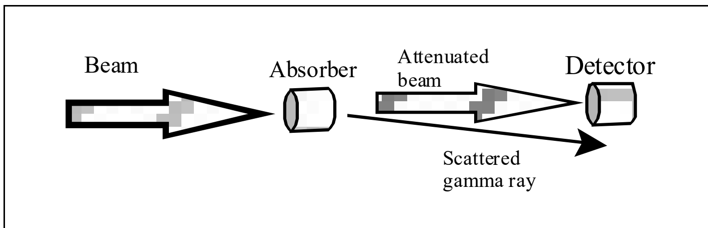
Then you should plot Ln(rate) vs thickness for both rates and do a regression on both of them to determine the slopes and their uncertainties. <u>How does your L compare to the generally accepted value of L</u>? Note that many sources do not give L directly. They give μ which is given by

$$\mu = \left(\frac{1}{\rho L}\right) \qquad or \qquad L = \left(\frac{1}{\rho \mu}\right)$$

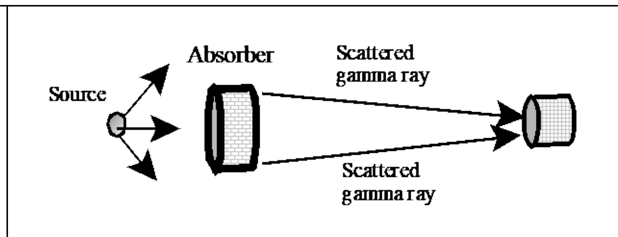
where ρ is the density of the material. In cgs units, $\rho_{lead} = 11.3 g/cm^3$.

<u>Note on range or attenuation length, L.</u>

Our experimental set up is not like the set up for a normal attenuation length measurement. Normally they only count the photons that get through the absorber without losing energy. The way you would normally measure this it is to have a collimated beam of gamma rays striking an absorber. The absorber and detector would be the same size and the detector some ways away. Then the photons that undergo Compton scattering will not strike the detector and be recorded unless the angle of scattering is very small. This geometry would measure the gamma rays that got through unscathed, or with very minimal scattering. Our geometry has a source sending out gamma rays in all directions



Normal setup



Our set up

(spherically symmetric). The absorber has a large area, so photons scattered through moderate angles can still strike the detector which is also fairly large. Their energies may overlap the lower edge of the photopeak, blurring out that part of the photopeak. However, we do not want to count those if we want to measure only the ones that get through unscathed. In that case, the net count may yield a better measurement of the attenuation length than the gross count. (Why?)

<u>Note on spectrum for Co-57</u>

The 122keV peak dominates (about 7 to 1) the 136keV and they almost overlap so they might not be distinct, especially for a NaI scintillation detector. You might also calculate the backscatter peak for the 122keV photon.