

LAB 2: γ -ray and X-ray attenuation (updated 2/15/15)

The objective of this experiment is to measure the mass absorption coefficient in lead and aluminum for γ -rays and X-rays of various energies. Gammas interact in matter primarily by photoelectric, Compton or pair-production interactions. The total mass absorption coefficient can be easily measured with a γ -ray spectrometer. In this experiment, we will measure the number of γ -rays that are removed from the photopeak by photoelectric or Compton interactions that occur in a lead (or aluminum) absorber placed between the source and the detector.

From Lambert's law the decrease of the intensity of radiation as it passes through the absorber is given by:

$$I = I_0 \exp(-\mu x)$$

where:

I = intensity after the absorber, I_0 = intensity before the absorber, μ = total mass absorption coefficient in cm^2/g , and x = density thickness in g/cm^2

The density thickness is the product of the density in g/cm^3 times the thickness in cm.

Densities:

Pb: $11.434 \text{ g}/\text{cm}^3$

Al: $2.702 \text{ g}/\text{cm}^3$

In this experiment we will measure μ for lead and aluminum using 662 keV Gamma Rays and low energy X-Rays from ^{137}Cs using 1173 and 1332 keV gammas from ^{60}Co .

Notes and Hints for this lab:

If you simply follow the procedure with your brain disengaged, this lab is likely to be tedious and your results are likely to be poor. To be successful, plot the data as you go, think critically about your preliminary results and discuss among your team, and collect additional data points as needed.

1. You will fit your data point to an exponential function. This generally works well if the range of the data points is large enough to that their pattern has a curved exponential shape. If the data points lie on a flat line, even if there are many of them, the fit will be unconstrained. If the points follow a straight line, the fit will be poor. What does this mean for this experiment? You should to plot your data during the lab and decide if you need make additional measurements with thicker or thinner absorbers to extend the range of the data points. If the difference between no absorber and the thickest absorber used is small compared to the error bars, the fit will not work well. You can also use multiple absorbers if necessary.
2. Past experience with this lab shows that the repeatability of individual data points is larger than the σ/\sqrt{N} statistical error in the photopeak area for one

measurement. You may want to measure several points multiple times and use that spread as your error.

Measurements:

1. Set up the NaI detector on the rail and the source holder about 15 cm away from the face of the detector.
2. Make sure the NIM crate power is off and the HV supply switch is OFF and both voltage knobs are set to ZERO. Connect PMT to HV power supply (use a SHV cable) and the PMT anode or dynode output directly to the oscilloscope. Obtain the ^{137}Cs source from the instructor or one of the TAs. The center of the source should be on the same height as the center of the detector crystal. Turn on HV to 500V, find the source signal on the oscilloscope.
3. Increase HV (by step of 100V) until the anode signal reaches a max amplitude (photopeak signal) of about 300-400mV. Connect the anode/dynode output to the amplifier input and the amplifier output to oscilloscope. The polarity of the output signal needs to be positive. Adjust the amplifier setting accordingly.
4. Set the amplifier gain, so that the amplitude of the photopeak signal from ^{137}Cs source is about 4V. Once done, connect the amplifier output to the Multi-Channel Analyzer (MCA). Start Maestro and acquire a sample energy spectrum. Make sure you see a well defined (not clipped! Why?) X-ray photopeak on the low energy end of the spectrum. Once you have a decent HV and amplifier setting, do not change them until you have finished recording all the ^{137}Cs data. Define a (fixed) Region of Interest around the ^{137}Cs photopeak.
5. Determine the count rate (net) in the photopeak region at your given distance without absorber foils (zero measurement). For this, you need to use an empty ring. Why?
6. Determine the count rate (net) in the photopeak region with a set of absorbers of aluminum and lead (pick the thicknesses carefully based on the results you are getting!). Make sure that the absorbers are aligned with the detector and the source. Take a couple of measurements with various foils/disks. You may need to use different combinations of absorber thickness for different energies and materials and perhaps use multiple absorbers in some cases. To recognize inadvertent changes in the detector/source alignment, perform a zero measurement frequently.
7. Create graphs showing count rate (including error from appropriate error propagation) as a function of absorber thickness for each energy considered. Using these data, you will be able to deduce later the mass absorption coefficient lead and aluminum for 662keV photons and for the low energy X-ray (see the calculations section).

- Repeat steps 5 to 7 for the ^{60}Co source. Set this source closer from the detector since it is a weaker source. You may need to reduce the gain of your detector if the 2 photo peaks are near or beyond the 10V range of the MCA. Use just one of the two ^{60}Co peaks for your analysis. Which peak is the better choice?
- When you are finished for the day, clean up your work space, check that the TA or instructor have collected all sources, HV supply switch and knobs are off/zero, the NIM bin is off, and you have a final OK from a TA/instructor to leave.

Plots to be provided at the end of the lab (these plots should also appear in your final report possibly associated with further analysis):

- STEP 5: Typical energy spectra from ^{60}Co and ^{137}Cs sources showing the photopeak(s) you are analyzing.
- STEP 7: Plots of count rate (counts/sec) as a function of absorber thickness for each absorber (aluminum / lead) and for each energy considered.

Calculations to be shown in your lab report:

- All your results, including errors, should be displayed in tabular and graphical form. Show the results of the individual trials and the averages for a given material and energy. Since you are making the measurement for 2 materials and for 4 energies, you will likely need more than one plot to display the results. Fit the data using Lambert's law and extract the mass absorption coefficients (in cm^2/g) including error bars for each case. Compare with the experimental (accepted) values available on the web. In comparing your results with the established values in your report, use your experimental error as the unit of difference, not % difference. Why? For better clarity, you may wish to display your final results and comparisons in a single table and in a single graphic.