

Experiment 5 Attenuation of Radiation in Matter

Gamma particle intensity decreases exponentially with distance into a material medium according to the formula:

$$I(x) = I_0 e^{-\alpha x} \quad (1)$$

where x is in units of length, and α is the linear absorption coefficient. Beta particles don't follow this formula precisely, but over a limited energy range their attenuation in matter is approximately exponential as well. See Chapter 6 for a more complete discussion of attenuation of radiation. This expression can also be written as

$$I(x) = I_0 e^{-\mu z} \quad (2)$$

where z is in units of grams/cm³, and μ is called the mass attenuation coefficient. Both of the above equations are referred to as Lambert's Law. As explained in Chapter 6,

$$\alpha = \mu\rho \quad (3)$$

where ρ is the density of the material.

Your task for this experiment is to examine if the attenuation follows Lambert's Law and if so, to measure the mass attenuation coefficient. We will examine the attenuation of gamma particles in lead, X-rays in aluminum, and betas in aluminum. You will spend two hours in room 4-3-567 measuring gamma attenuation with the NaI gamma detectors. You will spend two hours in room 8-35 measuring the attenuation of betas and X-rays.

Room 8-35

I. For the first experiment, we will examine beta attenuation in aluminum. We will detect the particles using the Geiger Counter, since the NaI detector only measures gammas. Here use the 12 thinnest aluminum absorbers from the box. Be careful not to damage the thin absorbers. Be sure to keep the same source-detector geometry throughout the experiment. Take two minute recordings for each absorber and make a table of your data. In class we will have a discussion as to how to interpret the data.

II. If there is time, you can measure X-ray attenuation. You will run this experiment via the Javascript program located on my home page. Although you should be able to do this experiment without any help, here are some tips. Measure the area (counts) under the 32 *KeV* photopeak for each of the absorber thicknesses, z . Graph Counts (area) versus z in Excel and try and fit the data via an exponential trendline. Determine if the attenuation is in fact exponential with absorber thickness z , and if so extract the attenuation coefficient μ from the trendline formula.

Room 4-3-567

III. Although you should be able to do the experiment with no help, here are some tips. Take a number of spectrum readings using ^{137}Cs or ^{22}Na as a source. Keep the source the same distance from the detector while you place the absorbers of various thicknesses between the source and the detector. Be sure you record data for a long enough time to obtain good statistics. Determine the area under each of the photopeaks for the gamma rays. The area is what we will consider as $I(x)$. Then plot your data using Excel and see if it is well described by an exponential trendline. Express your attenuation coefficients in units of cm^2/gm . For the gamma rays in lead, use the 5 lead absorbers (A, B, C, D, E). Be sure to keep the same source-detector geometry throughout the experiment.

Note: Lambert's law assumed that the beam is well collimated. However, very often in the laboratory these "good geometry" conditions are not satisfied. A photon may be scattered and yet still be recorded by the detector. Photon's may also be scattered off shielding and still be recorded under the photopeak. Thus, absorption may not follow Lambert's law exactly. Particularly with the β particles, since β decay does not emit the electron with the same energy every time, Lambert's law might not follow exactly.

Writeup for Experiment 5

1. (12 points) Turn in all data, calculations, and graphs for your measurements of the attenuation coefficients for the three different cases: gammas, X-rays, and betas. Be sure to include the correct units on all quantities.
2. (Question): (4 points) Discuss how well Lambert's law is satisfied for the three cases: a) 662 KeV or 1275 KeV gamma's through lead, b) X-rays, and c) β particles through aluminum.

3. (Question): (2 point) Which of these particles travels the furthest distance through matter? travels the shortest distance through matter?

4. (2 points) How do your values for μ for the gammas and X-ray compare to the values listed in the literature shown below?

Photon Energy (KeV)	Lead (cm^2/g)	Aluminum (cm^2/g)
20	85.7	3.41
30	29.7	1.12
40	14.0	0.567
50	7.81	0.369
60	4.87	0.280
80	2.33	0.203
100	5.4	0.171
150	1.97	0.138
200	.99	0.122
300	0.404	0.104
400	0.231	0.0927
500	0.161	0.0844
600	0.125	0.0780
800	0.0885	0.0684
1000	0.071	0.0615
1250	0.0588	0.0550
1500	0.0522	0.0501

Table I. Linear mass attenuation coefficients μ for photons passing through Lead and Aluminum. The units of μ are cm^2/g .