Absorption of Gamma Rays

Objective:

To investigate the absorption of gamma rays in a lead and to find a measured value for the mass attenuation coefficient in lead for ^{137}Cs and using this value to find the energy for the gamma ray.

Introduction:

Gamma radiation differs from alpha and beta radiation in that it consists of electromagnetic waves. Gamma rays are photons and are emitted as packets of energy called quanta, which travel at the speed of light. Only the position in the electromagnetic spectrum differentiates Gamma rays from x-rays, visible light and radio waves. Gamma rays have short wavelengths, shorter than those of visible light or x-rays. Gamma rays and x-rays are very similar but have one significant difference, and that is in where they are produced. X-rays are created in the electron shells when the electron undergoes a deceleration or jump to lower energy levels. Gamma rays are created by energy transition within the nucleus.

When gamma rays impacts on a sheet of absorbing material, some of the radiation will be absorbed or scattered. As the thickness of the material is increased, the fraction of the radiation passing through the material will decrease. A specific name is given to the thickness at which half the radiation is either absorbed or scattered and the other half passes through the material, this thickness is aptly called the half thickness $X_{1/2}$.

Thickness, X, in terms of its absorption ability is not normally how one would perceive thickness. It is not simply a distance to be measured. The thickness in terms of absorption ability is the materials "mass thickness". Materials such as aluminum and lead while they may be of the same measured distance would have different mass thickness. Mass thickness is used to represent how much matter is being passed through. It is a product of the material density in g/cm^3 and its linear thickness in cm. The units for mass thickness are g/cm^2. With this, comparisons of materials absorption ability can be readily made.

Gamma rays passing through a thickness of $X_{1/2}$ would have half the intensity, i.e. counts, as the original intensity. Passing through another thickness of $X_{1/2}$ would not mean a total reduction of intensity. Passing through this thickness would reduce the intensity by ½ again or down to 25% of the original intensity. As this would occur with each additional $X_{1/2}$ thickness added it should be obvious that it does not follow a linear relationship, eventually with enough thicknesses added the count rate should fall to that of the background counts.

The attenuation (or absorption and scattering) of the gamma rays is exponential in nature and is shown by the equation:

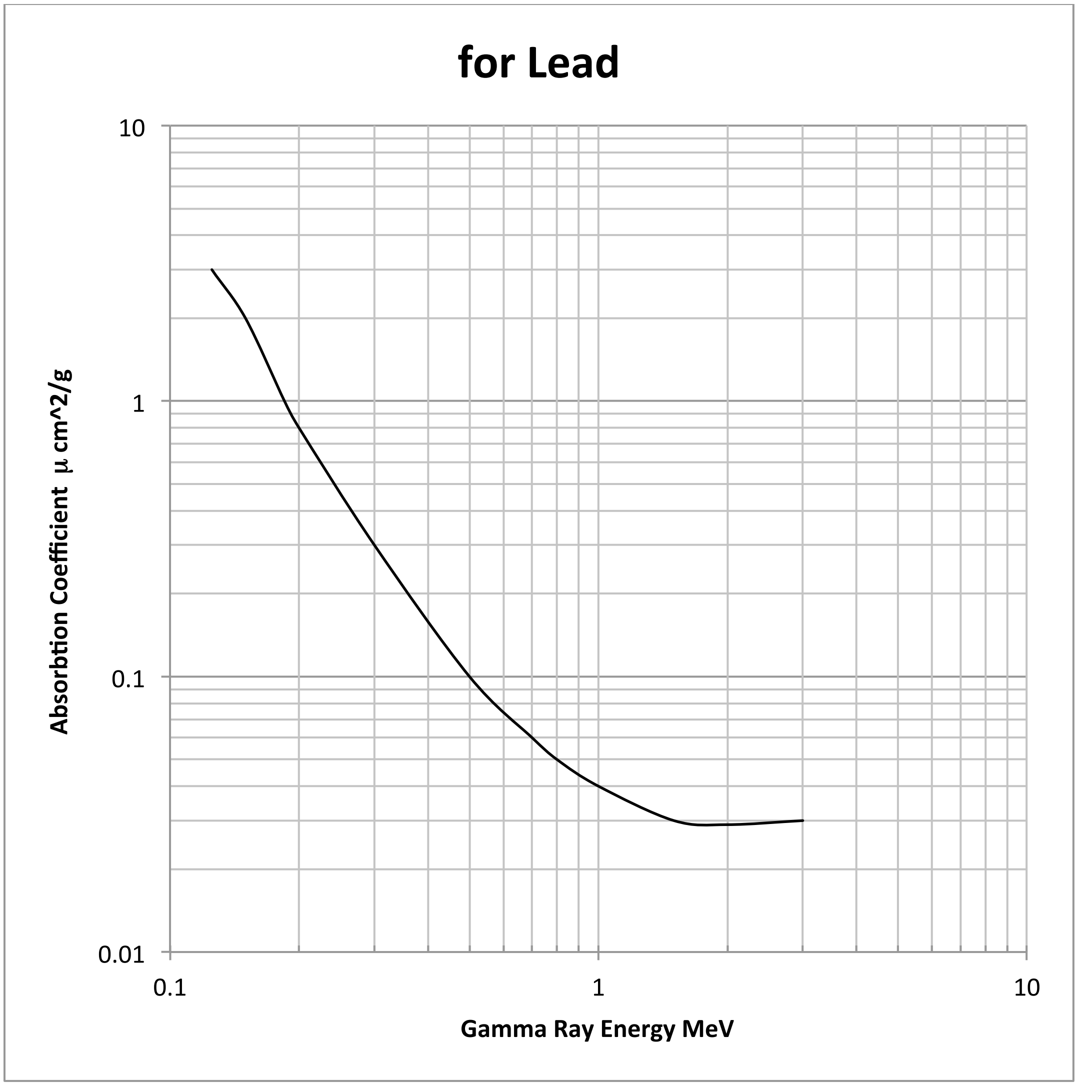
$$I = I_o e^{-\mu X} \qquad [1]$$

where I is the intensity of the beam after passing through the X amount of absorbing material, $I_o$is the initial intensity of the beam, μ is the mass attenuation coefficient in cm^2/g, and X the mass thickness in g/cm^2.

From this equation and realizing that when the intensity $I = ½ I_o$, $X = X_{1/2}$ an equation solving for the theoretical mass attenuation coefficient,μ, can be determine simply in terms of $X_{1/2}$ as:

$$\mu = \frac{\ln(2)}{X_{1/2}} = \frac{0.693}{X_{1/2}}$$

In this experiment you will attempt to find $X_{1/2}$, the mass attenuation coefficient, μ, for lead and the energy of the gamma ray emitted from the source.
The values for μ is dependent on the energy of the gamma ray being absorbed and the material.
The graph below represents the mass attenuation coefficient vs. Gamma ray energy for lead.



You will be using the G-M tube setup to perform this experiment. It should be noted that error between the true value and measured value of the gamma ray is to be expected. The detector cannot isolate the peak counts themselves but counts a broad spectrum of energy. Ideally using the MCA or SCA would allow narrowing the region of interest to only obtain the desired peak counts.
This experiment however should give a reasonable experimental value for $X_{1/2}$ for the source and material.

Procedure:

Setup the ST360 to the tube voltage marked on the tube.
Turn off step voltage.
Set time to 300s
Set runs to 1.

Place the aluminum absorption piece H in the 2nd tray position.
Place the ^{137}Cs source with paper side upwards 2 shelves below the aluminum. This should prevent scattering effects which may cause a slight rise in counts when you start stacking the lead sheets.
It has been discovered that the paper side of the source behaves mainly as the gamma emitter of the source. The beta particles are drastically reduced which may have been observed in the first two labs.

Start a data run. Record the counts. The absorption thickness of the aluminum is 0.161 **g/cm^2**.

There are 6 lead sheets, each has a absorption thickness of 1.644 g/cm^2.
Place a single sheet on top of the aluminum sheet and acquire another data run.

Record the data and the absorption thickness. Don't forget to add the aluminum.
Stack another lead sheet and repeat.

Replace the ^{137}Cs source with ^{60}Co. Repeat the above steps.
^{60}Co is a pure gamma emitter either side upwards produces statistically the same results.
However it does have two gamma emissions one at 1.173MeV and the other at 1.333 MeV.

Analysis:

From equation 1 is should be expected that the data should be exponential. However given the small range of absorption thickness it may not be immediately obvious.

Graph counts vs. absorption thickness for each source. A linear line fitted to the data should yield a line where
$y = -ax + b$ Using this line determine a value for $X_{1/2}$.
I_o is the counts after passing through only the aluminum thickness.

Make conclusions about the gamma emissions of the source and the necessary thickness for $X_{1/2.}$

For ^{137}Cs only
In equation 1 solve for μ when $I = 1/2I_o$ and $X=X_{1/2}$
I_o is the counts after passing through only the aluminum thickness.

Uses the value for $X_{1/2}$ for ^{137}Cs and find μ.
Use the provide graph of attenuation coefficient vs. gamma energy to find an energy for ^{137}Cs.
Compare it to the known value of 0.662 MeV.

Why would this method in finding the gamma energy not work as well for ^{60}Co?