Calculation of half value Thickness, Absorption of Gamma Rays in Lead and Aluminum Using Gm Counter

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Abstract

Half value thickness is the most frequently used important parameter for explaining both the penetrating ability of particular radiations and the penetration through specific objects or materials. Three standard lead sheet and three standard aluminum sheet samples were used as inspected objects in this research. In this work, measurements are performed by using GM counter with standard radioactive gamma source ^{137}Cs. The aim of this research is to determine the half value thickness of lead and aluminum for radiation shielding materials. Linear attenuation coefficient, half value thickness of absorber materials were calculated and study will be useful in selecting shielding material. Lead was found to have a higher attenuation coefficient and a better radiation shielding than aluminum.

Keywords: Linear attenuation coefficient, half value thickness of absorber materials

Introduction

Gamma radiation shielding is the absorption and attenuation of gamma energy in shielding material. Most materials absorb the energy of gamma rays to some extent. The extent of attenuation depends on the density and thickness of the shielding material. Hence a thick layer of a lighter material will have the same effect as a thin layer of a denser material. Radiation shielding is used to reduce radiation exposure to personnel and equipment in the vicinity of radiation sources. Radiation shielding is very pertinent in nuclear industries as well as in radioisotopes production and usage, and in particle accelerator facilities. Materials for shielding gamma rays are **typically** measured by the thickness required to reduce the intensity of the gamma rays by one half.

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Experimental Details

1. Study Area and sample collection

In this research work, the standard lead samples are Q (S–1), R (S–2), S (S–3) and standard aluminum samples K (S–1), O (S–2), P (S–3) and each is 0.1cm, 0.2cm, and 0.3cm thick.

They were collected at Department of Physics, Yadanabon University in the Nuclear Experiment Lab.

2. Experimental Set–Up for Gamma Emission Measurement

ST–360 counter is set up with GM tube. Power was supplied into any normal electricity outlet. Power supply was turned on the back of the ST –360counter ON position. The "voltage control" knob of the scalar unit was turned to its lowest position and the "voltage switch" and the "count switch" were switched. Firstly, the main supply was switched on and the background counting rate was noted without the radioactive sample for at least 300 sec and it was repeated three times. And then, the data were recorded.

Square pieces of lead samples with different thickness were placed on the source holder just below the Geiger tube and the power supply was adjusted at the high operating voltage was 900V. Second, the lead sample was placed for at least 300sec and repeated three times. Then, these data were recorded. After that, the lead sample was removed from the source holder. And then, square pieces of aluminum samples with different thickness were placed on the source holder just below the Geiger tube and above the standard sources. Then, the data were recorded. All the observations were repeated three times keeping operating voltage the same.

A Geiger–Muller Tube and radioactive source (137 Cs, 5μCi), standard lead and aluminum samples were used. The distance between the source and detector was 5cm. The samples were placed 1cm above the source.

3. Calculation of Half Value Thickness

When radiation passes through matter, it undergoes attenuation primarily by photoelectric effect, Compton scattering and pair production. The intensity of the radiation is thus decreased as a function of thickness of the absorbing material. The mathematical expression for intensity I is

$$I = I_o e^{-\mu x} \qquad (1)$$

where, I_o= the original intensity of the beam

I =the intensity transmitted through an absorber thickness x

μ = the linear attenuation coefficient for the absorbing material

If we rearrange equation (1) and take the natural logarithm of both sides, the expression becomes,

$$\ln\left(\frac{I}{I_o}\right) = -\mu x \qquad (2)$$

The half value thickness of the absorbing material is defined as the thickness $x_{1/2}$ which will decrease the initial intensity by half. This is,

$$I = I_o/2.$$

If we substitute this into equation (2), we get

$$\ln(2) = \mu x_{\frac{1}{2}} \qquad (3)$$

Rearranging equation (3) we get

$$x_{\frac{1}{2}} = \frac{\ln(2)}{\mu} = \frac{0.693}{\mu} \qquad (4)$$

Results and discussion

Table (1) Experimental results in different thicknesses of lead samples

Sr. No	Sample Name (Pb)	Thickness (cm)	Trial	Recorded gross count for 300 sec	Mean gross count per 300 sec	Mean gross count per sec	Net count rate I
			(i)	2795			
			(ii)	2843			
1	Q	0.1	(iii)	2948	2895	9.53	9.08
			(iv)	2994			
			(v)	2895			
			(i)	2463			
			(ii)	2517			
2	R	0.2	(iii)	2531	2530	8.43	7.48
			(iv)	2546			
			(v)	2593			
			(i)	2169			
			(ii)	2187			
3	S	0.3	(iii)	2216	2217	7.39	6.94
			(iv)	2238			
			(v)	2275			

Table (2) Value of thickness versus Ln (I/I_o) of lead samples

Sr. No	Thickness (cm)	Ln (I/I_0)
1	0.1	–4.8876
2	0.2	–5.0167
3	0.3	–5.1563

Table (3) Experimental results in different thicknesses of aluminum samples

Sr. No	Sample Name (Al)	Thickness (cm)	Trial	Recorded gross count for 300 sec	Mean gross count per 300 sec	Mean gross count per sec	Net count rate I
1	K	0.1	(i)	2871	3060	10.2	9.75
			(ii)	3061			
			(iii)	3125			
			(iv)	3092			
			(v)	3151			
2	0	0.2	(i)	2716	2849	9.5	9.05
			(ii)	2849			
			(iii)	2928			
			(iv)	2864			
			(v)	2888			
3	p	0.3	(i)	2657	2742	9.1	8.65
			(ii)	2812			
			(iii)	2741			
			(iv)	2782			
			(v)	2719			

Table (4) Value of thickness versus Ln (I/Io) of aluminum samples

Sr. No	Thickness (cm)	$Ln(I/I_0)$
1	0.1	–4.8164
2	0.2	–4.8909
3	0.3	–4.9361

Table (5) Result for Half value Thickness of Lead Sample

Sample	Source	Energy (keV)	Linear attenuation coefficient (cm^{-1})	Half-value Thickness (cm)
Lead	Cs-137	662	1.343	0.516

Table (6) Result for Half-value Thickness of Aluminum Sample

Sample	Source	Energy (keV)	Linear attenuation coefficient (cm^{-1})	Half-value Thickness (cm)
Aluminum	Cs-137	662	0.599	1.15

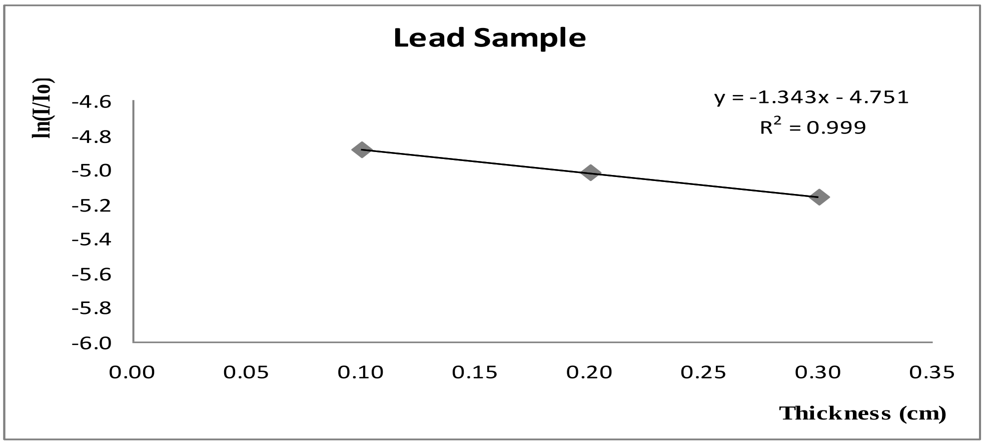

Figure (1) Attenuation graph for Cs-137 Gamma Source of Lead | Sample

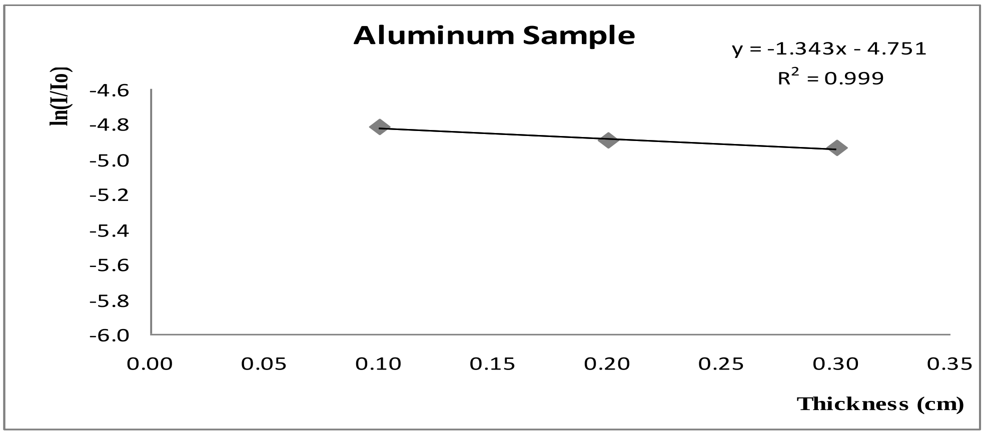

Figure (2) Attenuation graph for Cs-137 Gamma Source of Aluminum Sample

Conclusions

In this research work, standard radioactive source ^{137}Cs (5μCi), working voltage (900V), GM counter and three standard lead and three standard aluminum samples are used. One of the samples is placed between a radioactive source and a GM counter. All the samples are tested in similar ways. The data are analyzed and the results are shown in above Tables and Figures. From tables (3) and (4) and figures (1) and (2), it is seen that the net count is inversely proportional to the thickness of absorber. As the absorber's thickness increases, the net count decreases. This is imaginable, since the absorber is to shield, absorb or reduce the number of photons going into the GM tube, then the more the absorber thickness increases, the more it does this work and the lesser the number of photons that get to the GM tube and then the lower net count. It indicates that lead attenuates more gamma rays intensity as compared to the aluminum foil. Therefore lead is a more effective shielding material for gamma radiation.

The present study provides the values of the gamma-ray linear absorption coefficient and half value thickness of materials. The results show that attenuation can be achieved using a wide range of materials. In this present investigation, the linear absorption coefficients (μ) from the graph are used and calculated the half value thickness of lead and aluminum absorbing materials. So, it can be concluded that the half value thickness should be used in many nuclear fields for shielding material.

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