University of Cape Town
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PHY1004W
Radioactivity: Shielding Gamma Rays And Calculating The Linear Absorption Coefficient For a Material

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0.1 Introduction

Radioactivity refers to to the the emission of particles from nuclei as a consequence of nuclear instability. The three common types of radiation emitted in the decaying process are alpha, beta and gamma radiation. In this experiment, we will be observing the penetration of gamma rays through different materials as gamma rays are efficient at penetrating material and they have a longer range being able to penetrate materials with varying thickness. Using a Geiger Counter, we will measure the amount pulses of gamma rays detected per unit time after having to penetrate through a material since different materials will absorb different amounts of gamma rays. For such an experiment, we will use the radioactive source of an isotope of cobalt ^{60}Co. Cobalt ^{60}Co decays by emitting two gamma rays with a mean energy of $1.25 Mev$. There are also other sources of radiation in the environment and as a result we have to account for this when calculating the radiation from a source (this is known as background radiation).

0.2 Aim

The aim of this experiment is to calculate the linear absorption coefficient of a strong shielding material. This will be done by making use of equation 1.

$$N(x) = N_0 e^{-\alpha x} \tag{1}$$

In equation 1, $N(x)$ is the number of counts per second, N_0 is the number of counts per second with no absorbing material between the Geiger tube and the source of gamma rays and α is the linear absorption coefficient for the shielding material. If all other variables are kept constant and the thickness of the sheilding material and the amount of radiation detected change, we can use the linearised version of equation 1: $\ln(N(x)) = -\alpha x + \ln(N_0)$, to plot a linear graph and retrieve a gradient which will give us the linear absorption coefficient.

$$m = -\alpha \tag{2}$$

0.3 Method and Apparatus

The apparatus of this experiment consists of the following components: an electronic unit, a coaxial cable, a geiger tube, an absorber, a bench and a source of radiation.

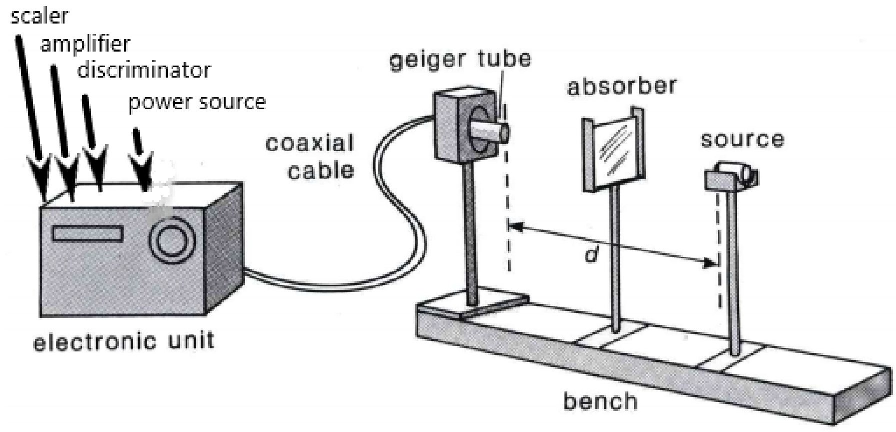

Figure 1: The apparatus used in the experiment to measure the shielding ablity of lead.

The method used to collect the data in this experiment is the following: With the apparatus set up, a reading is taken withshielding material out of place and the source far away and this is regarded as the background reading, this is done for four trials. The source is then placed in the position shown on Figure1 and a reading is taken without a shielding material in place, this will give the values of N_0 and this is done for four trials. For the first part of the experiment, different materials of the same thickness are placed as absorbers and a reading is taken for four trials with the apparatus as shown on Figure 1. For part two, the strongest shielding material will be compared to the same type of material for different thicknesses; a source, geiger tube and the electronic unit is setup as shown on Figure 1, the lead absorber is placed between the source and the geiger tube and four trials are taken for a lead absorber of a certain thickness.

0.4 Data and Results

Table A: The Thickness of Lead (x) Versus the Number of Counts in 60 Second Intervals Observed on the Counter

x $(\times 10^-3m)$	Average Counts per minute
0	580.5
2.2	491.75
4.4	413.25
6.6	353
8.8	298
13.0	215
15.2	185.25
17.4	161

Table B: The Thickness of Lead (x) versus the Number of counts per second accounted for the background $N(x)$

x $(\times 10^-3m)$	Average Counts per second $N(x)$	$u(N(x))$
0	9.35	0.09
2.2	7.87	0.08
4.4	6.59	0.07
6.6	5.56	0.06
8.8	4.64	0.05
13.0	3.25	0.03
15.2	2.76	0.03
17.4	2.35	0.02

Table C: The Thickness of Lead (x) versus the Natural Log of the Number of counts per second accounted for the background $\ln(N(x))$

x ($\times 10^{-}3m$)	Natural Log of the Average Counts per second $\ln(N(x))$	$u(\ln(N(x)))$
0	2.23	0.01
2.2	2.06	0.01
4.4	1.89	0.01
6.6	1.71	0.01
8.8	1.53	0.01
13.0	1.18	0.01
15.2	1.01	0.01
17.4	0.85	0.009

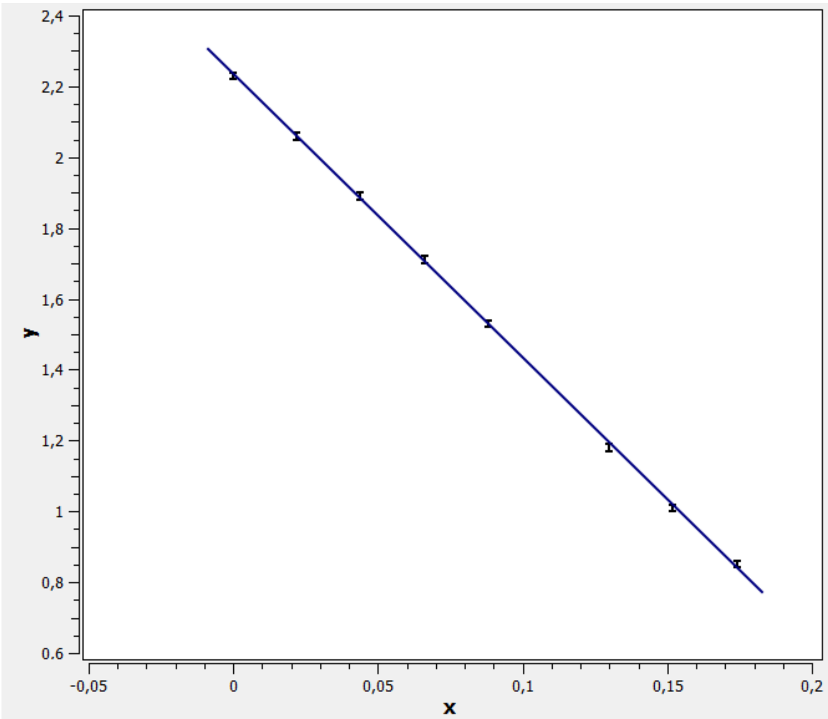

Figure 2: The linear graph resulting from the data in Table C, the gradient of this graph is equal to the linear absorption coefficient (α).

$m = -8.01602 \pm 0.049337$, $c = 2.23514 \pm 0.00521212$

0.5 Analysis and Intepretation

Part 1

From the results on the Table on part A of the handout ,Lead is the the best material for sheilding the gamma rays of energy $1.25Mev$. The shielding power depends on the density of the shielding material.

Part 2

In Table A, the thickness of the Lead shielding material is recorded alongside the average counts per minute which were calculated using results of the four trials done. To average all readings the following formula was used:

$$A = \frac{\Sigma a}{n} \tag{3}$$

,here A is the average, a is the different recordings of counts per minute and n is the number of recordings.
The values for the average counts per minute in Table A need to be corrected for the background and converted to counts per second in order to use equation 1 correctly. To convert the data to counts per second the following equation was used:

$$NB = \frac{M(counts/60seconds)}{60} \tag{4}$$

,here M is the value of counts per minute and NB is the value of counts per second with a background reading.
To correct for the background reading, the following formula was used:

$$N(x) = NB - B \tag{5}$$

,here $N(x)$ is the counts per second with no background reading. Using the value of background $B = 0.329counts/second$, the data in Table B is found. To calculate the uncertainty in Table B, it was assumed that the Geiger Counter has a rating of 1%. To find the uncertainty of $N(x) = NB - B$, the following formula was used:

$$u(N(x)) = \sqrt{(u(NB))^2 + (u(B))^2} \tag{6}$$

$$u(N(x)) = \sqrt{(0.01 \times NB)^2 + (0.01 \times (B)^2} \tag{7}$$

This equation is used for all the uncertainties in Table B.
The next step is to find the natural log of the $N(x)$ values and the uncertainty

$u(N(x))$, In Table C, these values are found by calculating the natural log of the $N(x)$ values $\ln(N(x))$ and the uncertainty of $N(x)$ is found using the following formula:

$$u(\ln(N(x))) = \frac{u(N(x))}{N(x)} \tag{8}$$

After using the data in Table C to plot a linear graph, the gradient (m) is found and it is used to calculate α using equation 2:

$$m = -\alpha \tag{9}$$
$$-8.01602 = -\alpha \tag{10}$$
$$\alpha = 8.01602 \tag{11}$$

From the linear fit: $\alpha = 8.01602 \pm 0.049337$

0.6 Conclusions and Recommedations

The expected value for linear absorption coefficient of Lead (α) is calculated in the following:

$$\begin{aligned} \lambda &= \frac{\rho}{\alpha} \\ \lambda &= 1.33 g/cm^2 \\ \rho &= 11.30 g/cm^{-3} \\ \alpha &= 8.50 \end{aligned}$$

As stated in the aim of this experiment, the value of the linear absorption coefficient α from the experiment is the following: $\alpha = 8.016 \pm 0.049$. The values are not in agreement. The inaccuracies in these results might arise from sources of uncertainty including the rating of the gieger counter as it was assumed and the thickness of the lead shielding materials as these might have not been properly cut. Recommendations to improve this experiment are to find the rating of the gieger counter and to cut the thick pieces of lead properly.