# MEASUREMENT OF GAMMA-RAY MASS ABSORPTION COEFFICIENT OF Pb USING NaI(Tl) SCINTILLATION DETECTOR

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**Abstract**

*This study intends to measure the transmission of gamma rays such as $^{137}Cs$, $^{60}Co$, $^{57}Co$, and $^{22}Na$ through a lead absorber using the Gamma Ray Spectroscopy Techniques. Electrical pulses, carrying the physical information, will be displayed on the computer screen with the number of channels on the horizontal scale and number of pulses on the vertical scale. The Multichannel Analyzer will then process these pulses, which are digitized.*

*It also aims to determine the mass absorption coefficient of the said absorber and to evaluate how it varies as a function of gamma ray energy. The mass absorption coefficient are then determined from the slope using the exponential absorption law. The net transmitted count will be plotted for every thickness of the absorber and the absorption coefficient versus the gamma energy. Results showed that the mass absorption coefficient of lead absorber is 11200.4 ± 66.46803 $cm^2/gm$.*

**Key Concepts:** *Absorption and scattering cross sections for photons*

## I. Introduction

Sunlight consists of a mixture of electromagnetic rays of various wavelengths, from the longest, infrared, through red, orange, yellow, green, blue, indigo, and violet, to the shortest in wavelength, ultraviolet. Gamma rays have the smallest wavelengths, even far shorter than ultraviolet. They are produced by such violent events as supernova explosions or the destruction of atoms, and by less dramatic events, such as the spontaneous decay of radioactive material. And it has the most energy compared to any other wave in the electromagnetic spectrum. These waves are generated by radioactive atoms and in nuclear explosions.

All forms of radiation are absorbed by matter, but to a varying degree, depending on the density and atomic number of the absorbing material. Gamma radiation is very penetrating and can pass through a considerable thickness of material.

In this study, a beam from a gamma source with intensity $I_0$ is made to pass through a given material of different thickness $x$.

Let $I_0$ be the intensity of $\gamma$ radiation detected at some distance from the source and $I$ the emergent intensity, reduced by the absorbing material of thickness $x$ between the source and the detector. With a small increase $\Delta x$ in absorber thickness, the fractional change in intensity, $\Delta I/I$ is proportional to $\Delta x$. Hence $\Delta I/I = -\mu\Delta x$ where $\mu$ is the proportionality constant called the absorption coefficient and depends on the energy of the incident radiation and the material being used. One way of determining the emergent intensity is to integrate the equation $\Delta I = -\mu I\Delta x$ using calculus. Thus we have the exponential absorption law, $I = I_0 e^{-\mu x}$, where $I_0$ is the incident intensity, i.e., $I = I_0$ when $x = 0$, $I$ is the intensity left after the radiation traverses a thickness $x$ of material and, $e = 2.718$ is the base of the system of natural logarithms.

Since $I = I_0 \ e^{-\mu x}$ is not a linear relationship, a plot of $I$ versus $x$ is not convenient for determining the absorption coefficient $\mu$. But if the natural logarithm of the above expression is taken, i.e., $\ln I = \ln I_0 - \mu x$, the plot of $\ln I$ versus $x$ for the data will yield a straight line with slope $-\mu$..

## II. Experimental Details

To determine the absorption coefficients, a NaI(Tl) scintillation detector is used to detect the radiation from gamma sources such as $^{137}$Cs(662 keV), $^{60}$Co(1.17 and 1.33 MeV), $^{57}$Co(122 keV), $^{22}$Na(511 keV, 1.27 MeV). Then PCA software will generate the spectral analysis of the sample data.

In this experiment, the absorption of the γ-rays emitted by different gamma sources using lead is measured.

The processes by which absorbing materials can reduce the intensity of γ radiation are: 1) the photoelectric effect, 2) the Compton effect and 3) pair production. Only the first two effects will occur with all the γ energies. The pair production will only be seen when we use γ sources with γ energy of at least 1.02 MeV.

### 1. Equipment

These are the equipment that will be used:

(1) Model 5010 Amplifier

(2) Model P-2000/2 NaI(Tl) Detector

(3) IBM Compatible PC

(4) Personal Computer Analyzer (PCA-II) Card and Software

Fig. 1 The Equipment

### 2. Experimental Arrangement

Throughout the course of the experiment, an operating voltage of 900 volts is maintained and the amplifier's coarse and fine grains are set to 20 and zero respectively. The PCA-II having the following settings:

Mode: PHA
Timer: Real
Group: Full
Gain: 1024
Offset: 0
Adc: Add
Display: 1024
Overlap: Off
Preset Time: 5000 seconds

After the warming up of the scintillator amplifier for about 20 to 30 minutes, the data taking starts. The scintillator detector is mounted on a stand while a gamma-ray source is inserted in the racks of the stand. Above this source is the lead absorber used in the experiment.

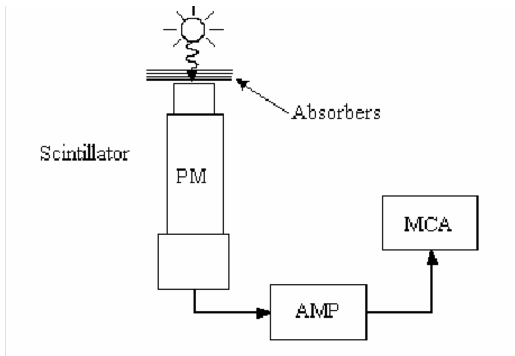


Fig. 2 Diagram of the apparatus.

## III. Results and Discussions

Below is a spectra of $^{137}Cs$ using lead absorbers of different thicknesses. This spectrum

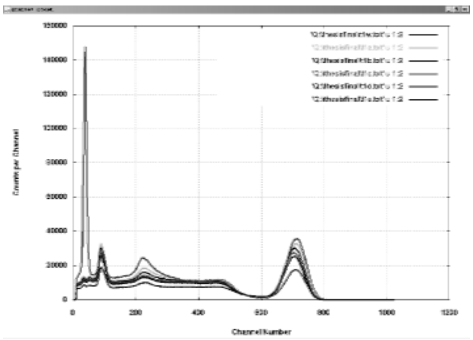

Fig. 3 The spectra of $^{137}Cs$.

will be used to locate the photo peak in order for the mass absorption coefficient to be solved.

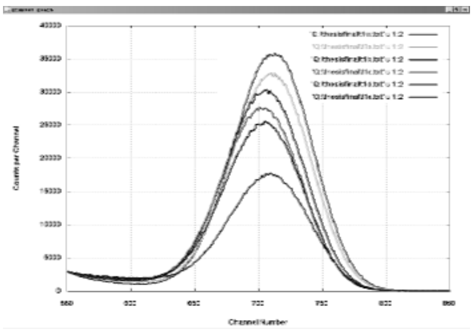

Fig. 4 The Photopeak

Since this study is concerned with finding the mass absorption coefficient of lead, the density thickness is used instead of the thickness of the material. The density thickness is the product of the thickness and the density of the material. The known value of the density of lead is 11.34 g/cm$^2$.

To get $I$ and $I_0$, the area of our region of interest, i.e., the photo peak, was solved. Adding the counts from the left bound channel, $a$ to the right bound channel, $b$ of the photo peak and subtracting from this the background, the net integral count is obtained.

$$A = \sum C_i - (1/2)(b - a)(C_a + C_b)$$

The *gnuplot* is used to obtain the slope, plotting the counts versus the density thickness. Then, the graph obtained is fitted with a line fit using the equation **f**($x$) = **a**$x$ + **b**, where **a** is the slope and **b** is the **y**-intercept.

The slope obtained is 11200.4 cm$^2$/gm. This value agrees with the results obtained by other researchers whose works were compiled by the Department of Earth and Planetary Science Home Page.

Table 1

| Emitter | Absor-ber | Henke Ebisu | Henke et al. | Bastin Heijligers |
|---|---|---|---|---|
| $^{137}Cs$ | Lead | 12470 | 12500 | 11000 |

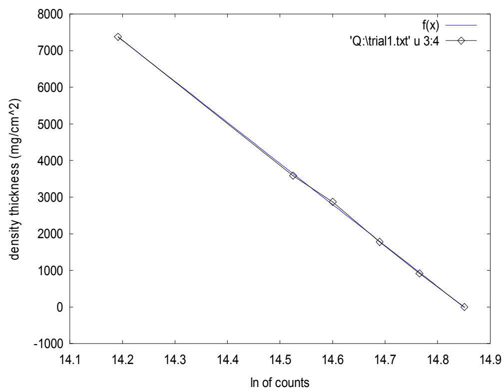


Fig. 5 Fitting the plot of counts vs. density thickness.

Final set of parameters Asymptotic Standard

Error

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a = -11200.4 +/- 95.07 (0.8488%)
b = 166324 +/- 1389 (0.8349%)

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## IV. Conclusion

Basically, the set-up of the experiment is valid considering the result obtained. And also the experimental result from this study agrees with the results from experiments done by other researchers.

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