

# Gamma Lab Report

## Introduction

Gamma radiation is electromagnetic radiation that ranges from 30EHz to 300EHz. It has the highest energy range within the spectrum and it is highly dangerous to be exposed to it.

The aim of this lab is to understand how gamma photons interact with matter by measuring the linear absorption coefficient ( $\mu$ ) of Lead (Pb) and Tin (Sn). This linear absorption can then be plotted as a function of energy up to 1332keV. The sources of gamma photons are  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$ , and  $^{241}\text{Am}$ .

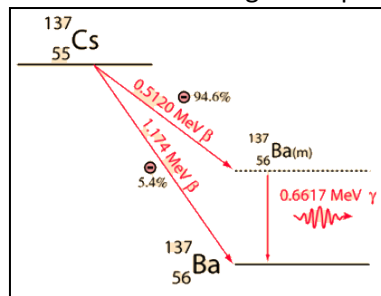


Figure 1: Decay Scheme of  $^{137}\text{Cs}$

## Experimental Set up and Procedure

The sources of radiation are sequentially placed within a 2-inch thick lead cave. The 2 inch-thick lead cave shields the detector from background radiation and shields the experimenter from possible harmful gamma radiation. A photo-multiplier coupled with a NaI(Sodium Iodide)Scintillator is inserted into the top of the lead cave. The data acquired by the Scintillator is then sent to the computer with Tukan 8k software.

Procedure:

1. The first sample,  $^{137}\text{Cs}$  was placed into the lead cave to acquire its gamma energy spectrum
2. Then  $^{60}\text{Co}$  replaced  $^{137}\text{Cs}$  in the lead cave and its spectrum was acquired as well
3. Calibration using  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  was then done and the energy was noted.
4. The absorption coefficient,  $\mu$ , was calculated for Lead and Tin.
5. The results obtained are then compared to the NIST graph.

The above procedure was then used to record the absorption coefficient of lead and tin with Am-241 as the radiation source. The spectrum was also recorded and analyzed. The detector was calibrated with polynomial function of second degree because of two reasons – It is much easier to work with energies than channel number and also a second degree polynomial gives an appropriate amount of accuracy.

## Results and Discussion

### Radiation Spectra of Radioactive Sources

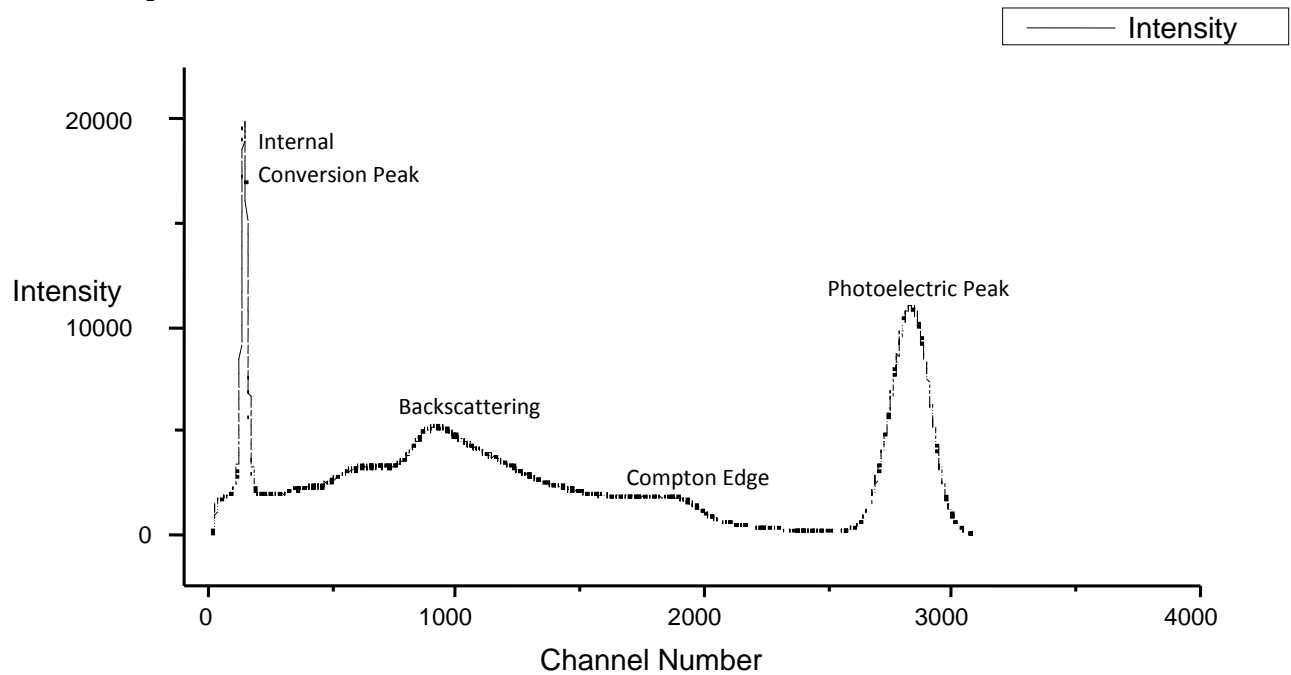


Figure 2: Plot of Channel number against Intensity of Cs-137 at Detector. A higher channel number denotes a higher energy value.

The first spectrum obtained is used to explain the process and the different types of interaction gamma radiation emitted by  $^{137}\text{Cs}$  go through. As seen from the table of isotopes that nearly 95% of times  $^{137}\text{Cs}$  nucleus decays to  $^{137}\text{Ba}$  through  $\beta^-$  interaction and this unstable  $^{137}\text{Ba}$  nuclei then stabilizes to its ground state emitting a gamma photon of energy which is equal to 662keV.

The peak to the extreme right shows the photoelectric effect which states that all the energy of the photon is transferred to the electron of the detector which is then detected to be 662KeV. The lower peaks to its adjacent left are due to Compton Effect also known as the Compton edge happens when the photon gives only part of its energy to the electron.

The next set of peaks on the left is due to backscattering, which occurs when the photon bounces back to the detector. The large peak that we see to the extreme left is due to internal conversion, which happens mostly because the excited  $^{137}\text{Ba}$  nuclei has a comparatively long half-life of 2.55 minutes.

### Absorption Coefficient of Lead and Tin

For calculating the absorption coefficient, we used layers of lead and tin between different sources and the detector. The sources used were  $^{241}\text{Am}$ ,  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , as the photon energy emitted by  $^{241}\text{Am}$  is low, it was calculated separately and other two were used together to get the data.

To deduce the absorption coefficient of the materials, we use the equation:

$$I = I_0 e^{-\mu l} \quad (1)$$

$\mu$  is the attenuation coefficient or, in this case, absorption coefficient  
 $I$  is the intensity of the gamma radiation at distance  $l$  into the material  
 $I_0$  is the original intensity of the source

By manipulating the equation (1), we can set the attenuation coefficient as a function of the gamma ray intensity at distance  $l$  into the material.

$$\mu l = -\ln \frac{I}{I_0} \quad (2)$$

The gradient of the plot will then be the attenuation coefficient. An example is seen below in Figure 5.

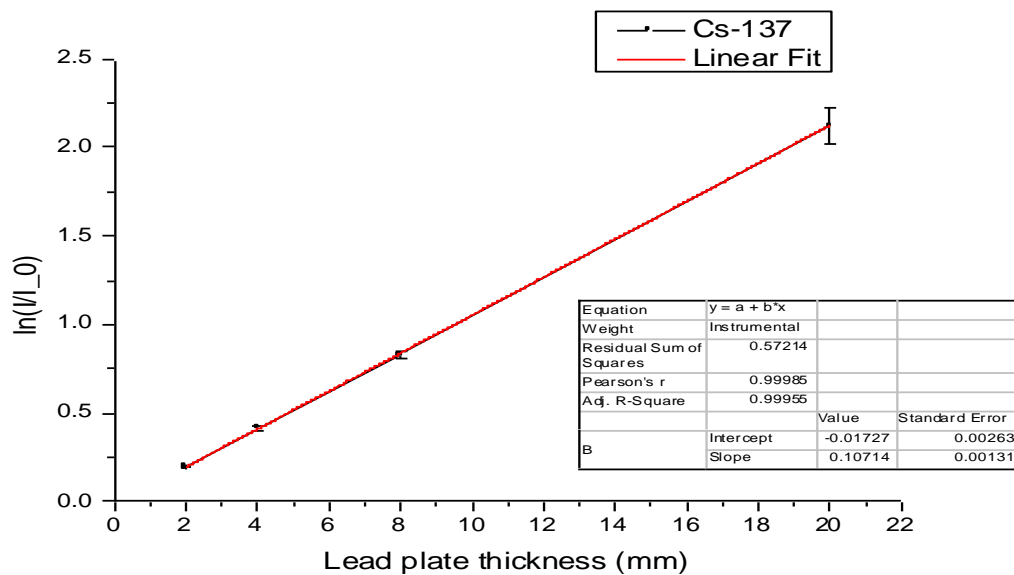


Figure 5: Plot of Lead (Pb) thickness (mm) against  $\ln \frac{I}{I_0}$  for the element Cs-137. By using the different intensities corresponding to different lead thickness, we can obtain  $\mu$  and compare it with data from NIST.

By using this plot of lead thickness against  $\ln \frac{I}{I_0}$ , the gradient obtained is  $\mu$ . This is done in an example in the next section. The example is a table of the different attenuation coefficients for different gamma energy values.

### $\mu$ value for Lead (Pb) and Tin (Sn)

Taking density of Lead (Pb): 11.35 cm<sup>3</sup>/g,

Energy/MeV	$\mu$ (cm <sup>-1</sup> )	$\mu/\rho$ (cm <sup>2</sup> /g)	Error propagation (cm <sup>2</sup> /g)
0.0595	58	5.11	0.2
0.662	1.07	0.094	0.001
1.173	0.616	0.054	0.003
1.337	0.557	0.049	0.002

Table 1: Table of  $\mu$  values against corresponding energy values for lead (Pb)

Taking density of Tin (Sn):  $7.31\text{cm}^2/\text{g}$

Energy/MeV	$\mu$ ( $\text{cm}^{-1}$ )	$\mu/\rho$ ( $\text{cm}^2/\text{g}$ )	Error propagation ( $\text{cm}^2/\text{g}$ )
0.662	0.49	0.067	0.001
1.173	0.29	0.040	0.004
1.337	0.31	0.042	0.005

Table 2: Table of  $\mu$  values against corresponding energy values for Tin (Sn)

In table 1 and 2, we evaluated the experimental values for  $\mu/\rho$  so we could match it to the gamma coefficient graphs.

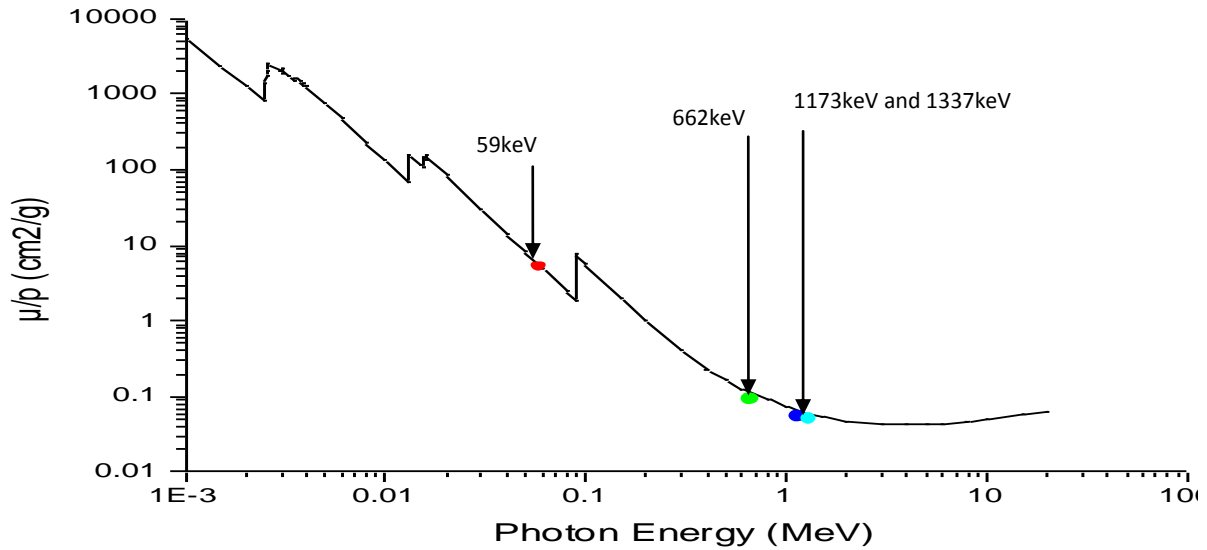


Figure 6: Plot of experimental values of  $\mu/\rho$  onto the NIST graph of the gamma energy coefficient of Lead (Pb) as a function of photon energy (MeV).

$^{241}\text{Am}$  gives off about 59keV, however, it was too weak to be sensed by the equipment, thus we could only attain one value for it. Plotting it into the NIST graph shows an accurate representation of the changing  $\mu$ -value with varying photon energies.

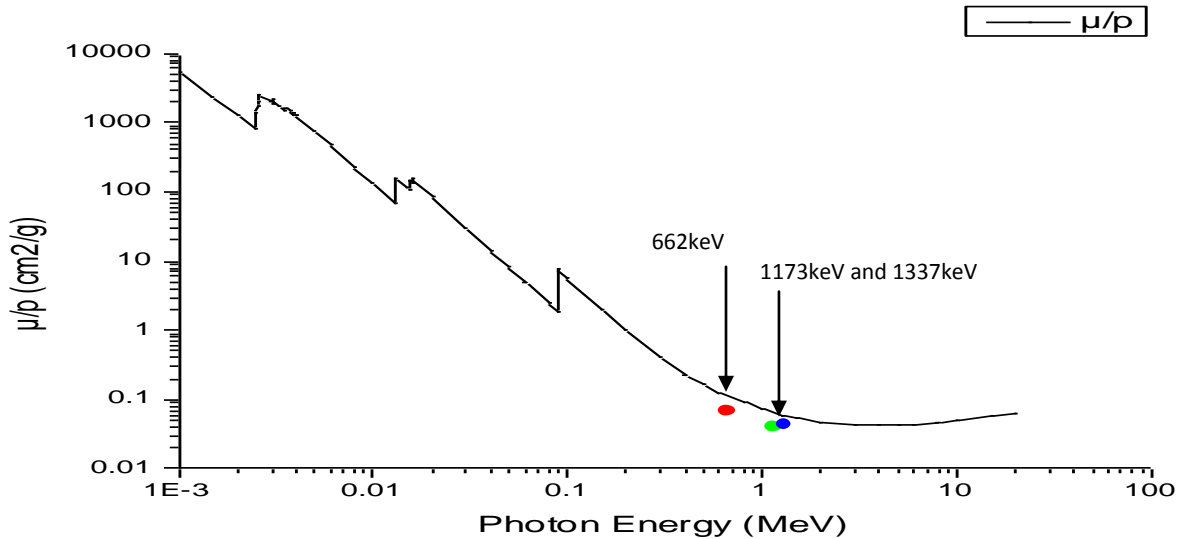


Figure 6: Plot of experimental values of  $\mu/\rho$  onto the NIST graph of the gamma energy coefficient of Tin (Sn) as a function of photon energy (MeV).

## **Conclusion**

The experimental values of the absorption coefficients do not deviate from the theoretical values. However, in Figure 6, the experimental coefficients of Tin deviated more than the ones in Lead. Systematic errors can be the cause of this. Gamma rays confined within the lead cave can reflect off its walls and cause a more inaccurate reading.

## **References**

NIST X-ray Mass Attenuation Coefficients:

<http://physics.nist.gov/PhysRefData/XrayMassCoef/ElemTab/z82.html>

Gamma Spectroscopy:

[http://en.wikipedia.org/wiki/Gamma\\_spectroscopy](http://en.wikipedia.org/wiki/Gamma_spectroscopy)