INVESTIGATION ON ATTENUATION CHARACTERISTICS OF Al-Zn METAL ALLOY FOR GAMMA RAY SHIELDING

Shwe Nan Htet[1], Aye Aye Mar[2], Shwe Sin Oo[3] and Nadar Hnin Yee[4]

Abstract

The main purpose of this study was to investigate gamma ray attenuation characteristics of Al-Zn metal alloy shielding material. The attenuation coefficients of Al-Zn metal alloy for various gamma sources were determined using gamma ray spectrometer systems. The gamma ray attenuation characteristics of Al-Zn metal alloy shielding material could be tested by calculating half value layer (HVL), tenth value layer (TVL) and mean free path (MFP).It was found that the photon intensity decreased as attenuator thickness increased. It was seen that linear and mass attenuation coefficients of Al-Zn metal alloy sample decreased while half value layer (HVL), tenth value layer (TVL) and mean free path (MFP) of that sample increased when the gamma energies increased. Therefore, Al-Zn metal alloy shielding materialwere applicable for low energy gamma ray.

Keywords: Al-Zn metal alloy, half value layer (HVL), tenth value layer (TVL),mean free path (MFP)

Introduction

The practice of absorber material blocking radiation consists in placing a barrier between the external radioactive source and the receptor. By doing this, some or all amount of the radiation emitted by the source will be scattered or absorbed by the constitutive atoms of the material. This process is called attenuation and is the fundamental physical principle upon which radiation shielding is based. With shielding, radiation dose can be lowered to a desired level. Furthermore; different types of radiation can be shielded by different types of materials. The attenuation capability of a given material is strongly dependent on the type of radiation and the range of energies associated with the radiation. (Anon, 2003)

For shield designs, gamma ray was one of the main types of nuclear radiation, which have to be considered; since any shield attenuates the gamma rays will be more effective for attenuating other radiations.

The ability of an absorber material to absorb gamma rays is expressed by the linear attenuation coefficient for that material

Therefore, design and construction of effective radiation shields require an in-depth knowledge of the types of interaction between radiation and the target material.(Anon, 2003)

Linear Attenuation Coefficient

The attenuation of gamma radiation can be described by the following equation.

$$I=I_0 .e^{-\mu x} \qquad (1)$$

where I is intensity after attenuation, I_o is incident intensity, μ is the linear attenuation coefficient (cm^{-1}), and physical thickness of absorber (cm).

[1] Dr, Lecturer, Department of Physics, University of Yangon
[2] Assistant Lecturer, Department of Physics, University of Yangon
[3] Assistant Lecturer, Department of Physics, University of Yangon
[4] MRes Student, Department of Physics, University of Yangon

Mass Attenuation Coefficient

The mass attenuation coefficient is defined as the ratio of the linear attenuation coefficient and absorber density (μ/ρ). The attenuation of gamma radiation can be then described by the following equation:

$$I=I_0 .e^{-(\mu/\rho).\rho x} \quad (2)$$

whereρ is the material density, (μ/ρ) is the mass attenuation coefficient and ρ.x is the mass thickness. The measurement unit used for the mass attenuation coefficient cm^2/g.

Half Value Layer

The thickness of any given material where 50% of the incident energy has been attenuated is known as the half value layer (HVL). The HVL is inversely proportional to the attenuation coefficient and the two values are related by the following equation. Since μ is normally given in units of cm^{-1}, the HVL is commonly expressed in units of cm.

$$HVL= 0.693/\mu \quad (3)$$

where, μ is linear attenuation coefficient (cm).

Tenth Value Layer

The tenth value layer (TVL) is the average amount of material needed to absorb 90% of all radiation, i.e., to reduce it to a tenth of the original intensity. TVL is greater than or equal to $\log_2 (10)$ or approximately 3.32 HVLs, with equality achieved for a monoenergetic beam.

$$TVL= \ln 10/ \mu \quad (4)$$

where, μ is linear attenuation coefficient (cm).

Mean Free Path

Mean free path (λ) is the average distance a gamma ray travels in the absorber before interacting and is given by formula

$$\lambda= \frac{1}{\mu} \quad (5)$$

where μ is the linear attenuation coefficient of glass samples.

Experimental Procedure

Sample Preparation

To measure the attenuation coefficients of Al-Zn alloy sample, square shape of that sample (7 cm × 7 cm) was cut with increasing five different thickness ranging from 0.1025 to 0.9225cm.

Experimental Measurement

The measurement of gamma attenuation for Al-Zn metal alloy was carried out Nuclear Physics Laboratory, Department of Physics in University of Yangon. The experimental arrangement in the present attenuation measurement consists of NaI (Tl) detector (working high voltage, 650V) with photomultiplier tube connected to a high voltage supply and a multichannel analyzer, MCA controlled by a connected computer installed Phywe Systeme Gmbh Software 'measure' MCA Module Gamma Acquisition & Analysis software. The gain and offset of MCA measure software in present measurement were gain level 1 and offset 1.

In this study, each attenuator sample was placed between gamma ray detector and sources as the same experimental set-up. The distance between source and detector was 12 cm and the source to sample distance was 4 cm only. To get various thicknesses, the samples were stacked on one by one. The incident beam intensity I_0(without sample) and attenuated beam intensity I (with samples) for^{137}Cs,^{22}Na and ^{60}Cogamma ray sources were measured with accumulation time 900 s. Half value layer (HVL), tenth value layer (TVL) and mean free path (MFP) of Al-Zn metal alloy were tabulated for shield design. The arrangement of the experimental set up was shown in Figure 1.

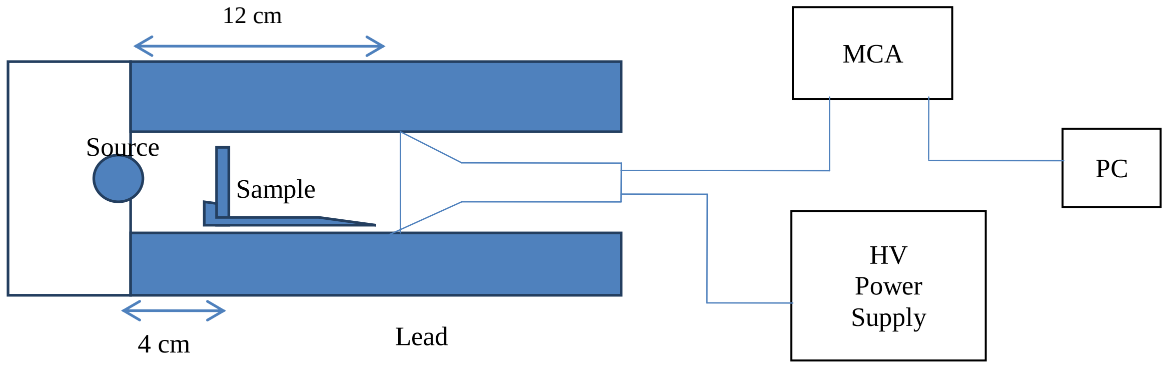

Figure 1 The arrangement of Experimental Setup

Results and Discussion

The behavior of the investigated alloys against γ radiation sources (Cs-137, Na-22 and Co-60) were studied experimentally. The transmission of γ rays were measured at four different γ energies. Tables 1 described the experimental attenuation coefficient results of alloy sample for each source. Figures 2, 3, 4, 5, 6, 7, 8 and 9show the attenuation graphs for material thickness and density thickness for samples. Due to the good geometry, the slopes of these graph lines gave the straight lines because of the less scattering effect. The slopes of attenuation graph for material thickness gave the experimental linear attenuation coefficient values, μ(cm^{-1}) and in this way, density thickness graph gave the experimental mass attenuation coefficient values, μ/ρ (cm^2/g). These experimental results as a function of γ energies were shown in Figure10 and Table 2. It also described that the attenuation coefficient values, half value layer (HVL), tenth value layer (TVL) and mean free path (MFP) of the sample were varied with different gamma energies. Thus, it is easier to attenuate low γ photons. As the γ energy increases, the coefficient of the samples decreases. It can be said that high energy photons are able more deeply compared to a lower energy photon.

Table 1 Gamma ray attenuation parameters of Al-Zn alloy sample with different thicknesses and density thicknesses by using gamma source

Thickness		lnI (Cs)	ln I(Co)	ln I(Na)	ln I(Co)
cm	gcm^{-2}	(662 keV)	1173 keV	1275 keV	1332 keV
0.1025	0.5535	9.1526	7.784	7.4261	7.5592
0.3075	1.6786	9.0832	7.7285	7.3883	7.521
0.5125	2.8051	9.0192	7.6779	7.3493	7.4764
0.7175	3.9449	8.9572	7.616	7.2862	7.4322
0.9225	4.999	8.8991	7.5575	7.2488	7.3875

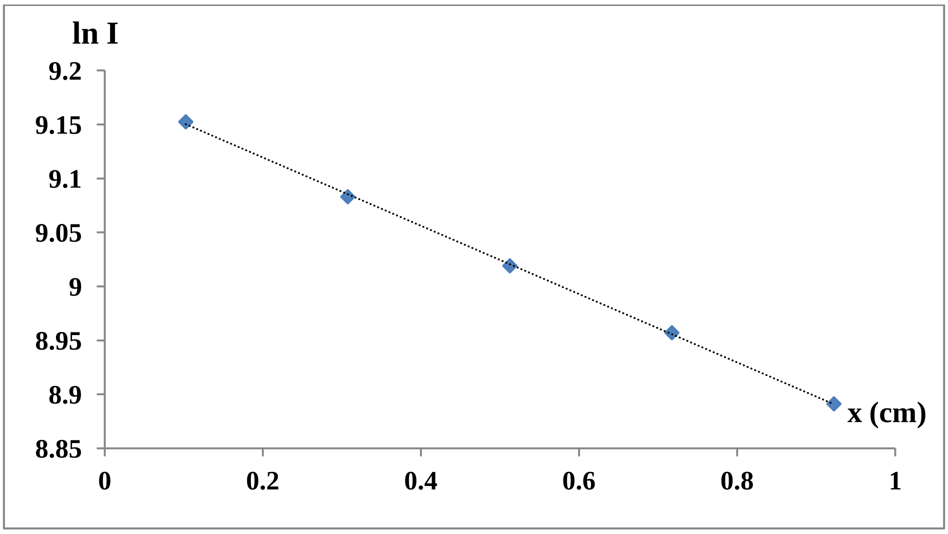

Figure 2 Attenuation graph for 5 different thickness of Al-Zn alloy against Cs-137 gamma source

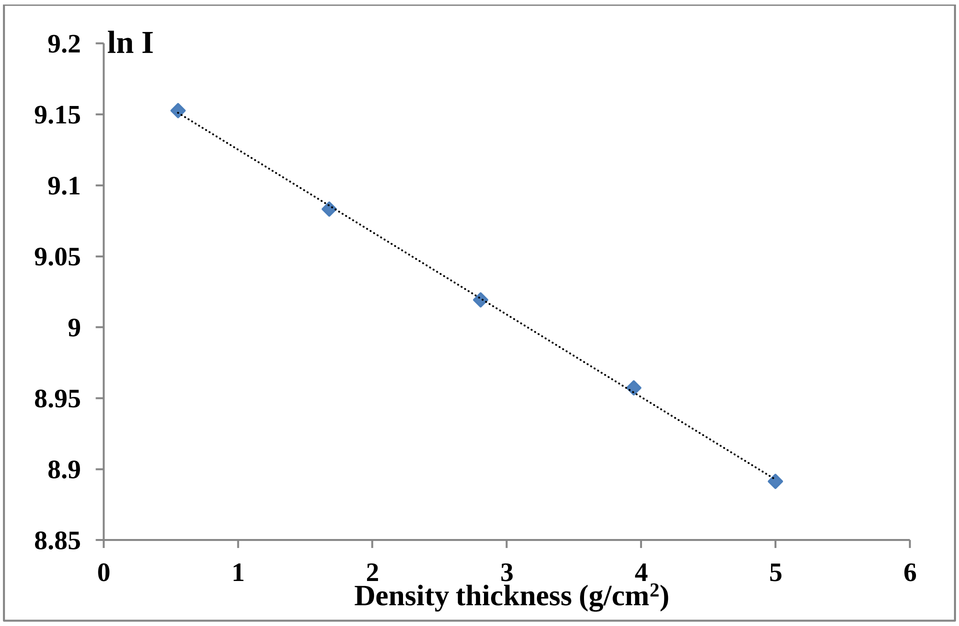

Figure 3 Attenuation graph for 5 different density thickness of Al-Zn alloy against Cs-137 gamma source

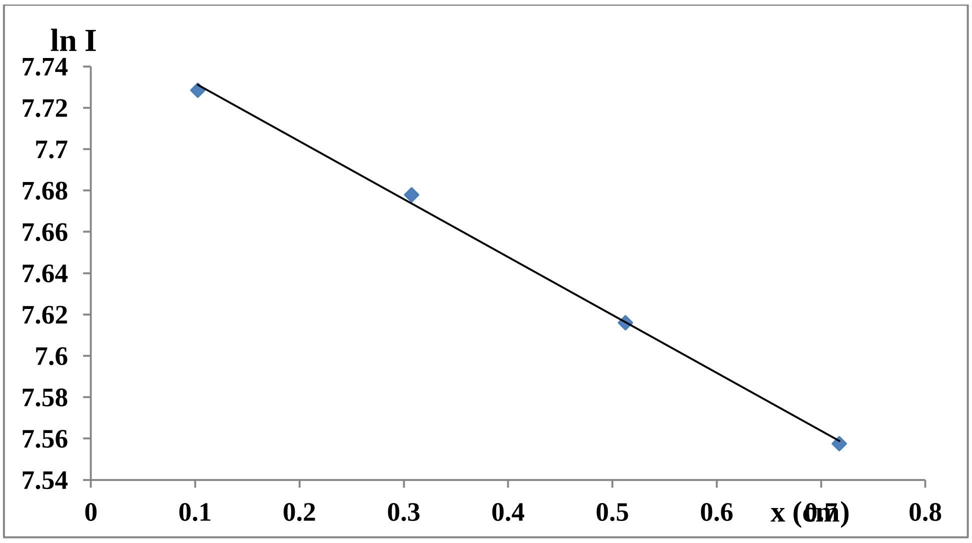

Figure 4 Attenuation graph for 5 different thickness of Al-Zn alloy against Co-60 gamma source at energy 1173 keV

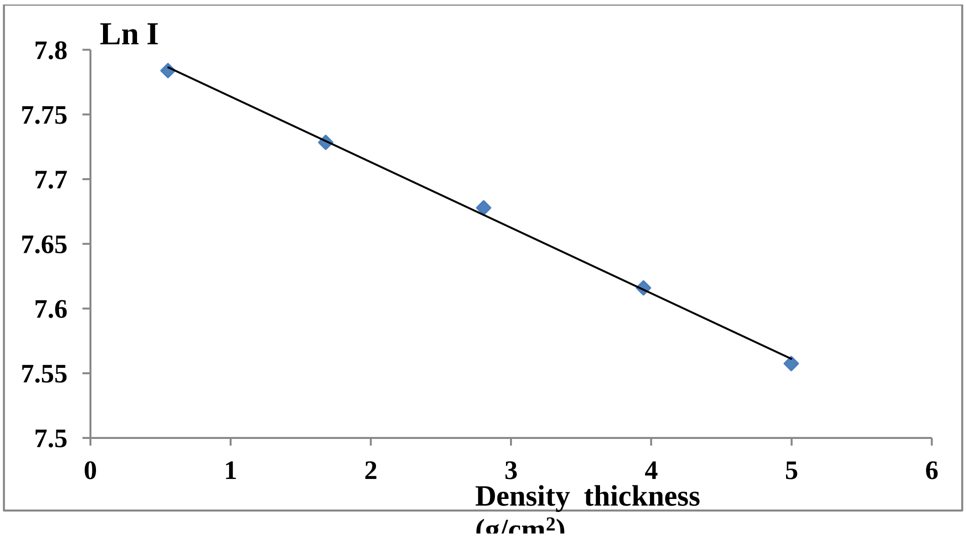

Figure 5 Attenuation graph for 5 different density thickness of Al-Zn alloy against Co -60 gamma source at energy 1173 keV

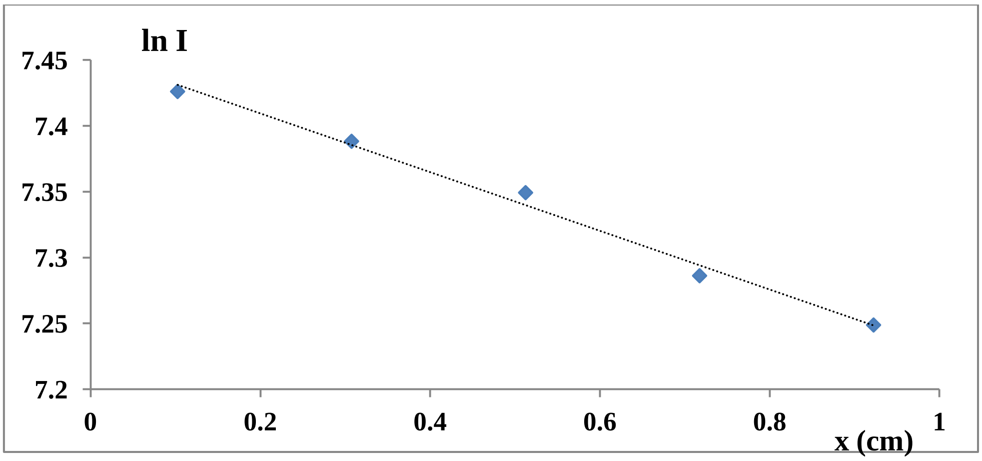

Figure 6 Attenuation graph for 5 different thickness of Al-Zn alloy against Na- 22 gamma source at energy 1275 keV

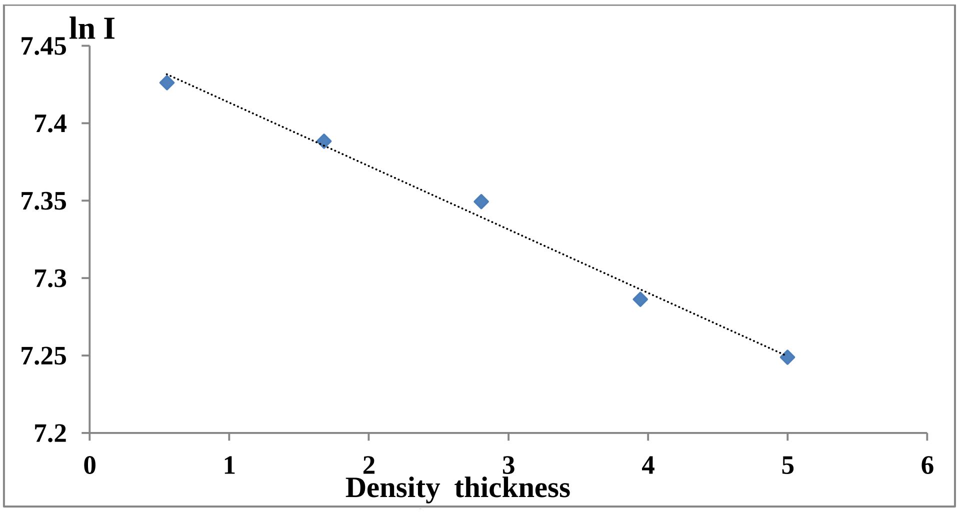

Figure 7 Attenuation graph for 5 different density thickness of Al-Zn alloy against Na- 22 gamma source at energy 1275 keV

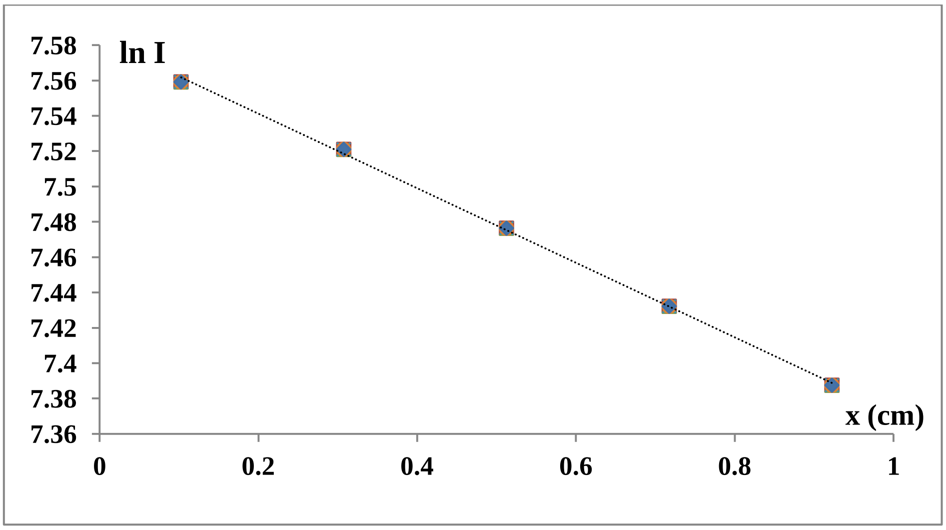

Figure 8 Attenuation graph for 5 different thickness of Al-Zn alloy against Co-60 gamma source at energy 1332 keV

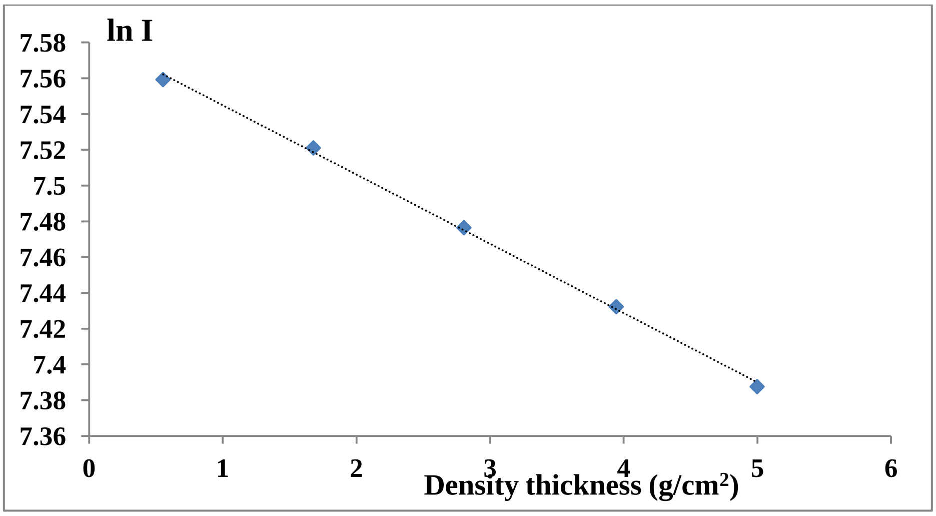

Figure 9 Attenuation graph for 5 different density thickness of Al-Zn alloy against Co-60 gamma source at energy 1332 keV

Table 2 Attenuation Coefficients, half value layer (HVL), tenth value layer (TVL) and mean free path (MFP) of Al-Zn alloy Samples with Various Gamma Energies

Sources	Energy (keV)	μ (cm^{-1})	μ/ρ(cm^2/g)	HVL (cm)	TVL (cm)	λ(cm)
^{137}Cs	662	0.3164	0.0581	2.1906	7.2775	3.1606
^{60}Co	1173	0.2804	0.0507	2.4718	8.2118	3.5663
^{22}Na	1275	0.2228	0.0409	3.1109	10.3348	4.4883
^{60}Co	1332	0.2108	0.0387	3.2880	10.9231	4.7438

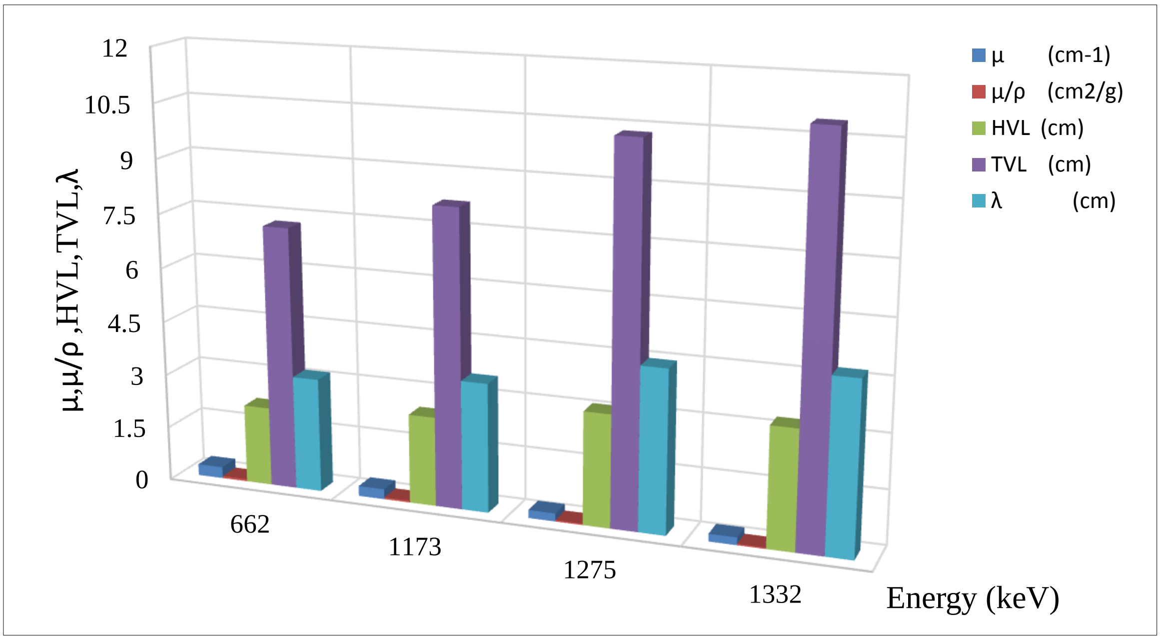

Figure1 Attenuation Coefficients, half value layer (HVL), tenth value layer (TVL) and mean free path (MFP) of Al-Zn alloy Sample with Various Gamma Energies

Conclusion

In view of this study, radiation shielding characteristics such as linear attenuation coefficient, mass attenuation coefficient, half- value layer, tenth value thickness and mean free path of Al-Zn metal alloy were measured using different gamma energies. The results of γ-ray attenuation values of Al-Zn metal showed that the linear and mass attenuation coefficients decreased but the half value layers (HVL) and tenth value layers (TVL) were increased with increase of gamma energy. It was observed that Attenuation coefficient depends on the energy of incident photons and the nature of the material and half value layers (HVL) and tenth value layers (TVL) are also photon energy dependent, like the attenuation coefficient. So, the shielding materials tend to attenuate double range energies source more than single energy. Thus, gamma irradiation is an efficient factor of Al-Zn metal alloys to be used as shielding materials.

Acknowledgements

I would like to thank Professor Dr Khin Khin Win, Head of Department of Physics, University of Yangon, for her kind permission and encouragement to carry out this work.

I would like to thank Professor Dr Aye Aye Thant, Professor Dr Myo Lwin and Professor Dr Yin Maung Maung, Department of Physics, University of Yangon for their encouragement.

References

American University in Bulgaria. Retrieved 27 March 2016 "Gamma Spectroscopy with a Scintillation Detector and Multichannel Analyzer" *(PDF).*

Anon, (2003), "Radiation Shielding Internet Information Radiation Protecting & Shielding".

G. Nelson, D. Reilly, (1991), "Gamma Ray Interactions with Matter", in Passive Nondestructive Analysis of Nuclear Materials (Los Alamos National Laboratory)

Gilmore G & Hemingway J D, (1995), "Practical Gamma Ray Spectroscopy" (Chichester: John Wiley)

Harvard University Radiation Protection Office, Providing radiation guidance to Harvard University and affiliated institutions.

Hubbell, J. H.; Seltzer, S. M. Retrieved September (2007)"Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients". National Institute of Standards and Technology (NIST).

N. Damla, U. Cevik, A.I. Kobya, A. Celik, N. Celik, I. Yildirum, "Assessment of natural radioactivity and mass attenuation coefficient of brick and roofing tile used in Turkey", Radiation Measurements, 46, 701-708, (2011).