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Gamma Radiation Absorption of (Al ,Cu, Pb) Alloys

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ABSTRACT

In this paper, four samples of some binary and triple alloys (Al, Cu, Pb) have been studied theoretically and experimentally. For the gamma rays shielding parameters, a good agreement was observed between the theoretical and experimental values for each of mass attenuation coefficient (μ_m), half-value layers (HVL), mean free path (MFP) the radiation protection efficiency (RPE) of the samples . The theoretical measurements were carried out using XCOM program in the energy range from 1 keV to 100 GeV, and practical values for 662, 1173, and 1332 keV gamma-ray energies of ^{137}Cs and ^{60}Co radiation sourcesusing NaI (Tl) detector.

1. INTRODUCTION

Lead (Pb) is material that has been widely used since ancient times for radiation protection due to the various advantages provided by its physical and chemical properties. With the developing technology, lead, which has been discovered to be a heavy metal by spectroscopic analysis, has a high density and therefore is in the heavy metals class. Thanks to this feature, it has been discovered that it is the best absorbent material environment when it interacts radiation energy, and it has been used for shielding and it continues to be widely used today[1,2]. Due to its widespread use, the structure of lead accumulated in the environment is not suitable for biodegradation, and therefore, with its increasing biodegradation, and therefore, with its increasing concentration, it causes a permanent threat to nature and living things by taking place in the environment. Almost all in human body can be affected by the toxic effects caused by lead through respiration, skin absorption, and digestion. These disadvantages of lead accelerated the search for materials that can be used as an alternative to traditional materials used for shielding [3,4]. Cevik *et al*.,[5] It was possible to measure the natural radioactivity in marble samples in Turkey using gamma spectrometer and the mass attenuation coefficients were obtained experimentally and theoretically ,and it was found that there is a good agreement. Jameel *et al* ., [6] They could compare between of gamma ray linear attenuation coefficient of two types of shielding materials made of Saudi white and red sand, it was found that the attenuation of white sand much better than that of red sand. Korkt *et al*., [7] They measured the linear attenuation coefficient for conceret containing zeolite a an aggregate in different concentrations, and the results are compared with calculation. Rezaei *et al*., [8] manufactured shields resistant to gamma rays by adding lead powder and silica fumes to concrete. Attenuation measurements were carried out using gamma ray sources. Results are shown that the attenuation coefficients increase with the increase of the lead powder and silica. Singh *et al*., [9] were able to study the shielding properties of some alloys and their ability to attenuate gamma-shielding effectiveness of the alloys was studied by calculating the mass attenuation coefficient and it was found that Cupper-Nickel provides the best protection.

In this work, we aimed is to find the best materials for gamma ray attenuation. The shielding parameters were calculated experimentally and theoretically for alloys (Al-Cu-Pb) containing different concentrations of lead, and the effect of the change in lead ratios on the shieling parameters was noted. Four samples with different compositions were prepared. The alloys were used for the manufacture of shields due to its high attenuation of radiation, also is less expensive.

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2. THEORETICAL BACKGROUND

The linear attenuation coefficient (μ_L) is the decrease in photon beam intensity crossing an absorber material and can be determined by the Lambert-Beer rule[10]

$$I = I_{\circ} e^{-\mu_L x} \qquad (\mathbf{1})$$

where I is intensity of the incident gamma radiation and $I_{\circ}$ is intensity of the attenuated gamma radiation, and x denoted the thickness of the absorbed sample. it is possible to determine μ_L experimentally, and hence, it is just required to measure the incoming and outgoing photon beam intensity that passes through a slap of x. mass attenuation coefficient $\left(\mu_{m=}{}^{\mu_L}/_{\rho}\right)$ is more fundamental, where ρ is the density of absorbent sample.[11]

The Mean Free Path (MFP) is dictator for measuring the rate of penetration of rays through a solid body before it losses energy , is expressed as;

$$MFP(cm) = \frac{1}{\mu_L} \qquad (\mathbf{2})$$

The Half - Value Layer (HVL) which is the thickness of the sample, that reduces the intensity of the radiation beam entering it to half its original value , which is given as [12,13].

$$HVL(cm) = \frac{0.693}{\mu_L} \qquad (\mathbf{3})$$

The radiation protection efficiency (RPE) is to demonstrate the effectiveness of the shielding material, calculate from the equation [14],

$$RPE = (1 - I/I_{\circ}) \times 100\% \qquad (\mathbf{4})$$

3. EXPERIMENT TECHNIQUE

Manufacturing alloys

The alloys manufacturing process took place in three stages:

a- oven preparation and casting molds
An oven was manufactured for this purpose, which is a gas oven, as well as the stainless steel molds were designed and manufactured locally.

b- Alloys production processes by smelting and casting
Weighing operations were carried out for the elements to be cast, then they were placed with a graphite lid inside the oven, after the mixture reached the molten poured into the casting molds.

c- Thermal processes for casting
Thermal handing operations were conducted for a group of models and other models, and then heat-handing operations were conducted on them to find out which one is better in shielding.

4. Alloys preparation and Analysis

In this study, four samples of alloys (Al-Cu-Pb) in different compositions were manufactured by melting metals in a furnace, where copper, which melting point 1080°C, was placed in a puddle and then placed in the furnace and melted for 18 minutes, aluminum was added after that, whose melting point 660.3 °C, finally, lead is added, which has a melting point 327°C, the process continued after that for 8 minutes. The molten material was poured into a wrought iron mold on a cylinder shaped with a diameter of 1 cm and a height of 3 cm [15]. Chemical composition is given in Table 1.

The Scheme of the special system for measuring the coefficient of attenuation is shows in Fig 1 Where count the number$I_{\circ}$ of whole particles without a sample for 1800s .and then radiation counts I was measured by inserting the manufactured sample.

Table (1): Chemical compositions of the prepared alloys.

Sample	Composition	Thickness (cm)	Volume (cm^3)	Density ($g\ cm^{-3}$)
A1	Al67Cu33	0.9	0.854	18.01
A2	Al67Cu33	1.2	1.133	13.51
A3	Al67Cu23Pb10	0.9	0.854	18.71
A4	Al67Cu23Pb10	1.2	1.139	14.03

5. RESULT AND DISCUSSIONS

5.1. Mass Attenuation Coefficient

Table 2 Present the theoretical values calculated by XCOM and the experimental values and their comparison. The values of the mass attenuation coefficient increased with the increase in rate of lead and the increase in thickness, where the sample A4 (67%Al,23%Cu and 10% Pb) recorded the highest attenuation rate. Fig. 2, shows the relationship between the incident photon energy and the total mass attenuation coefficient $\mu_m$calculated by XCOM program at the energy range (1 keV-100 GeV) and its comparison together with the experimental values.

5.2. Half Value Layer and Mean Free Path

Tables 3 and 4 present the values of HVL and MFP measured theoretically by XCOM and the experimental values then compared between them, respectively. It has been found that the half value layer (HVL) and mean free path (MFP) values decrease gradually together with an increase in the rate of lead at the sample and increase with the increase in thickness .Fig.3 and 4. Shows the relationship between the incident photon energy and HVL,MFP values calculated by XCOM and comparison with experimental values.

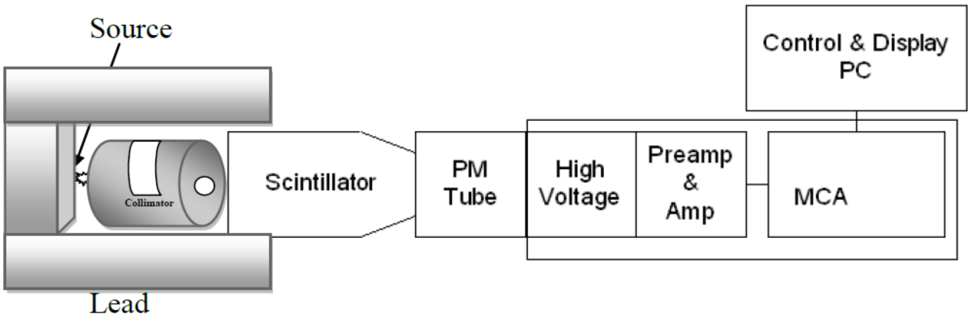


Fig. (1): Scheme of the special system for measuring the coefficient of attenuation and homogeneity of samples.

Table (2): The comparison between the theoretical and the practical mass attenuation coefficient ($cm^2 g^{-1}$) values

Energy	**662 keV**		**1173 keV**		**1332 keV**	
Sample	Exp.	XCOM	Exp.	XCOM	Exp.	XCOM
A1	0.046	0.049	0.041	0.044	0.041	0.045
A2	0.048	0.049	0.043	0.044	0.044	0.045
A3	0.056	0.069	0.064	0.070	0.064	0.071
A4	0.068	0.069	0.070	0.070	0.070	0.071

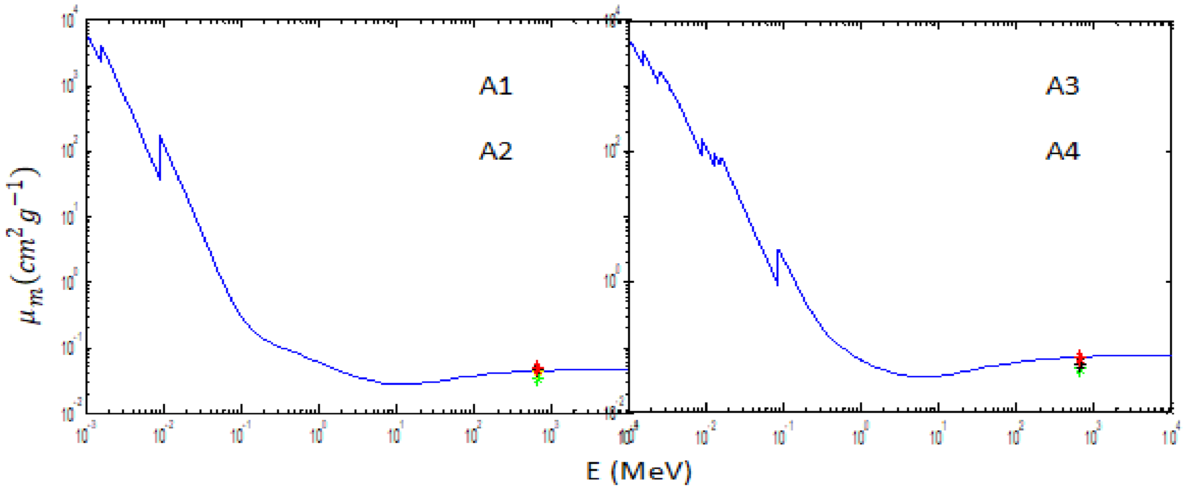


Fig. (2): The comparison between theoretical total μ_m calculated by XCOM and the measured experimental values.

Table (3): The half-value layer (HVL) using XCOM, and experiment value.

Energy	**662 keV**		**1173 keV**		**1332 keV**	
Samples	Exp.	XCM	Exp.	XCM	Exp.	XCOM
A1	0.800	0.778	0.936	0.855	0.937	0.851
A2	1.065	1.038	1.166	1.140	1.152	1.135
A3	0.657	0.536	0.576	0.523	0.571	0.499
A4	0.716	0.714	0.702	0.698	0.696	0.695

Table (4): The Mean Free Path (MFP) using XCOM, and experiment value.

Energy	**662 keV**		**1173 keV**		**1332 keV**	
Samples	Exp.	XCOM	Exp.	XCOM	Exp.	XCOM
A1	1.155	1.237	1.351	1.233	1.352	1.228
A2	1.537	1.498	1.168	1.645	1.663	1.638
A3	0.947	0.773	0.832	0.755	0.824	0.752
A4	1.034	1.031	1.013	1.007	1.004	1.003

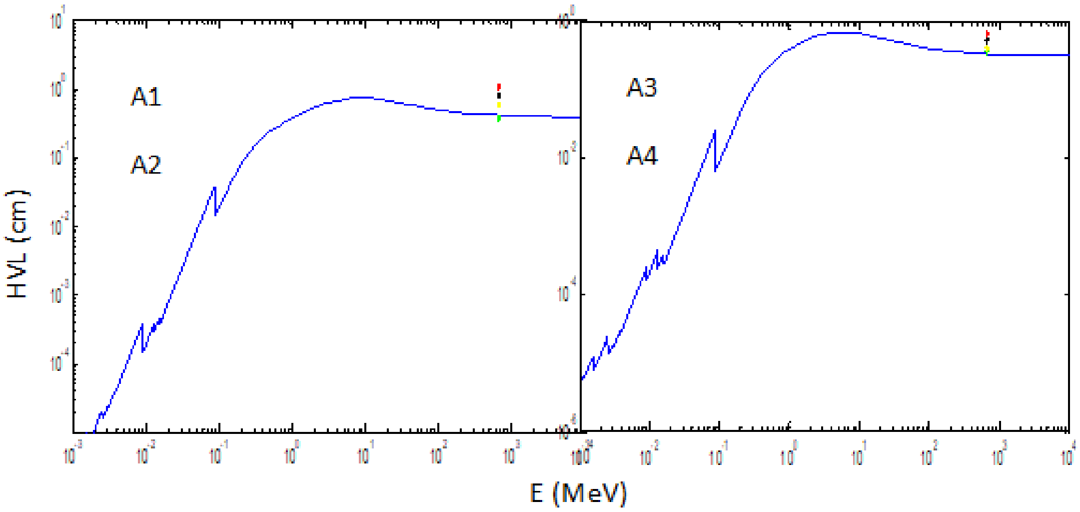


Fig. (3): The comparison between theoretical HVL calculated by XCOM and the experimental values.

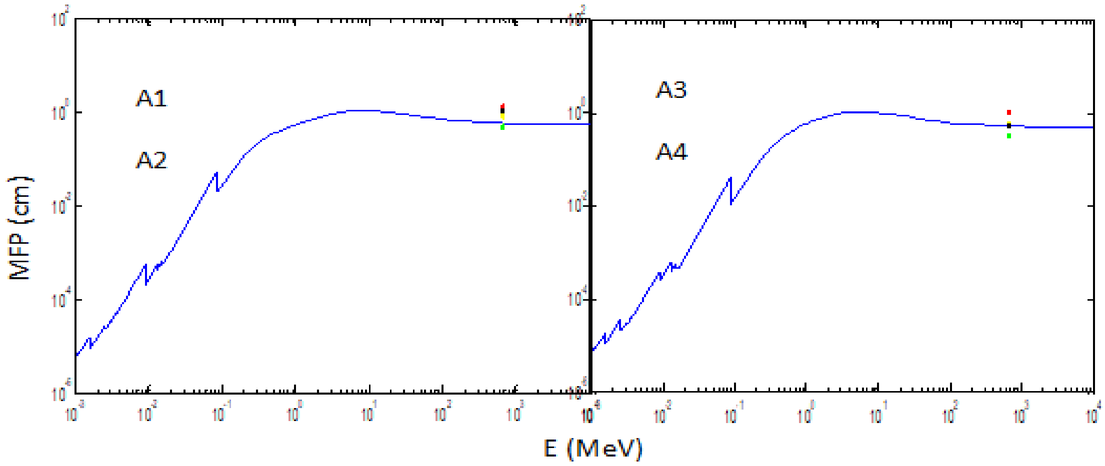
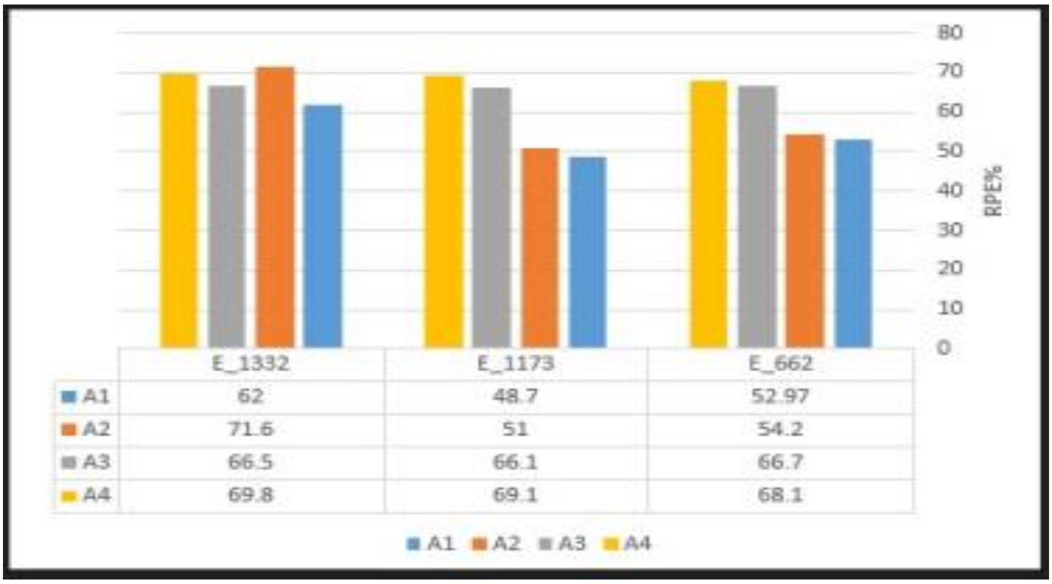


Fig. (4): The comparison between theoretical MFP calculated by XCOM and the experimentally measured values.



	E_1332	E_1173	E_662
A1	62	48.7	52.97
A2	71.6	51	54.2
A3	66.5	66.1	66.7
A4	69.8	69.1	68.1

Fig. (5): Radiation protection efficiency (RPE%) at energy (662,1173 and 1332) keV for alloys samples.

5.3 Radiation protection efficiency (RPE)

The focus in this study is to determine the radiation protection properties through equation (4), the radiation protection efficiency value was calculated for four samples and it was found that sample A4 has the highest value for radiation protection efficiency because it has a greater rate of lead and a higher thickness as in Fig. 5.

CONCLUSIONS

In conclusion, this study reported on good agreement between the theoretical and experimental values of alloys Al, Cu, and Pb. Using software XCOM was used to calculate the alloy in energy range from 1keV - 100 GeV , and another calculate the experimental values using the NaI(Tl) detector . It was found by comparing the values that the attenuation coefficient increases with the increase in the percentage of lead , while both decreases HVL and MFP .

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