



Mass Absorption Coefficient of Gamma Radiations for Aluminum, Copper, Lead and Plastic (LDPE) Material

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Abstract

Shielding materials for nuclear gamma radiations are important in applied nuclear radiation fields such as nuclear radiation therapy, radiation health physics, nuclear reactors shielding, storage of radioactive materials etc. In addition to this, the study of interactions of gamma radiations with different materials are also prime important in basic physics. In view of this, mass absorption coefficients of gamma radiations for Aluminum, Copper, Lead and Plastic (LDPE) for Cs-137 gamma radiations are measured and results are reported in the present work. Gamma mass absorption coefficients are estimated using the NaI(Tl) scintillation detector coupled to the computer based 8K M.C.A. gamma ray spectrometer system. The values of gamma ray mass absorption coefficients for aluminum, copper, lead and plastic (LDPE) are found to be $14.20 \text{ cm}^2/\text{gm}$, $5.17 \text{ cm}^2/\text{gm}$, $0.76 \text{ cm}^2/\text{gm}$ and $14.0 \text{ cm}^2/\text{gm}$. The results are in good agreement with the literature values.

Keywords: Gamma radiation; Mass absorption coefficient; Gamma ray spectrometer; 8K M.C.A analyzer.

Introduction

The studies of interactions of gamma radiations with different materials are of prime important in basic physics. In addition, shielding materials for nuclear gamma radiations are important in applied nuclear radiation fields such as nuclear radiation therapy, radiation health physics, nuclear reactors shielding, storage of radioactive materials etc. In view of this, gamma radiation mass absorption coefficients for Aluminum, Copper, Lead and Plastic (LDPE) using Cs-137 gamma source are measured and reported in the present work. Gamma mass absorption coefficients are estimated using the NaI(Tl) scintillation detector coupled to the computer based 8K M.C.A. gamma ray spectrometer system.

Experimental Work

The mass absorption coefficients of gamma radiations for Aluminum, Copper, Lead and Plastic (LDPE) for Cs-137 gamma radiations are measured. Gamma mass absorption coefficients are estimated using the NaI(Tl) scintillation detector coupled to the computer based 8K M.C.A. gamma ray spectrometer system.





Material and Methods

Ten samples of pure aluminum, copper, lead and plastic (LDPE) were prepared for each element with increasing thickness ranging from 0.01 mm to 5.0 mm, each of circular size of diameter 3 cm. The average thickness of each circular sample was measured by taking ten observations with micrometer screw gauge and travelling microscope.

Procedure

The standard gamma ray Cs-137 source of activity strength 0.45 µci made by BARC, Mumbai was used in the present work. Cs-137 gamma source has half life of 30 years and gamma energy of 0.662 MeV [10]. This source of gamma radiation was selected to study the low gamma ray interaction such as photoelectric and Compton scattering interaction with aluminum, copper, lead and plastic (LDPE). In the present work 3[°]x 3[°] NaI(Tl) gamma ray detector was used for measuring gamma radiation transmitted intensity through the absorber samples. The gamma ray spectrum was analyzed with the help of 8K M.C.A coupled to the NaI(Tl) gamma ray detector and computer. A sample of each element under study was placed between gamma ray detector and Cs-137 source. Gamma ray intensity for each sample was counted for fixed time period of 100 seconds.

Analysis of Data

The linear absorption coefficient (μ) of each element under study was estimated using the relation [1 - 3]:

where,

 I_{O} = the incident gamma ray intensity with zero thickness of sample

I = the transmitted intensity through the sample after absorption

x = sample thickness in cm

 μ = total linear absorption coefficient.

The gamma ray intensities I_0 and I of Cs-137 source were measured using the NaI(Tl) detector coupled to the M.C.A and computer. The linear absorption coefficient of gamma radiations for each element was estimated using the relation [1]. Mass absorption coefficient for each element was also calculated by using standard density values of each element under study and using the relation [3, 8]:

$$\mathbf{I} = \mathbf{I}_{\mathbf{0}} \mathbf{P}^{-\frac{1}{2}\mathbf{P}_{\mathbf{0}}} -\dots (2)$$

where,

 ρ = density of absorber material in g/cm³

 ρ_x = thickness of sample in cm²/g.





Results and Discussions

The results of gamma ray mass absorption coefficients for aluminum, copper, lead and plastic (LDPE) samples are shown in Table 1.

Name of material	Density	Linear mass absorption	Mass absorption
	gm/cm ³	coefficient (μ) cm ⁻¹	coefficient (44m) cm ² /g
Aluminum	2.71	38.5077	14.206
Copper	8.93	31.6936	3.549
Lead	11.34	7.7602	0.6831
Plastic (LDPE)	0.7655	10.8728	14.2036

Table 1. Gamma ray mass absorption coefficient

Figure 1 shows the gamma ray spectrum of Cs-137 source ($E_{\gamma} = 0.662$ Mev) counted by NaI (Tl) detector coupled to 8K M.C.A without absorber foil. Figure 2 shows gamma ray spectrum of Cs-137 source ($E_{\gamma} = 0.662$ Mev) with aluminum absorber foil of thickness 1 mm. Figure 3 shows gamma ray spectrum of Cs-137 source ($E_{\gamma} = 0.662$ Mev) with lead absorber foil of thickness 1 mm. Figure 4 shows the variation of gamma ray intensity (Counts) with lead absorber thickness. The absorption probability due to photoelectric interaction of low energy gamma radiations ($E_{\gamma} < 200$ kev) is given by the relation [1, 4, 5]:

where,

Z = atomic number of target element

n = 4 or 5 depends on materials

P = absorption probability due to photoelectric effect.

This shows that absorption probability of gamma radiation ($\mathbb{E}_{\gamma} < 200$ MeV) is directly proportional to the Z of target material. The results are in good agreement with expected values for gamma absorption coefficient. The gamma ray absorption is maximum for lead and therefore lead is found to be best material for shielding of gamma radiations. This can be used in reactor shielding material along the concrete bricks. In addition, lead mixed material can be developed to protect the workers from gamma radiation, in radiation therapy units.







Figure 1. Typical gamma ray spectrum of Cs-137 source (0.662 mev) counted by NaI(Tl) detector coupled to 8K M.C.A without absorber foil



Figure 3. Typical gamma ray spectrum of Cs-137 source (0.662 MeV) with lead absorber foil of thickness 1 mm



Figure 2. Typical gamma ray spectrum of Cs-137 source (0.662 MeV) with aluminum absorber foil of thickness 1 mm



Figure 4. Variation of gamma ray intensity (Counts) with lead absorber thickness.

Conclusions

Figure 1, 2 and 3 are drawn with same scale. Comparison of figures 1 and 2 clearly indicate that there is decrease of gamma ray intensity from 6000 counts to 4000 counts when aluminum absorber foil of thickness 1 mm is placed between detector and Cs-137 gamma source. This clearly indicates that the aluminum foil attenuate the gamma ray intensity. The comparison of figures 2 and 3 indicate that the gamma ray intensity has been attenuated to a considerable amount with lead absorber foil of thickness 1 mm as compared to the aluminum absorber foil of same thickness 1mm. This indicates that lead attenuates more gamma ray intensity as compared to the aluminum foil. Therefore, lead is more effective shielding material for gamma radiations. The figure 4 shows the decrease of gamma intensity with increase of lead absorber thickness. In general, the results are in good agreement with expected values



for gamma absorption coefficient [7]. The gamma ray absorption is maximum for lead compared with aluminum and copper, which means that lead has good capacity to absorb gamma radiations incident on it as compared with aluminum and copper that's why lead is used for shielding of gamma radiations. This can be used in reactor shielding material along with the concrete bricks. Gamma ray mass absorption coefficient for LDPE plastic has competitive value with aluminum.

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