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Measurement of mass and linear attenuation coefficients of gamma-rays of Al for 514, 662 and 1280 keV photons

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ABSTRACT

Measurements have been made to determine gamma ray attenuation coefficients very accurately by using a narrow-collimated-beam method which effectively excluded corrections due to small-angle and multiple scattering of photons. Mass (μ/ρ) and linear attenuation coefficients (μ) of Al for 514, 662 and 1280 keV gamma-rays photons have been measured using the well-type scintillation spectrometer. The values of μ and μ/ρ thus obtained are found to be in good agreement with the theory.

Keywords: Mass attenuation coefficients, Linear attenuation coefficients, Gamma-rays.

INTRODUCTION

The photoelectric effect, the Compton scattering and the pair production processes are the predominant interactions between the photons and atoms apart from other types over a wide range of energies.

With wide spread utilization of radiation and radioisotopes in medicine ,industry and basic sciences, the problem of radiation protection has become important aspect while handling radiation sources and radiation generating equipments. Selection of materials for radiation shielding and protection needs accurate assessment of interaction parameters. These parameters are of immense importance for photons being highly penetrating radiation as compared to particulate radiations.

A survey of other relevant measurements [1-12] reported shows that in many of these measurements the experimental results for the same elements at the same energies are somewhat inconsistent. Appreciable discrepancies between the experimental and theoretical values were observed in some of these measurements. In view of this situation a series of accurate and consistent measurements of γ-ray mass attenuation coefficients was undertaken by author. The results of these measurements covering Al element at three photon energies. A possible effect due to multiply scattered photons from thick attenuators on the measurements has been minimized to a great extent by using extremely –narrow-beam collimation and selected attenuator thicknesses.

THEORY

When I and I_0 are the intensities of gamma radiation of energy E traversed through the container respectively with and without the absorber of thickness t then the linear (μ) and mass (μ/ρ) attenuation coefficients are given from the exponential law viz:

$$I = I_0 e^{-\mu t}$$
$$I = I_0 e^{-\mu/\rho(\rho t)} \quad \text{..........(1)}$$

as

$$\mu = 1/t \ln(I_0/I) \quad \text{...........(2)}$$

and

$$\mu/\rho = 1/\rho t \ln(I_0/I) \quad \text{............(3)}$$

For the container of the absorber in cylindrical form of inner cross-section Πr^2,

$\rho = m/ \Pi r^2 t$ where r is the inner radius of the container and m is the absorber mass of thickness t.

Eq. (3) then simplifies to

$$\mu/\rho = \Pi r^2/m \ln(I_0/I) \quad \text{.............(4)}$$

EXPERIMENTAL SECTION

The authors measured the mass attenuation coefficient of the element by performing vertical narrow beam geometry. The diameter of the collimator is 1.18cm .Alluminium foils of uniform thicknesses was placed below the source at a distance of 12.3 cm and 9.0 cm above the detector .To increase the thickness of Al absorber foil ,place the Al absorber of known thickness one by one between the source and the detector. The Sodium Iodided detector [0.75"x2"] was connected to PC based 8k-MCA.The authors measured (μ/ρ) for Al foils at three photon energies 514, 662 and 1280 keV. Three standard gamma sources Sr^{90}(0.514), Cs^{137} (0.662) and Na^{22} (1.280) MeV are used .The results are shown in table 1.

Table1: Linear attenuation coefficient μ (cm^{-1}) and mass attenuation coefficient μ/ρ (cm^2/g) of Al absorber at Photon energies 514, 662 and 1280 keV.

Sr. No.	Energy keV	μ (cm^{-1})	μ/ρ (cm^2/g)
1	514	0.216 a	0.080 a
		0.218 b	0.081 b
		0.917 c	1.234 c
2	662	0.197 a	0.073 a
		0.199 b	0.074 b
		1.005 c	1.351 c
3	1280	0.140 a	0.052 a
		0.143 b	0.053 b
		2.097 c	1.886 c

a (experimental)
b (Hubbell and Seltzer) values.
c (Percentage deviation)

RESULTS AND DISCUSSION

The comparison of their measurements with the theoretical values [13] is done by calculating the Percentage deviation as:

$$\% \text{ deviation} = \frac{(\mu/\rho)_{theo} - (\mu/\rho)_{exp}}{(\mu/\rho)_{theo}} \times 100$$

These are also presented in the tables and the author found the deviation mostly below 2% indicating thereby excellent agreement of the author's measurements with theory. The linear attenuation coefficient is obtained by multiplying the mass attenuation coefficient of the element by its density. Figure 1-3 shows plot of $\log I/I_0$ Vs thickness t for Al at 514, 662 and 1280 keV.Using this graphs, slope can be calculated and these slope is nothing but the (μ/ρ) mass attenuation coefficient of element at that particular energy.

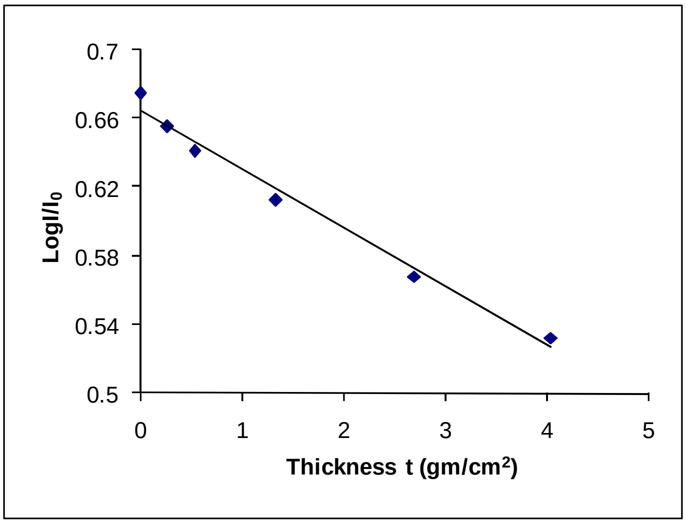

Figure 1 .Plot of $\log I/I_0$ Vs thickness t for Al at 514 keV.

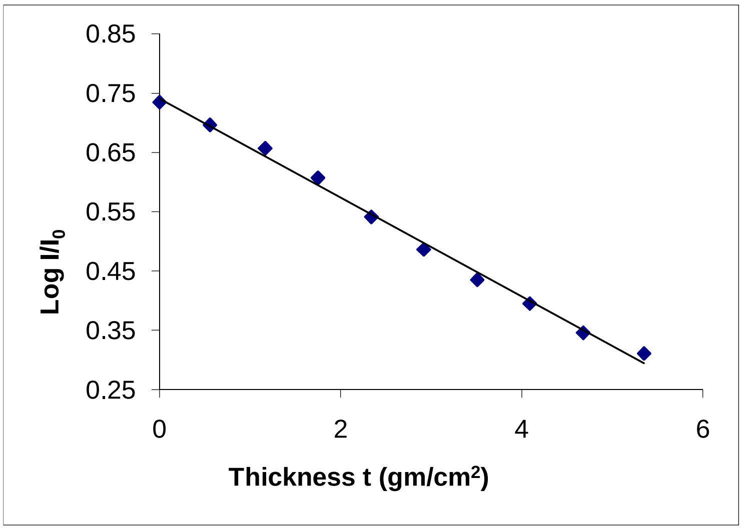

Figure 2. Plot of logI/I_0 Vs thickness t for Al at 662 keV.

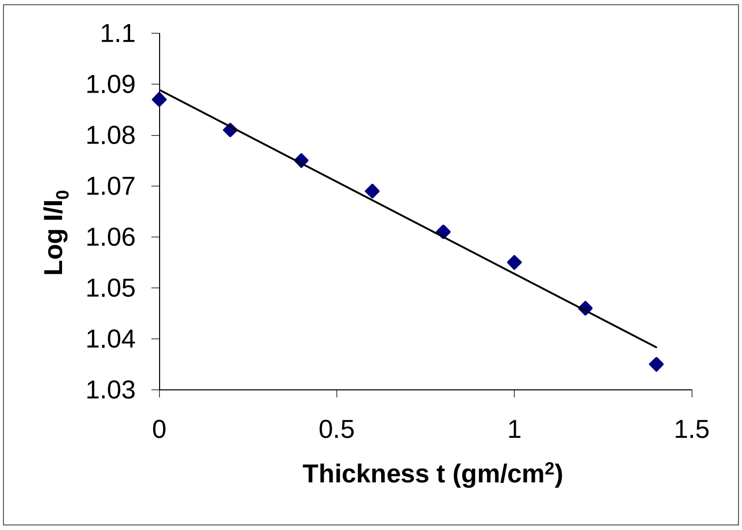

Figure 3 .Plot of logI/I_0 Vs thickness t for Al at 1280 keV.

CONCLUSION

The theoretical values of mass attenuation coefficient for element are available from [13] and the author carried out the work of their experimental measurement with excellent accuracy. The agreement of the author so measured values with theory confirms the theoretical considerations of the contribution of various processes such as photoelectric effect, the Compton scattering and the pair production. The measured mass and linear attenuation coefficients of element are useful for dosimetry and radiation shielding purpose.

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