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Research Article

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Studies on Mass & linear attenuation coefficients of γ- rays of photons for Ag in the energy range 360-1330 keV

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ABSTRACT

Measurements of mass (μ/ρ) and linear (μ) attenuation coefficients of silver in the energy range 0.360Mev to 1.33Mev have been carried out under narrow-collimated-beam method with scintillation detector. The values of mass (μ/ρ) and linear (μ) attenuation coefficients thus obtained are found to be in good agreement with the values computed theoretically available in the literature by J.H.Hubbell and S.M. Seltzer [Tables of X-Ray Mass Attenuation coefficients (1995).

Keywords: Mass attenuation coefficients, linear attenuation coefficients, gamma rays, Silver (Ag) NaI (Tl) detector.

INTRODUCTION

Radio isotopes are being increasingly used in radiation therapy and oncology. Therefore, a through knowledge of the photon interaction cross sections in the energy range 360-1330 keV is desirable. These sources are used in medical field, industry, biological studies and radiation sterilization because of high energy along with its optimal long life. 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. A scientific study of interaction of radiation with matter demands a proper characterization and assessment of penetration and diffusion of rays in the external medium. The attenuation coefficient is an important parameter, which is widely used in industry, agriculture, science, and technology, etc. [1].

The study of mass attenuation coefficient of various materials has been an important part of research in Radiation Chemistry and Physics. 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 Accurate values of photon interaction parameters like mass and linear attenuation coefficients in several materials are needed in solving various problems in radiation physics and other related areas.

Interaction of radiation with matter:
Nuclear radiations (α, β, γ-rays) have been used for a long time and serious accidents leading to confirmed and suspected deaths of persons arising from direct and indirect effects of radiations have occurred. In different applications of radiations it is observed that, over-exposure is harmful and under-exposure is ineffective. Gamma rays and ultraviolet radiations, for instance, produce electrons through the well-known mechanism of photoelectric, Compton and pair production.

In Photoelectric effect Absorption of x-rays occurs when the x-ray photon is absorbed, resulting in the ejection of electrons from the outer shell of the atom, and hence the ionization of the atom. Subsequently, the ionized atom returns to the neutral state with the emission of an x-ray characteristic of the atom. This subsequent emission of lower energy photons is generally absorbed and does not contribute to (or hinder) the image making process. Photoelectron absorption is the dominant process for x-ray absorption up to energies of about 500 KeV. Photoelectron absorption is also dominant for atoms of high atomic numbers.

In Compton scattering when the incident gamma-ray photon is deflected from its original path by an interaction with an electron. The electron gains energy and is ejected from its orbital position. The x-ray photon loses energy due to the interaction but continues to travel through the material along an altered path. Since the scattered x-ray photon has less energy, it therefore has a longer wavelength than the incident photon. The event is also known as incoherent scattering because the photon energy change resulting from an interaction is not always orderly and consistent. The energy shift depends on the angle of scattering and not on the nature of the scattering medium.

Pair production occurs when an electron and positron are created with the annihilation of the x-ray photon. Positrons are very short lived and disappear (positron annihilation) with the formation of two photons of 0.51 MeV energy pair production is of particular importance when high-energy photons pass through materials of a high atomic number.

The gamma rays are highly penetrating and can therefore, reach easily the internal organs of the body. Therapy of deep-sited tumors is, therefore amenable to gamma rays. Gamma rays have different penetration depths in different materials. Lead is the most efficient absorber of gamma rays. Gamma ray shielding is usually described in terms of a parameter known as the half value layer (HVL) of the absorber. HVL is the absorber thickness that reduces the original gamma ray intensity I0 to half, the transmitted intensity. It of the gamma ray beam from a material containing (n), HVL is given by [2].

Theory:
The mass absorption coefficient is used alternatively with linear attenuation coefficient in calculation it is defined as,

$I = I_0\rho - \mu t$

$I = I_0\rho - \mu/\rho\ (\rho t)$ ---- (1)

as $$\mu = \frac{1}{t} \ln\left(\frac{I_0}{I}\right) \quad ----- \quad (2)$$

A narrow beam of monoenergetic photons is attenuated to intensity I from incident intensity I_0 according to the exponential absorption law .The exponential attenuation law can be rewritten as [3-5]

and $$\mu/\rho = \frac{1}{\rho t} \ln\left(\frac{I_0}{I}\right) \quad ----- \quad (3)$$

Where I and I_0 are intensities of gamma radiation of energy E transferred through the container respectively with and without absorber of thickness t then the linear (μ) and mass (μ/ρ) attenuation coefficient are given from the above experimental law.

EXPERIMENTAL SECTION

The main aim of the present work is to determine the linear (μ) and mass (μ/ρ) attenuation coefficient of silver in the energy rang 360-1330 keV. For the present study a good resolution NaI(Tl) detector is used for measurements. The present experimental arrangement can be identified as being of narrow beam attenuation geometry which avoids the scattered and the secondary radiations reaching from the detector. The gamma ray spectrometer will be calibrated using standard multi energy gamma sources.[7-10]

All the samples of elemental solids are thin uniform circular shaped of diameter 3cm for each irradiated samples material and for a given gamma ray energy. We measure the number of gamma ray photons detected when place the sample to be irradiated in the path of gamma rays, for different atomic number foils.[11-12].

Table 1: Linear attenuation coefficient μ (cm^{-1}) and mass attenuation coefficient μ/ρ (cm^2/gm) of Ag absorber in the energy range 360-1330keV.

Sr. No.	Energy KeV	μ(cm^{-1}) (Theortical)	μ(cm^{-1}) (Experimental)	μ/ρ (gm/cm2 (Theortical)	μ/ρ (gm/cm2) (Experimental	% Deviation
1	360	0.174	0.173	1.003	1.001	0.5747
2	511	0.147	0.146	0.080	0.081	0.6802
3	662	0.137	0.138	0.078	0.079	-0.7299
4	1170	0.087	0.088	0.050	0.051	-1.1494
5	1280	0.093	0.092	0.054	0.053	1.0752
6	1330	0.091	0.090	0.052	0.051	1.0989

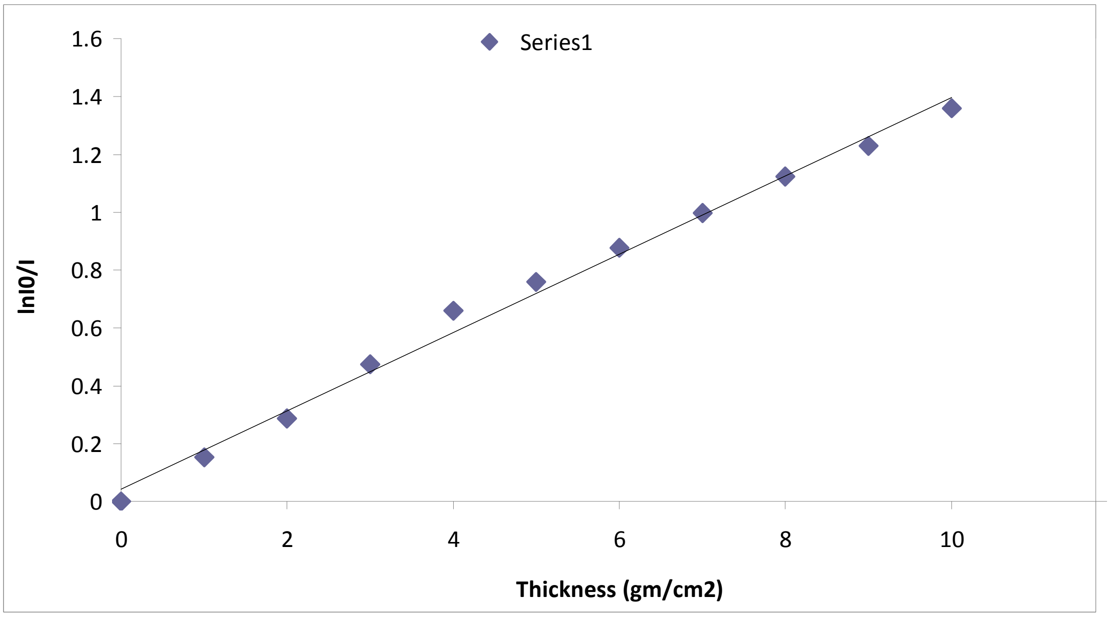

Fig.1 Thickness in gm/cm2 vs.ln I_0/I for silver at 0.360 MeV

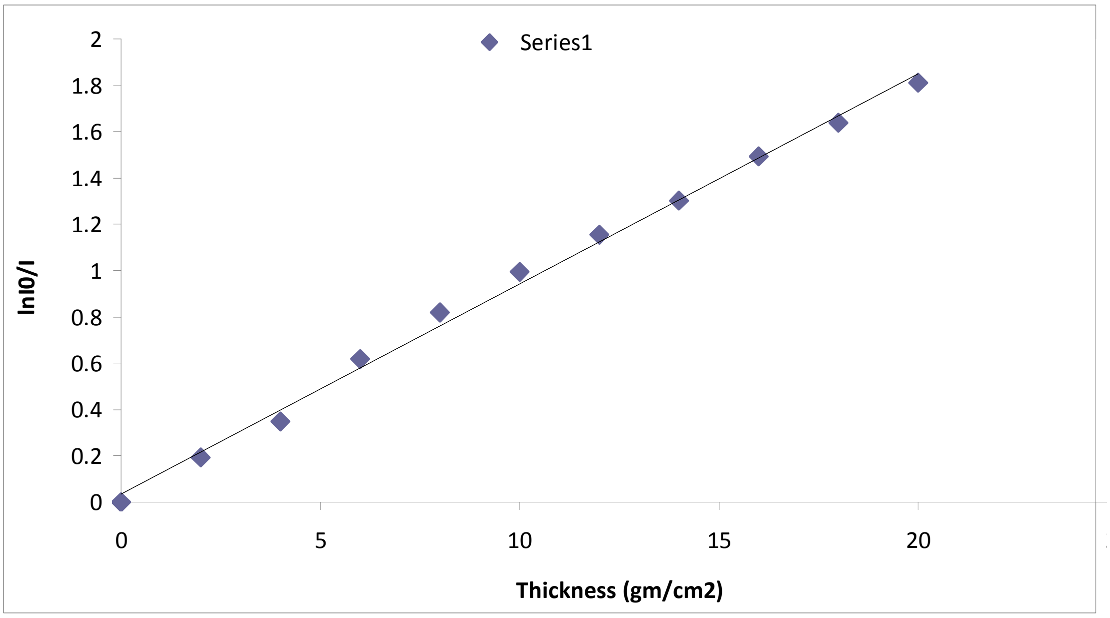

Fig.2 Thickness in gm/cm2 vs.ln I_0/I for silver at 0.511 MeV

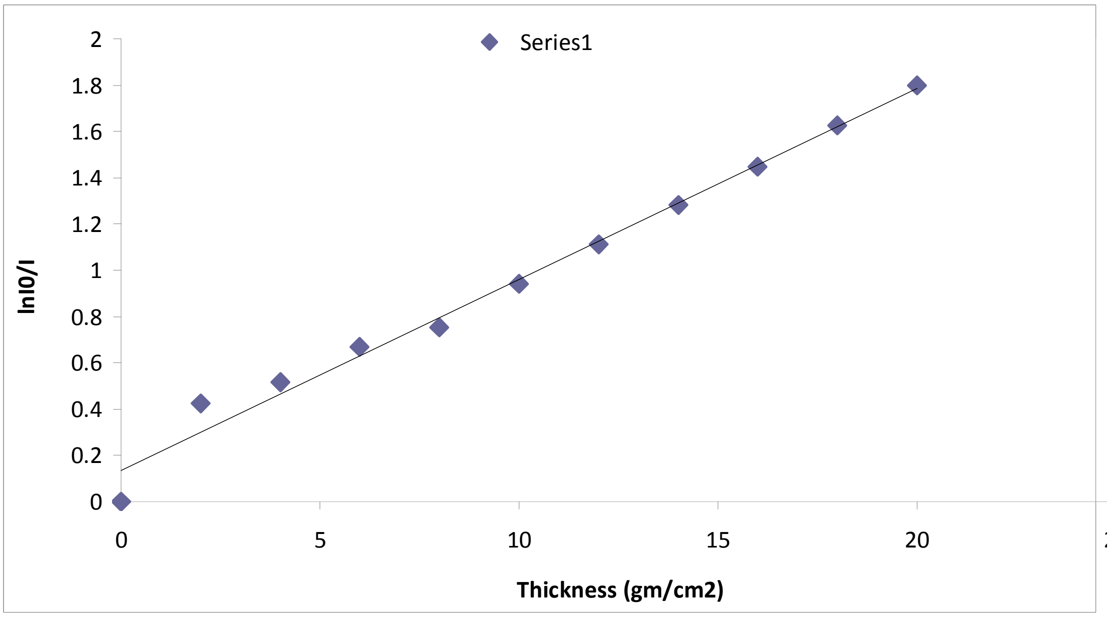

Fig.3 Thickness in gm/cm2 vs.ln I_0/I for silver at 0.662 MeV

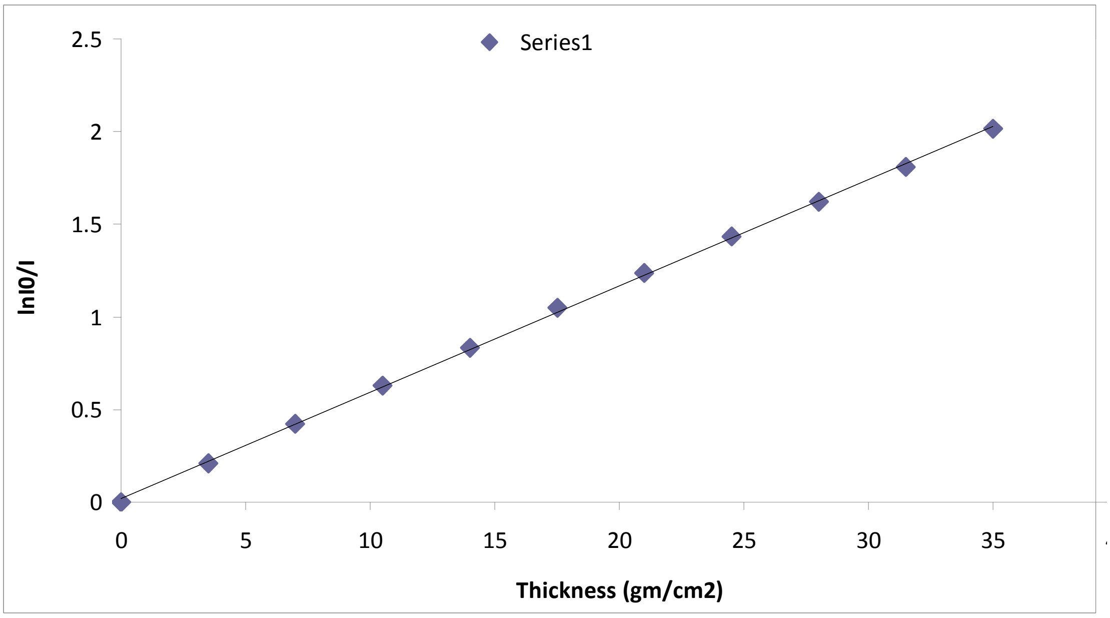

Fig.4Thickness in gm/cm2 vs.ln I_0/I for silver at 1.170 MeV

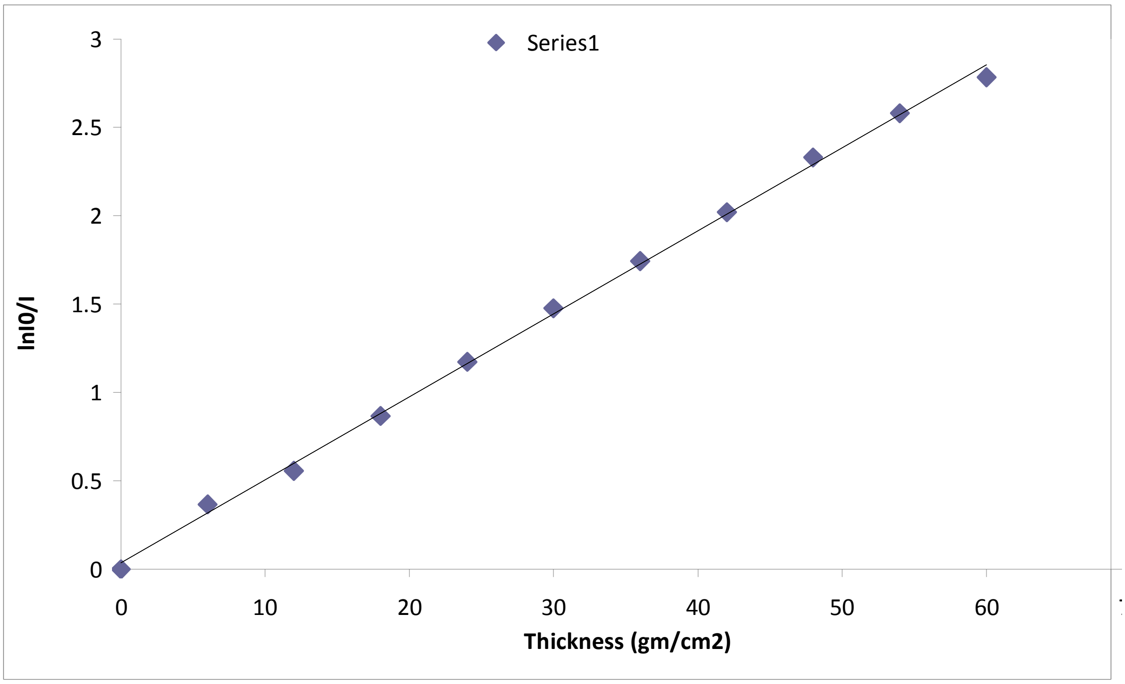

Fig.5Thickness in gm/cm2 vs.ln I_0/I for silver at 1.1280 MeV

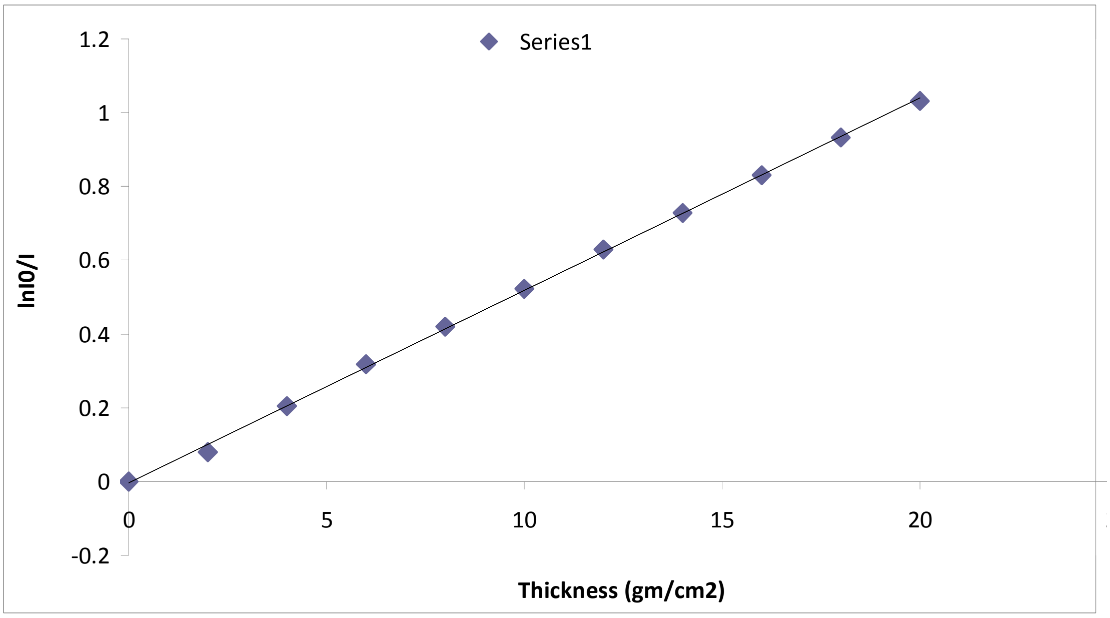

Fig.6Thickness in gm/cm2 vs.ln I_0/I for silver at 1.330 MeV

RESULTS AND DISCUSSION

Mass attenuation coefficient of elemental solids (Ag) absorber for multi gamma ray energies (Ba^{133},Na^{22}, Cs^{137}, Co^{60},) has been studied. Various parameters such as linear attenuation coefficient (μ), mass attenuation coefficient (μ/ρ), photo-electric cross-section, total photon interaction cross section (σ_{tot}) have been obtained for elemental solids.The comparison of their measurement with the theoretical values [6] is done by calculating the percentage deviation as,

$$\text{Percentage deviation} = \frac{\frac{\mu}{\rho}\,\text{(theor)} - \frac{\mu}{\rho}\,\text{(expt)}}{\frac{\mu}{\rho}\,\text{(Theor)}} \times 100$$

These are also presented in the Table 1 and the author found that the deviation mostly below 2% indicating these by excellent agreement of the authors measurements with theory. The linear attenuation coefficient is obtained by multiplying the mass attenuation coefficient of the element by its density. Fig. 1 to 6 shows plot of ln I_0/I v/s thickness (t) for Ag at 360, 511, 662, 1170, 1280 and 1330 keV using this graphs, slope can be calculated and this slope is nothing but the μ/ρ mass attenuation coefficient of element at that particular energy.

CONCLUSION

The theoretical values of mass attenuation coefficient for element are available from [6] 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 process such as photo electric effect, Compton scattering and the pair production. The measured mass and linear attenuation coefficient of elements are useful for dosimetry and radiation shielding purpose. It is found that there is a good agreement with theoretical and experimental measured values.

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