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MASS ATTENUATION COEFFICIENT AND ATOMIC CROSS SECTION OF GeO2 IN THE ENERGY RANGE 122-1330KeV

PRADIP DAHINDE*[1], R.R.BHOSALE[2],PRAVINA P.PAWAR[3]

[1]R.B.Attl Art,Science &Commece College Geoai,Dit.Beed. [2]Balbhim Art,Science and Commerece College Beed. [3]Dr.Babasaheb Ambedkar Marathwada UniversityAuangabad. E-mail: dahinde1986@gmail.com and pravinapawar4@gmail.com

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ABSTRACT

In the present investigation, we have determined here the mass attenuation coefficients (μ_m) of germanium oxide for energies of 122 -1330 keV. Photon energies are measured using the different radioactive sources Co^{57}, Ba^{133}, Cs^{137}, Na^{22}, Mn^{54} and Co^{60}. In the current investigation to detect gamma rays NaI(Tl) scintillation detection system were used. The investigated attenuation coefficient values were then used to determine the important parameters i.e. total atomic cross sections (σ_t) for germanium oxide.

Graphically it is observed that the variations of μ_m and σ_t with energy The values of μ_m, σ_t, are higher at lower energies and they decrease sharply as energy increases. The XCOM data is used to calculate Theoretical values. We were observed that the Theoretical and experimental values are found to be in a good agreement (error < 3-4%).

Keywords: attenuation coefficient; total atomic cross sections

INTRODUCTION

The mass attenuation coefficient values of partial photon interaction processes such as photoelectric effect, Compton scattering, pair production and all these are available in the form of software package XCOM from Berger and Hubbell (1987) by substituting the chemical composition of compound or mixture the mass attenuation coefficient of the In recent years the study of photon atom interaction with different materials has becomes more importance because of extensive use of radioactive sources in different field like industrial, chemical and other field. The proper characterization is must require for scientific study of different interaction of radiation with matter and also the penetration ability and diffusion of gamma radiation in external medium is required. The nature of the material is also important factor because from many studies it is observed that the Mass attenuation coefficient (μ_m) usually depends upon the energy of radiations and nature of the target material.

The Oxide covers a wide range of applications almost in every field. The study on the interaction of gamma rays with oxide materials are of great interest from theoretical and experimental point of view. It is found that the values of mass attenuation coefficients, total atomic cross section of metal oxides in the energy range of 122-1330 keV are studied. These studied values are compared with theoretical values calculated using XCOM program (Berger M.J. and Hubbell J.H., 1987, 1999).are found to be good match between each other. Mass attenuation coefficient (μ_m) is a most important and measure factor of the average number of interactions between incident photons and substance that occur in a given mass per unit area thickness of the material under investigation (Hubbell, 1999). Because of their diverse applications in industrial, chemical, biological, medical, shielding, agricultural applications also in food technology, biosensor, photovoltaic cell and solar cells ultra sound are more recent applications.

The useful parameters, like total atomic are critical parameters in applied field as well as fundamental science is obtained by using mass attenuation coefficient. The Shielding materials will be generated in the different energy range. Hubble (1982) are published tables of mass attenuation coefficients and the mass energy absorption coefficients for 40 elements and 45 mixtures and compounds for 1 keV to 20 MeV.

Hubbell and Seltzer (1995) replaced these tables in form of tabulation for all elements having 1 ≤ Z ≤ 92 and for 48 additional substances for dissymmetric interest. XCOM program converted to windows version is now called as Win XCOM Gerward et al.(2001,2004).

Oxides and biological material plays an important role. The knowledge of Interaction of photons with different substances (i.e. alloy, plastic, soil, role in radiation biology, nuclear technology, and space research as radioactive sources such as Co^{57} (122 keV), Ba^{133} (356 keV), Na^{22} (511 and 1275 keV), Cs^{137} (662 keV), Mn^{54} (840 keV) and Co^{60} (1170 and 1330 keV) are more significant in biological studies, radiation sterilization, industry (Hall, 1978). Photons in the high energy range are vital for radiography and medical imaging, the giga-electron-volt energy range are important in astrophysics and cosmology (Manohara et al. 2008).There have been several experimental and theoretical investigations for the determination of mass attenuation coefficient (μ_m) of different materials can be used to determine other related parameters like, total atomic cross (σ_t) (El-Kateb and Abdual-Hamid, 1991; Gowda et al., 2005; Manjunathaguru and Umesh, 2006; Pawar P.P. and Bichile sections(σ_t), molar extinction coefficients(ε), Electronic cross sections (σ_e), effective atomic numbers G.K., 2013; Sandhu et al., 2002).

Many researcher are interested and attracted towards the study of mass attenuation and different values of complex molecules in the energy range 5-1500 keV as the photons in this energy range are widely used in medical and biological applications (Hubbell, 1999) via different methods (Murut Kurudirek, 2013, 2014a, 2014b, 2014c, 2015; Midgley, 2004, 2005; Manohara and Hanagodimath, 2007; Demir et al., 2012; Murat Kurudirek and Tayfur Onaran, 2015; Danial Salehi et al., 2015).

CALCULATION METHODS

Mass attenuation coefficient

The inverse exponential power law that in the present work we study some theoretical parameters of some oxide that have been used to determine the mass attenuation coefficient μ_m. And other related parameters which are based on it. A parallel beam of the measured intensity I of the transmitted mono-energetic X-ray or γ-photons passing through matter is related to the incident intensity I_0 is is usually referred to as Beer-Lambert law is given by the relation.

$$I = I_0 e^{-\mu_m X} \qquad (1)$$

Where, I_0 and I are incident and transmitted photon intensities respectively, *X* is mass per unit area (g/cm^2), μ_m is mass attenuation coefficient (cm^2/g) given by the following equation for a compound or mixture of elements (Jackson D. F. and Hawkes D.J., 1981; Hubbell and Seltzer, 1995). By using the Eq. (1) we obtain the following equations for linear attenuation coefficient;

$$\mu = 1/t \ln (Io/I) \qquad (2)$$

The mass attenuation coefficient of the sample is measured by using the following equation:

$$(\mu/\rho)_i = \sum_i W_i (\mu/\rho)_i \qquad (3)$$

Where W_i is the weight fraction and $(\mu/\rho)_i$ is the mass attenuation coefficient of the i^{th} constituent element. Weight fraction is given by

$$W_i = n_i A_i / \sum_j n_i A_j \qquad (4)$$

Where A_j is the atomic weight of i^{th} element and n_i is the number of formula units.

Total atomic cross section

Total attenuation cross section (σ_t) is a fundamental parameter to describe the

Photon interacts with matter. The value of mass attenuation coefficient (μ_m) is used to determine Total atomic cross section (σ_t) by using the following relation (Hubbell, 2006; Erzeneoğlu et al.,2006).

$$\sigma_t = \frac{A}{N_A X} \ln(I_o / I) \qquad (5)$$

Where, *A* is molecular weight and N_A is Avogadro's number

EXPERIMENTAL DETAILS

In the presented studies we measured incident and transmitted photon energies by using a narrow-beam good geometry set up. Fig. 1 shows the experimental set up used in the current investigation. The six radioactive sources, Co^{57} (122 Kev), Ba^{133} (356 Kev), Na^{22} (511 and 1275 Kev), Cs^{137} (662 Kev), Mn^{54} (840 Kev) and Co^{60} (1170 and 1330 Kev) are used. i Gamma rays emitted by these radioactive sources were collimated and detected by a NaI(Tl) scintillation detector. The Signals emitted from the detector (2''×2'') NaI (Tl) crystal having energy resolution of 8.2% at 0.662 MeV. Stability and reproducibility of the arrangement were checked before and after each set of runs. In order to minimize the effects of small-angle scattering and multiple scattering events on the measured intensity, the transmitted intensity was measured by setting the channels at the full-width half-maximum position of the photo-peak.

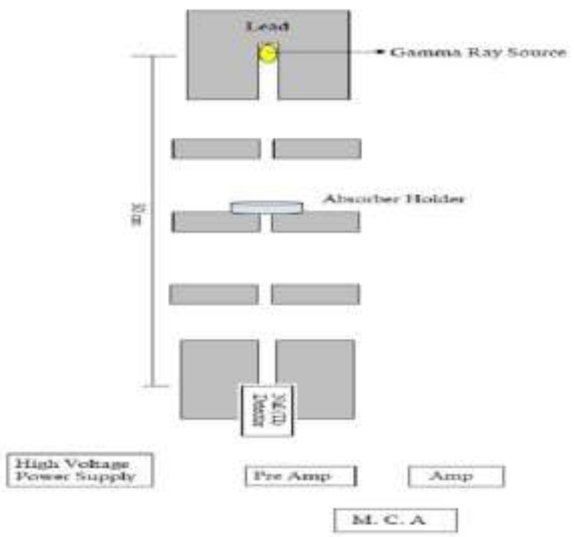

Fig.1: Narrow beam good geometry set up.

Pellet shaped uniform thickness of chosen oxides such as Germanium oxide (GeO2) under investigation were confined in a cylindrical plastic container with diameter similar to that of the sample pellet. The diameters of the sample pellets were determined using a traveling microscope. The attenuation of photons in the empty containers was negligible. Each sample pellet was weighted in a sensitive digital balance with an accuracy of 0.001 mg several times to obtain the average value of the mass.

The mass per unit area were determined by using the diameter of the pellet and mean value of the mass of the pellet. The sample thickness was selected in order to satisfy the following ideal condition as far as possible (Creagh D.C., 1987):

$$2 \le \ln(\frac{I_o}{I}) \le 4.$$

The values of attenuation coefficients (μ/ρ) of Germanium oxides (GeO_2) were calculated from the measured values of incident photon intensity I_0 (without sample) and transmitted photon intensity *I* (with sample) Eq. (2). The full experiments were performed in an air-conditioned room to avoid possible shifts of the photo-peaks. Other sources of error were evaluated and reduced. The maximum angle of scattering was maintained <30 min by properly adjusting the distance between the detector and source (30cm ≤ d ≤ 50 cm), as the contribution of coherent and incoherent scattering at such angles in the measured cross sections at intermediate energies is negligible (Hubbell, 1999). Hence, no small-angle scattering corrections were applied to the measured data. All the oxides samples used in this study were of high quality sigma Aldrich and of high purity (99.9 %) without high-Z impurities. Hence, sample impurity corrections were not applied to the measured data. In the presented investigation, uncertainty in the mass per unit area and the

Error due to no uniformity of the sample are <0.05% for all energies of interest. Optimum values of count rate and counting time were chosen to reduce the effects of photon built-up and pulse piles.

The photon built-up effect, which is a consequence of the multiple scattering inside the sample, depends on the atomic number and sample thickness, as well as the incident photon energy. A built-in provision for dead time correction was present in the MCA used during this investigation.

RESULTS AND DISCUSSION

In the current investigation, the variation between experimental and theoretical values of μ_m (cm^2/g) for germanium oxide (GeO_2) studied for the energies of 122, 360, 511, 662, 840, 1170, 1275- and 1330-keV. Photon energies are shown in Table 1, and those for germanium oxide samples are plotted in Figure 2. It can be observed from the figure and table that μ_m decreases with increasing photon energy. It is observed that he experimental values of μ_m agree with the theoretical values calculated using the XCOM program.

Table1. Attenuation coefficient (μ_m) and total atomic cross section (σ_t) of GeO_2

	(μ_m)		(S_t)	
Energy	**Ept.**	**Theo.**	**Ept.**	**Theo.**
122	0.292	0.296	50.72	51.42
356	0.103	0.1	17.89	17.37
511	0.086	0.083	14.93	14.41
662	0.071	0.073	12.33	12.68
840	0.066	0.064	11.46	11.11
1170	0.06	0.062	10.42	10.77
1275	0.057	0.054	9.96	9.38
1330	0.048	0.045	8.33	7.81

The total uncertainties in experimental values of the μ_m depend on the uncertainties of I_0 (without attenuation), *I* (after attenuation) measurements of mass thickness values, and counting statistics.

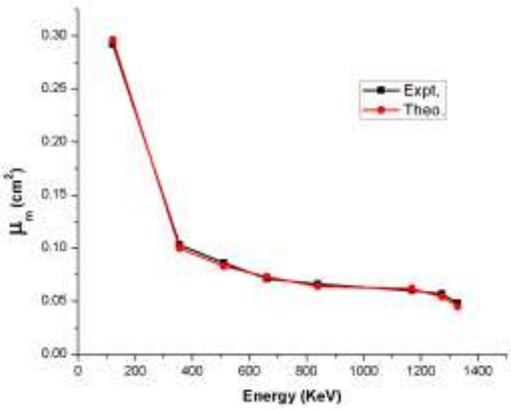

Fig. 2: Typical plot of μ_m versus energy for oxides

The estimated total uncertainty in the measured experimental values of μ_m was found to be in the range of 2-3%. The another important parameter, the measured total atomic cross section (σ_t) of GeO2.oxides are studied and displayed in Tables 2 the typical plots show the variation of σ_t versus E shown in Figure 3. It is observed that the behavior of σ_t with photon energies is almost similar to that of μ_m.

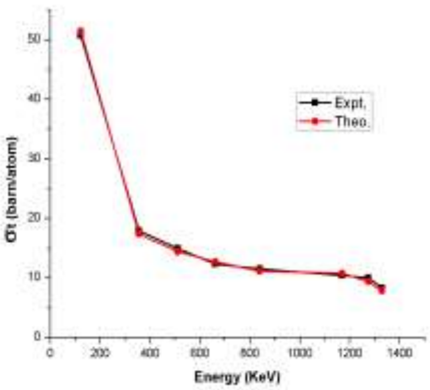

fig. 3 Typical plot of σ_t versus energy for GeO_2.

CONCLUSION

The present experimental study was carried out to obtain information on mass attenuation coefficient, μ_m and related parameters σ_t for Germanium oxide samples. It has been found that μ_m is an extremely useful and sensitive physical quantity for the determination of these parameters for the chosen oxide samples. The total atomic cross sections of GeO_2 with low and medium-Z elements are determined in the chosen energy range (122-1330 keV) which is emitted by the radioisotopes ^{60}Co, ^{57}Co, ^{133}Ba, ^{54}Mn, ^{22}Na, and ^{137}Cs. For the interaction of photons with matter the values of that μ_m depend on the physical and chemical environments of the samples. These values were found to decrease with increasing photon energies. From the study it is observed that the parameters σ_t changed similar to that of μ_m and it is clear that ε depends totally on the number and nature of atoms. In the present work, it has been observed that the data on mass attenuation coefficient (μ_m) and other parameters are very useful in industrial, biological, medical, shielding and other technological applications, solar cell and recently in sensors field. The measured data were compared against Win-XCOM-based data the agreement within 4%.

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