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Research Article

LINEAR ATTENUATION COEFFICIENT AND MASS ATTENUATION COEFFICIENT OF LEAD BORATE (30.4PBO-69.6B2O3) GLASS SYSTEM WITHIN THE ENERGY RANGE OF 0.122-1.330 MEV

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ABSTRACT

Gamma ray attenuation coefficient calculation methods used to accurately study the properties of lead borate such as (30.4PbO-69.6B2O3). In this study, mass attenuation coefficients (μm) of these lead borate for 0.122-, 0.356-, 0.511-, 0.662-, 0.884-, 1.170, 1.275-, 1.330- MeV photons are determined using the radio-nuclides Co57, Ba133, Cs137, Na22, Mn54, and Co60. NaI (Tl) scintillation detection system. The attenuation coefficient values (μm) and linear attenuation coefficient (μ) of lead borate. Theoretical values were calculated with the help of XCOM data. Theoretical and experimental values are found to be in a good result. The variations of μm and μ with energy are shown graphically. The values of μm and μare higher at lower energies, and they decrease sharply as energy increases.

INTRODUCTION

For radiation detection the new suitable thermo luminescence materials from last several years had been produced and studied. Due to the properties of high thermo luminescence (TL) sensitivity and their negligible fading, there is different glass system of our groups for attenuation. [El-Adawy A *et al*. 2004; Hussein A. etal.1989; El-Sersy A.R. & Khaled N.E. 2004].The gamma ray detection are depends on the atomic number of material and its constituents; In recent times, glasses based on heavy metal ions have received a great deal of attention due to their important optical applications. [Fu J.& Yatsuda H.1995; Pan A. & Ghosh J.2000]Radioactive waste disposal, using vitreous solids for containment, is another important application. Hence, radiation damage caused by electrons, alpha particles and gamma rays has been thoroughly investigated [DeNatale J.F.& Howitt D.G., 1984;.

Exarhos G.J.1984;Cases R.& Griscom D.L.1984]. The structural and physical properties of PbO glasses are well described by Worrel and Henshell [Worrel C.A.& Henshell J. 1978]. In earlier work, we have studied borate glasses containing heavy-metal oxides and shown that they have potential applications in radiation shielding [Khanna A., *et al*.1996;Singh K *et al*.2002;Singh H *et al*.2002].For standard measurement mass attenuation coefficients at energies from 1 keV to 100 GeV, Berger and Hubbell [Berger M.J.& Hubbell J.H.1987] developed a computer program, XCOM, for any element, compound or mixture. Now a day there are many updates are developing in this program in web version.. Recently, this well-known and much used program was transforming to the Windows platform by Gerward *et al*. [Gerward L *et al*. 2001], the Windows version being called WinXCom. Several authors had been published recently radiation shielding by glass development for several glass matrices, silicate glass, borate glass, and phosphate glass [Ruengsri S.2014].

Calculation Method

Linear attenuation coefficient

Gamma rays which are electromagnetic radiation show characteristic exponential absorption in matter and have no definite range such as for charged particles [Serge E.*et al*.1953]. The interaction of gamma rays with matter can takes place as fallows

$\square I = \square\square I \square x$ and $I/I_0 = e^{-\square x}$ (1)

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Where, I_0 and I – the initial intensity and incident intensity of gamma radiation
x is the thickness of material and μ known as linear absorption coefficient.

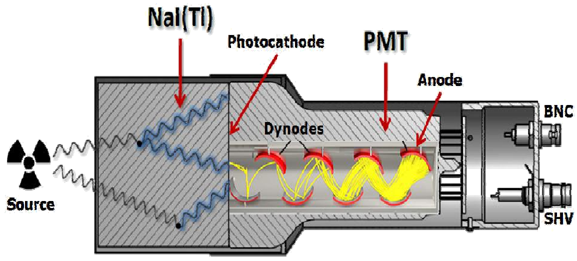

Fig 1 Schematic picture of the detector with NaI(Tl) crystal

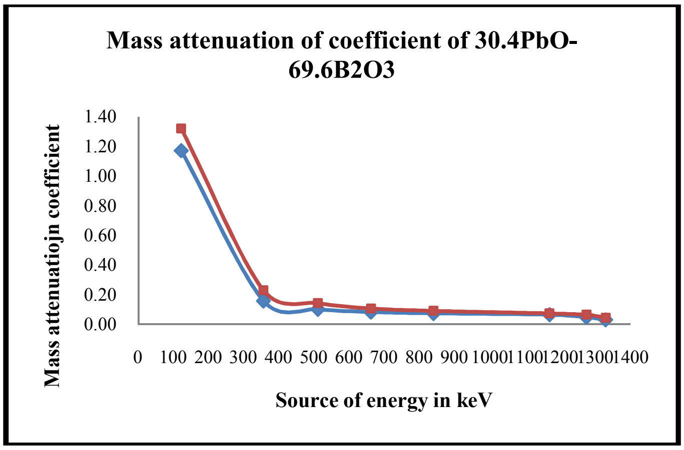

Fig 2 Typical plot of mass attenuation coefficient versus source of energy for 30.4PbO-69.6B2O

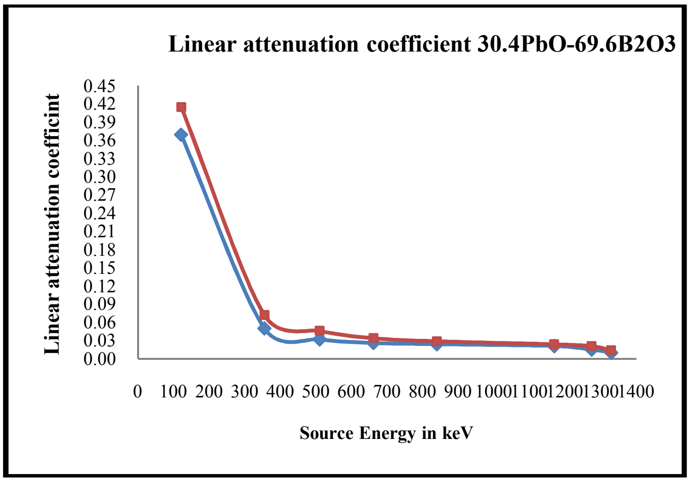

Fig 3 Typical plot of linear attenuation coefficient versus source of energy for 30.4PbO-69.6B2O

Table 1 Mass attenuation coefficient of $30.4PbO-69.6B_2O_3$

Sr.No.	Source	Energy in keV	μ/ρ th	μ/ρ Exp
1	**Co^{57}**	122	1.172	1.320
2	**Ba^{133}**	356	0.159	0.230
3	**Na^{22}**	511	0.103	0.145
4	**Cs^{137}**	662	0.084	0.108
5	**Mn^{54}**	840	0.075	0.092
6	**CO^{60}**	1170	0.066	0.075
7	**Na^{22}**	1275	0.049	0.066
8	**CO^{60}**	1330	0.031	0.045

Table 2 Linear attenuation coefficient of $30.4PbO-69.6B_2O_3$

Sr.No.	Source	Energy in keV	μ/ρ th	μ/ρ Exp
1	**Co^{57}**	122	0.369	0.415
2	**Ba^{133}**	356	0.050	0.072
3	**Na^{22}**	511	0.032	0.046
4	**Cs^{137}**	662	0.026	0.034
5	**Mn^{54}**	840	0.024	0.029
6	**CO^{60}**	1170	0.021	0.024
7	**Na^{22}**	1275	0.015	0.021
8	**CO^{60}**	1330	0.010	0.014

Mass Attenuation Coefficient

A parallel beam of mono-energetic X-ray or γ-photons passing through matter is attenuated due to absorption and scattering. Attenuation due to absorption follows the Beer-Lambert law:

$$I = I_0 e^{-\mu_m X} , \qquad (2)$$

Where I_0 and I are un-attenuated and attenuated photon intensities, respectively, X is mass per unit area (g/cm^2), and μ_m is mass attenuation coefficient (cm^2/g) given by the following equation for a compound or mixture of elements [Jackson D.F.& Hawkes D.J. 1981;Hubbell J. H. & Seltzer S.M. 1995]:

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

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.

Experimental Details

The $30.4PbO-69.6B_2O_3$ glass system of sample were preparing with help of melt quenching method. The batch of formulas had weighted to 30 g and melted at 1100 °C in alumina crucible by an electrical furnace. These melts was quenching at room temperature by pouring between stainless steel plates which produces circular shape with top side opened and when filled, a top part was press by top stainless steel plate for circular shape. The quench glass was annealed at 500 °C for 3 hour at room temperature. Geometry set up (Fig. 1). The 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), were obtaining from Bhabha Atomic Research Centre, Mumbai, India. A NaI (Tl) scintillation detector is used to detect Gamma rays emitted by these radioactive sources. Signals from the detector (2"′2") NaI (Tl) crystal. Checked Stability and reproducibility of the arrangement before and after each set of runs. Circular shaped lead borate ($30.4PbO-69.6B_2O_3$) under investigation was confining in a cylindrical plate. Mass attenuation coefficients (*m/ρ*) and linear attenuation coefficient (*m)* were calculating by lead borate Eq. (2).

RESULTS AND DISCUSSION

The experimental and theoretical values of µm (cm2/g) for lead borate studied at 122-, 360-, 511-, 662-, 840-, 1170-, 1275- and 1330-keV photon energies is shown in Table 1. The experimental values of mm agree with the theoretical values calculated using the XCOM program based on the mixture rule. The total experimental uncertainties of the mm values depend on the uncertainties of I0 (without attenuation), I (after attenuation), measurements of mass thickness values, and counting statistics. The estimated total uncertainty in the measured experimental values of mm was found in the range of 2-3%. It is clear that all the Lead borate have almost same behavior. Measured the linear attenuation coefficient for the lead borate using density of glass system studied are displaying in Table 2. Fig.1 shows the Schematic picture of the detector with NaI(Tl) crystal. Typical graphical representation of linear attenuation coefficient and mass attenuation coefficient versus source of energy in keV are shown in fig.2 and fig.3 respectively

CONCLUSION

This study was conducted to obtain information on mass attenuation coefficient, μ_m, and related parameters (μ) linear attenuation coefficient for the chosen lead borate sample. the physical and chemical environments of the sample of μ_m depend on interaction of photons with matter. The author measured experimental values with help of theoretical values using the various processes such as photo electric effect, Compton scattering, and the pair production. Graphical representation shows that good agreement for mass attenuation, which gives lead borate is use for radiation shielding purpose.

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