ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

EFFECTIVE ATOMIC NUMBERS AND EFFECTIVE ELECTRON DENSITIES OF INORGANIC NONLINEAR OPTICAL MATERIALS IN THE ENERGY RANGE 356 KEV-1330 KEV

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Abstract-In this study, effective atomic numbers (Z_{eff}) and effective electron density (N_{eff}) of inorganic nonlinear optical (NLO) materials such as Bab_2O_4 and $LiNbO_3$ have been calculated and compared with the values obtained from the WinXCOM program in the energy range 356 keV to 1330 keV. It is observed that there is a good agreement between theoretical and experimental values. From the present work, it is observed that the variation of obtained values of all parameters strongly depends on the photon energy; it decreases or increases due to chemical composition and density of the sample. These samples have been studied extensively using transmission method with a view to utilize the material for radiation dosimetry. Effective atomic numbers (Z_{eff}) and effective electron density (N_{eff}) of two samples have been carried out and transmission curves have been plotted. The transmission curve shows the variation of two sample materials decreases with increasing photon energy. The results of this present study can be useful in diagnostic imaging, radiation dosimetry, and other technological applications.

Keyword: Effective atomic number and effective electron density

1. INTRODUCTION

The study of high energy of photons interactions with matter is great significant. The increasing use of photons interactions in various fields such as medical, industry, agriculture, nuclear weapon, and radiation shielding. The knowledge of absorption and scattering of gamma rays in the compound materials has become an interesting and exciting field of research (Manohara et al., 2007). The mass attenuation coefficient, total atomic cross section, and total electronic cross sections are essential parameters for penetration and diffusion of x-ray or gamma ray in extended media. These parameters are valuable in many diverse fields such as radiation protection, nuclear diagnostics, nuclear medicine, and radiation dosimetry. The correct values of the mass attenuation coefficient are widely used in research for solving different problems in radiation physics and radiation chemistry (Kaewkhao et al., 2008). The accurate determination of the mass attenuation cross sections in different materials is therefore essential in the development of high accuracy semi-empirical formulation (Jackson et al., 1981). It is well known that mass attenuation coefficients mainly depend on the photon energy, the nature of the material and the density (Baltas et al., 2007).

Some of the authors were represented the table in the form of tabulation for all elements and developed new computer program i.e. WinXCOM program (Hubbell, 1982, Hubbell and Seltzer, 1995, Berger and Hubbell, 1987, Gerward et al., 2004). Numbers of research papers are available in various energy ranges on theoretical and experimental investigations to determine (μ_m) values in various elements and compounds/mixtures. The gamma ray interaction studies on C, H, N and O based biological materials have been carried out by well collimated narrow beam good geometry set up and reported mass attenuation coefficient decreases with increasing photon energy (Gowda et al., 2005, Manohara & Hanagodimath, 2008, Pawar & Bichile, 2013, Ladhaf & Pawar, 2015, Gaikwad et al., 2016). Few investigators have been carried out the mass attenuations coefficient and other related parameters with high energy photons such as minerals, alloys and dosimetric materials (Han et al., 2009, El-Kateb, 2000, Murthy, 2004, Awasarmol et al., 2017a, 2017b, and 2017c).

Nonlinear optical materials are attractive materials in the study of the interaction of light with a substance under the situation which is the nonlinear response of the atoms (Suresh et al., 2012). NLO materials have numerous advantages due to their high density and high refractive index. Moreover, these materials properties are helpful for the progress of advanced optical telecommunication, laser, optics, photonics, optical switching, data storage, dosimetric and radiation sensing. Also, this material is used for the new development techniques of fabrication and growth of the crystal.

In literature, we observed that no experimental data is available on the study of inorganic nonlinear optical materials. The main aim of the present study, we have measured the effective atomic numbers and effective electron density of two inorganic nonlinear optical materials in the energy region 356 keV to 1330 keV by using the transmission method and compared with Win XCOM data.

2. CALCULATION METHOD

2.1 Calculation of effective atomic number (Z_{eff})

The effective atomic number is determined by the following equation:

$$Z_{eff} = \frac{\sigma_{t,a}}{\sigma_{t,el}} \quad 2.1$$

where $\sigma_{t,a}$ and $\sigma_{t,el}$ are the total atomic cross section and total electronic cross section, respectively.

2.2 Calculation of effective electron density (N_{eff})

Similarly, effective electron density is determined by following equation:

$$N_{eff} = N_A \times \frac{Z_{eff}}{A_{eff}} \quad 2.2$$

Where, $N_A = 6.02486 \times 10^{23}$

3. EXPERIMENTAL DETAILS

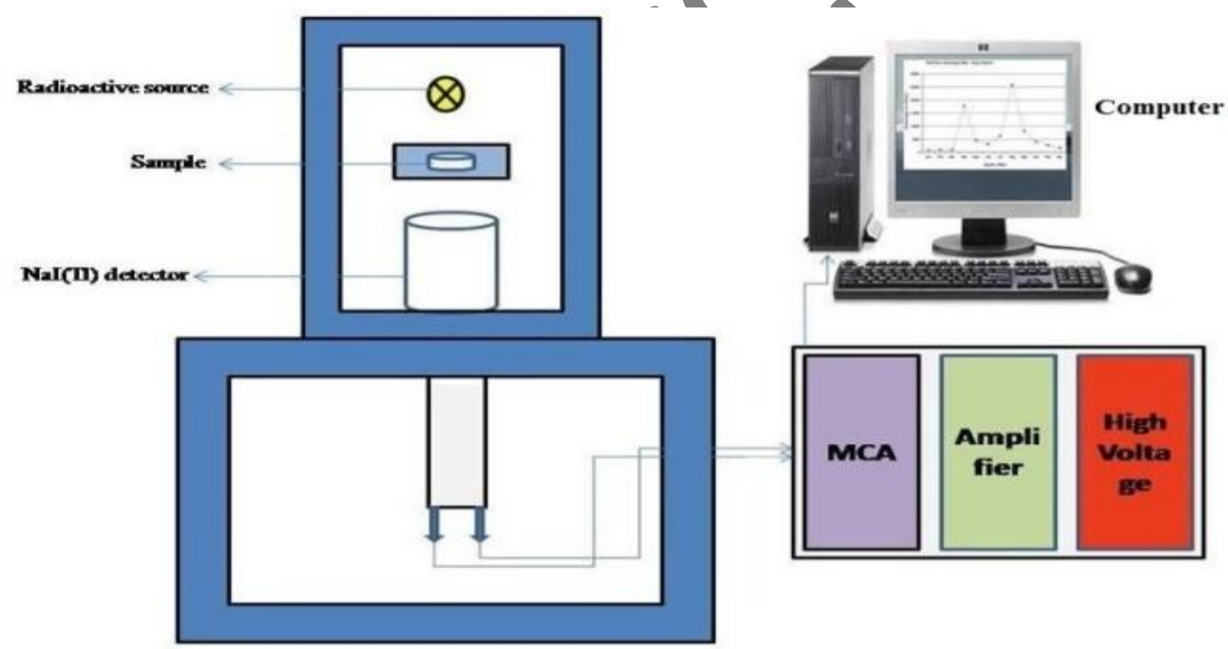

Fig. 3.1 The Schematic View of the Experimental Set up

The present experiments were done with the help of narrow beam good geometry set up and the schematic arrangement of the experimental set up is shown in Fig.1. In this experiments, the six radioactive sources were used such as ^{57}Co, ^{133}Ba, ^{137}Cs, ^{54}Mn ^{60}Co and ^{22}Na. All these radioactive sources were obtained from Bhabha Atomic Research Centre, Mumbai, India. These radioactive sources emitted energies 356, 511, 662, 840, 1170, 1275 and 1330 keV further they were collimated and detected by a NaI (Tl) scintillation detector. The signals were amplified and analyzed by gamma ray spectrometry which includes (2″×2″) NaI (Tl) crystal with an energy resolution of 8.2% at 662 keV and 8 K multichannel analyzer. The inorganic NLO materials such as BaB_2O_4 and $LiNbO_3$ samples under investigation were pellets shaped (uniform-thickness, 0.13 g/cm^2). The attenuation of photons in the empty container was negligible. The diameters of the pellets were determined using a traveling microscope. For the preparation of the sample in the form of a pellet, the sample was weighed in a sensitive digital balance and having a good accuracy of measurements about 0.001 mg. Stability and reproducibility of the arrangement were tested before and after each set of runs in the usual manner. The weighing of samples was repeated three times to obtain the consistent value of the mass. The KBr press machine was utilized to make the pallets of measured samples. The mean of this set of values was taken to be the mass of the sample. 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. Uncertainty in the measured mass per unit area is < 0.04%. The samples were put one by one between the source and detector. Optimum thickness of the samples (2 <ln (I_0/I) <4) was selected to minimize multiple scattering (Creagh, 1987). The details of experimental arrangement have been discussed by Awasarmol et al., 2017a, 2017b, and 2017c).

RESULTS AND DISCUSSION

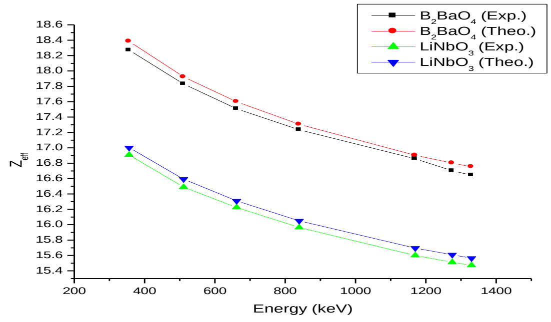

Fig. a The typical plots of Z_{eff} versus E for inorganic nonlinear optical materials

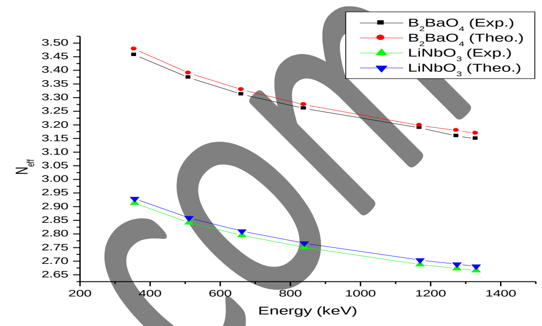

Fig. b The typical plots of N $_{eff}$ versus E for inorganic nonlinear optical materials

In this work, the experimentally and theoretically measured attenuation cross sections values of two inorganic NLO materials were measured at 356 keV - 1330 keV photon energies and carried out by employing the NaI(Tl) detector with a well-collimated narrow beam good geometry setup and are shown in Tables 1 and 2. The Z_{eff} values of two samples were measured experimentally and theoretically listed in Table 2 at given photon energies and variation with energy (E) is displayed in Fig. 2. It is observed that the Z_{eff} values depends on photon energy (E) and decreases with increasing photon energy. The measured values of Z_{eff} agree with theoretical values calculated using the WinXCOM program. The measured effective electron densities were studied for two samples in the present case and its variation with photon energy (E) is displayed in Figs. 2 represented in Table 2. From Figs. 2, it is clearly seen that the behavior of Neff with photon energy are decreases with increasing photon energy. The variation of the all attenuation parameters were systematically studied in the given photon energy region.

CONCLUSION

Effective atomic numbers (Z_{eff}) and effective electron density (N_{eff}) of two inorganic NLO samples has been calculated at 356 keV-1330 keV photon energy. These two samples have been calculated extensively using transmission method with a view to utilize the material for radiation dosimetry. This study concludes that any dosimetric material depends on its chemical composition, density, and concentration of the elements that it contains. In this research BaB_2O_4 and $LiNbO_3$ were investigated to get sufficient information about Z_{eff} and N_{eff} of inorganic NLO materials and it has been observed that the present BaB_2O_4 sample can be used in radiation environment without radiation damage and $LiNbO_3$ undergone radiation damage. From this study, we can conclude that the attenuation parameters of inorganic NLO materials are very important in diagnostic imaging and many other technological applications. In present paper, was reported first time investigation on (Z_{eff}) and (N_{eff}) parameters of inorganic NLO materials at different photon energies.

ACKNOWLEDGMENTS

The author (VVA) would like to thank University Grants Commission, New Delhi for providing RGNF.

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