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Mass Attenuation Coefficient and Molar Extinction Coefficient of 2-Amino-3-Nitropyridinein the Energy Range356KeV to 1330 KeV

Vishal Awasarmol[1], Ankur Awasarmol[2], Sandip Mahajan[3], R.R. Bhosale[4], Rajkumar Lokhande[5], Bharat Surung[6]

[1]Department of Physics, Swami Vivekanand Senior College, Mantha, Jalna, Maharashtra, India

[2]Department of Chemistry, Pratistan College, Paithan, Cha Sambhaji Nagar, Maharashtra, India

[3]Department of Physics, Shikshan Maharshi Dnyandeo Mohekar College, Kalamb, Dharashiv, Maharashtra, India

[4]Department of Physics, Arts, Commerce and Science College, Kille-Dharur, Beed, Maharashtra, India

[5]Department of Physics, Shirish Madhukarrao Chaudhari College, Jalgaon, Maharashtra, India

[6]Department of Physics, Lal Bahadur Shastri Senior College, Partur, Jalna, Maharashtra, India

ABSTRACT

In present experimental study the mass attenuation coefficient and molar extinction coefficient of nonlinear optical material i.e. 2-amino-3-nitropyridine have been measured at 356keV to 1330 keV photons in narrow beam good geometry set-up by using NaI (Tl) Scintillation detector with resolution 8.2% at 662 keV. The mass attenuation coefficients were calculated at different photon energies and data of mass attenuation coefficient were then used to the total interaction cross section, and molar extinction coefficient of 2-amino-3-nitropyridine. The experimental results are found to be in good agreement with XCOM data.

Keywords: Mass attenuation coefficient, Molar extinction coefficient, Nonlinear optical material

I. INTRODUCTION

Wide use of photons interactions with matter is great significant in various fields such as medical, industry, and agriculture. The knowledge of absorption and scattering of gamma rays in the compound materials has become an interesting and exciting field of research [1].Mass attenuation coefficient, total interaction cross section and molar extinction coefficient are basics parameters. These basic parameters are used for characterizing the penetration and diffusion of gamma rays in the medium through which they passes and mainly depends on the photon energy, the nature of the material and the density of medium through which radiation passes[2].

The correct values of the mass attenuation coefficient for X-ray and gamma ray in several materials (alloy, semiconductor, plastic, soil, biological materials etc.) are valuablein various applied fields such as medical, agriculture, industrial, biological, radiation protection, and radiation dosimetry[3-5].Nonlinear optical (NLO) materials have proven to be an interesting contender for a number of applications such as optics, photonics, optical memory, laser, frequency shifting and radiation sensing for the emerging technologies in areas i.e. signal

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processing, optical interconnections, and optical telecommunications. In recent years, many researchers have been tried to find out a diversity of nonlinear optical materials in order to satisfy the above said applications. But in the recent past, nonlinear optical materials are gaining attention because they share the wide advantages of both inorganic and organic materials[6]. In the NLO materials, have been of particular interest because the nonlinear optical response in this broad class of materials is microscopic in origin, offering an opportunity to use theoretical modeling coupled with the synthetic flexibility to design and produce novel materials [7].

Mass attenuation coefficient (μ_m) values are widely used in research for solving different problems in radiation physics and radiation chemistry [8-13]. The Mass attenuation coefficientdata can be used for the determination of some parameters such as total atomic cross section and molar extinction coefficient. In the present article, we have reported the detailed mass attenuation coefficients and another related parameter.

II. THEORY

In this section we summarize some theoretical relations that have been used for the determination of (μ_m) in the present work. When a monochromatic beam of gamma photons is incident on a target, some photons are emitted due to the dominant interaction processes and therefore, the transmitted beam is attenuated. The extent of attenuation depends on given elemental target. This attenuation of the beam is described by the following equation:

$$I = I_0 e^{-\mu t} \qquad (1)$$

Where, I_0 and I are the incident and transmitted photon intensities, respectively, μ (cm^{-1}) is the linear attenuation coefficient of the material and t (cm) is the sample thickness. Rearrangement of Eq. (1) yields the following equation for the linear attenuation coefficient:

$$\mu = \frac{1}{t}\ln\left(\frac{Io}{I}\right) \qquad (2)$$

In Eq. (2), the mass attenuation coefficients μ/ρ ($cm^2\ g^{-1}$) for the samples were obtained from Eq. (3) by using the density of the corresponding samples:

$$\mu_m = \frac{\mu}{\rho}\left(cm^2 gm^{-1}\right) = \frac{1}{\rho t}\ln\left(\frac{Io}{I}\right) \qquad (3)$$

Where, ρ (g/cm^3) is a measured density of the corresponding sample. The values of mass attenuation coefficients were then used to determine the total attenuation cross section (σ_{tot}) by the following relation

$$(\sigma_{tot}) = \mu_m (M / N_A) \qquad (4)$$

Where, M= $\sum_i n_i A_i$ is the molecular weight of the compound, N_A is the Avogadro's number, n_i is the total number of atoms in the molecule and A_i is the atomic weight of the i^{th} element in a molecule. The total atomic cross-sections ($\sigma_{t,a}$)has been determined from the following equation:

$$(\sigma_{t,a}) = \frac{1}{N_A} \sum_i f_i A_i (\mu_m)_i \qquad (5)$$

The values of molar extinction coefficients were determined using the following relation:

$$\varepsilon = 0.4343 N_A \sigma_{tot} \; (6)$$

III.EXPERIMENTAL SET UP AND MEASUREMENTS

The present experiments were done with the help of narrow beam good geometry set up.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 NLO materials such as 2-amino-3-nitropyridine samples under investigation were pellets shaped (uniform-thickness, 0.12g/cm^2).

The diameters of the pellets were determined using a traveling microscope. The attenuation of photons in the empty container was negligible. 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. The weighing of samples was repeated five 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. Stability and reproducibility of the arrangement were tested before and after each set of runs in the usual manner. 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 [17]. The details of experimental arrangement have been discussed by [14-16].

IV.RESULTS AND DISCUSSION

The experimentally measured values of μ_m (cm^2/g) for nonlinear optical material i.e. 2-amino-3-nitropyridineat 356, 511, 662, 1170, 1275 and 1330keV photon energies presented in Table 1. The typical plot of μ_m versus energy E for 2-amino-3-nitropyridineis displayed in Fig.(1).The Fig.(1) also includes the variation of theoretically determined μ_m values versus energy.

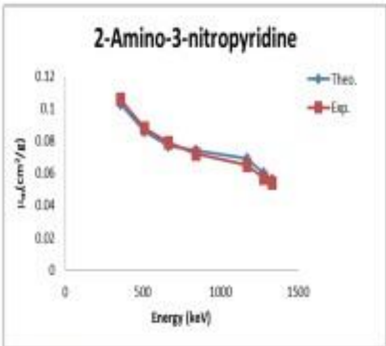

Fig. 1. Mass attenuation Coefficient of NLO sample

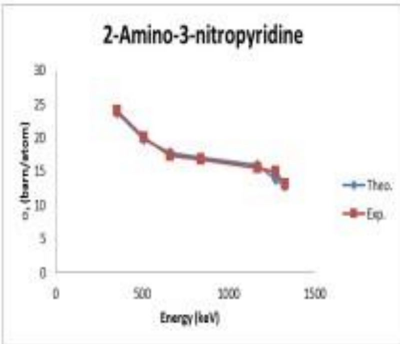

Fig. 2 Total atomic cross section of NLO sample

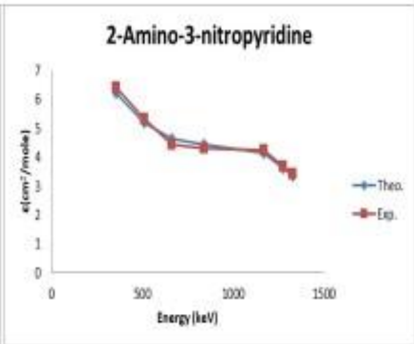

Fig. 3 Molar extinction Coefficient of NLO sample

Table 1. Mass attenuation Coefficient of Sample.

Energy	Theo.	Exp.
356	0.103	0.106
511	0.086	0.088
662	0.077	0.079
840	0.074	0.072
1170	0.069	0.065
1275	0.06	0.057
1330	0.056	0.054

Table 2. Total atomic cross section of Sample.

Energy	Theo.	Exp.
356	23.782	23.964
511	19.857	20.109
662	17.779	17.431
840	17.086	16.843
1170	15.932	15.625
1275	13.854	14.957
1330	12.93	13.216

Table 3. Molar extinction Coefficient of Sample.

Energy	Theo.	Exp.
356	6.223	6.431
511	5.196	5.327
662	4.652	4.458
840	4.471	4.315
1170	4.169	4.265
1275	3.625	3.713
1330	3.383	3.423

It is clearly seen that the μ_m depends on photon energy and decreases with increasing photon energy. The experimental (μ_m) values agree with theoretical values calculated using the Win-XCOM program based on the mixture rule. The total experimental uncertainty of the (μ_m) values depend on the uncertainties of I_0 (without attenuation), I (after attenuation), mass thickness measurements and counting statistics. Typical total uncertainty in the measured experimental (μ_m) values is estimated to be 2-3%. Measured total atomic cross section (σ_t) and molar extinction coefficient (ε) values for the presently studied 2-amino-3-nitropyridinehave been displayed in Table 2 and Table 3, respectively. The typical plots of σ_t versus E and ε versus E are displayed in Figs.(2) and Fig.(3) respectively. The behavior of σ_t and ε with photon energies shows almost similar behavior to (μ_m) plots.

V. CONCLUSIONS

In the present experimental study, mass attenuation coefficients and other related parameters of 2-amino-3-nitropyridineNLO samples has been calculated at 356 keV-1330 keV photon energy. These all 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 case, the mass attenuation coefficients (μ_m) were investigated to study sufficient information about total atomic cross sections ($\sigma_{t,a}$), and molar extinction coefficient (ε) of the samples. From this study, we can conclude that all the attenuation parameters of NLO materials are very important in diagnostic imaging and many other technological applications.

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