Coherent scattering cross sections of some rare earth compounds at small angles below 10^o for 662 keV gamma rays

P V Thulasi[1],* Antony Joseph[1], Somashekarappa H M[2], and Vinayak Anand Kamat[2]
[1] Department of Physics, University of Calicut, Kerala - 673635, India and
[2] Centre for Application of Radioisotopes and Radiation Technology(CARRT), Mangalore University, Mangalagangotri - 574199, India

Introduction

Studies on coherent scattering cross-sections have remarkable applications in various fields. But, experimental studies are scarce for small angles below 10^o and at low momentum transfer region, due to the difficulty of resolving the coherent scattered peak from the main peak, even using the high resolution detectors. A new method had been suggested by Puttaswamy et al.[1], using a simple geometrical set up, earlier used for gamma ray transmission studies. In the present work, using this method, we have determined the angle integrated total (coherent+ incoherent) scattering cross sections of $CeO_2, Yb_2O_3, Nd_2O_3, Dy_2O_3$ and Gd_2O_3 for 661.6 keV gamma rays, in the angular range of ($0-4^o, 0-6^o, 0-8^o$ and $0-10^o$). From the total scattering cross sections, corresponding angle integrated incoherent scattering cross sections obtained from Evaluated Nuclear Reaction Database (ENDF) library (based on the Non relativistic Hartree-Fock form factor method) is subtracted to obtain the angle integrated coherent scattering cross sections. The obtained angle integrated coherent scattering cross sections are compared with that determined from ENDF database and its variation with effective atomic numbers of the selected rare earth oxides have been studied.

Estimation of parameters

When perfect narrow beam geometry is ensured, no scattered radiations are assumed to fall on the detector, then the transmitted intensity is represented by I_1. Now, if we allow some scattered radiations also to fall on the detector, it will reduce the value of the mass attenuation coefficient of the scatterer. Let I_2 be the intensity of transmitted plus scattered radiations within a cone of forward acceptance angle θ^0. Then $\Delta\mu$, the corresponding reduction in mass attenuation coefficient, can be expressed by the relation,

$$\Delta\mu = \frac{\ln\left(\frac{I_2}{I_1}\right)}{t} \quad (1)$$

where t is the thickness of the absorber. The total scattering cross section $\Delta\sigma_{sca}$ from 0 to θ^0 in barn/molecule is then given by[2],

$$\Delta\sigma_{sca} = \left(\frac{A}{0.60225}\right)\frac{\Delta\mu}{\rho} barn/molecule \quad (2)$$

where A is the molecular weight and ρ is the density of the scatterer. $\Delta\sigma_{sca}$ constitute both the coherent and incoherent scattering cross sections within the angular range of 0 to θ^0, which is expressed as,

$$\Delta\sigma_{sca} = \int_o^\theta d\sigma_{coh} + \int_o^\theta d\sigma_{incoh} \quad (3)$$

The effective atomic number of the rare earth oxides are obtained from the ratio of the atomic cross section σ_a to the electronic cross section σ_e. Accordingly,

$$\sigma_a = \frac{\mu_c}{N_o \sum_i \frac{\omega_i}{A_i}} \quad (4)$$

$$\sigma_e = \frac{1}{N_o}\sum_i \frac{\omega_i A_i \mu_i}{z_i} \quad (5)$$

In the above equations, N_o, ω_i and μ_i are the Avogadro number, weight fraction and mass

*Electronic address: thulasiabhilash@uoc.ac.in

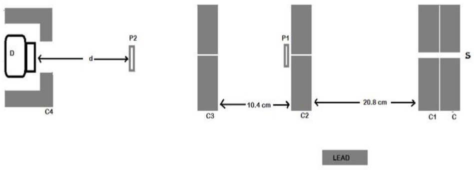

FIG. 1: The experimental setup. S is the source, D is the NaI detector and C, C1, C2 C3, C4 are lead collimators

attenuation coefficient of the i^{th} constituent element of the compound, respectively.Then,

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \tag{6}$$

Experimental details

In the present study, a ^{137}Cs source with activity of 0.191 GBq and a NaI(Tl) detector of crystal size 76 mm x 76 mm were used.The geometry of the experimental set up used is displayed in Fig 1. First, the scatterer was placed at the position P_1 such that the in-scattering angle was 0.28^o, so that the perfect narrow beam geometry condition has been ensured. No scattered radiations were allowed to reach the detector and pure transmitted beam intensity I_1 was measured. Subsequently, the scatterer was placed at the position P_2 so that the scattered radiations within a forward cone of $0 - \theta^o$ were allowed to reach the detector along with transmitted radiations. The corresponding intensity I_2 was determined, which contains the transmitted as well as scattered photons within an angle θ. From the background subtracted counts of I_1 and I_2, the total scattering cross section $\Delta\sigma_{sca}$ for an angular range of 0- θ^0 was determined . The statistical error estimated in each measurement is less than 0.1% and the error arising from multiple scattering is negligible due to the selection of optimum sample thickness (μt< 0.5).

Results and discussion

Angle integrated coherent scattering cross sections of selected rare earth oxides were determined experimentally for 661.6 keV gamma

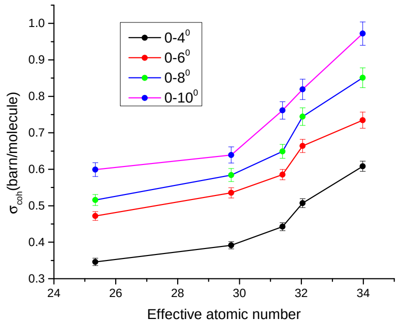

FIG. 2: Variation of coherent scattering cross section with effective atomic number for 661.6 keV gamma rays

rays for small angles below 10^o. The present experimentally determined values of coherent scattering cross sections, agree well with the theoretical angle integrated coherent scattering cross sections of ENDF. The coherent scattering cross section is found to increase with the effective atomic number of rare earth oxides and the variation is displayed in Fig 2.

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References

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