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Measurement of large angle Rayleigh scattering cross sections for 39.5, 40.1 and 45.4 keV photons in elements with 26 ≤ Z ≤ 83

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HIGHLIGHTS

- Rayleigh scattering cross sections for the $_{62}$Sm (Kα_2, $K\alpha_1$ & $K\beta_{1,3}$) X-rays at 139° with 26 ≤ Z ≤ 83 are measured.
- The scattering cross sections based on the MFASF are in general higher for up to 7% for the medium- and high-Z elements.
- The S-matrix values exhibit in general good agreement with the measured cross sections.

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ABSTRACT

The present work reports Rayleigh scattering cross section measurements for the 39.5 keV (Sm- $K\alpha_2$), 40.1 keV (Sm-$K\alpha_1$) and 45.4 keV (Sm-$K\beta_{1,3}$) X-ray photons in 35 elements with 26 ≤ Z ≤ 83 at backward angle of 139°. The scattering measurements were performed in reflection mode geometrical set up involving a secondary photon source consisting of Samarium ($_{62}$Sm) target excited by the 59.54 keV γ-rays from the ^{241}Am radioactive source. The scattered photons were detected using a low energy germanium (LEGe) detector. The product of detector efficiency, intensity of incident photons and other geometrical factors were determined by measuring the K X-ray yields from targets with 47 ≤ Z ≤ 59 and knowledge of the respective K X-ray fluorescence cross sections. The measured cross sections are compared with the theoretical cross sections based on the modified form factor (MF) formalisms and the second-order S-matrix approach. The experimental results demonstrate large deviations from the MF values for the elements with K shell binding energy (B_K) in vicinity of the incident photon energy (E_{in}), which smooth out with inclusion of the anomalous scattering factors (ASFs). The S-matrix values, in general, agree with the measured cross sections for all the elements under investigation.

1. Introduction

Rayleigh scattering is one of the predominant modes of photon interaction with atom in the X-ray energy region (< 100 keV). In this process, the photons are scattered by bound electrons mainly in the forward direction and the atom is neither ionized nor excited. Since the recoil is by the entire atom including the nucleus (rather than by an individual atomic electron as in the Compton effect) and photon loses only a negligible fraction of its energy, the Rayleigh scattering is coherent or elastic in nature resulting in interference effects. In case the coherence is spread over an array of atoms (photon wavelength ~ inter atomic distance), the interference becomes the Bragg diffraction, which is of importance in X-ray crystallography, crystal diffraction spectrometry and studies of molecular structures of biological interest.

The theoretical methods used to evaluate the Rayleigh scattering cross sections are based on the form factor formalisms and the S-matrix approach. The form factor was included as a correction factor for scattering by an extended charge distribution in the Thomson formula for the point charge, i.e., $d\sigma_T/d\Omega = (1/2)\, r_o^2(1 + \cos^2\theta)$ weighted by $F^2(x,Z)$, where $F(x,Z)$, is the atomic factor. In the sequential development of form factor formalism, non-relativistic and relativistic individual electron and total atomic wave functions were utilized to derive the electron charge density, and later, the relativistic modified form factor (MF), $g(x,Z)$, [$x = (E/hc)\sin(\theta/2)$, is the momentum transfer] was introduced to include the effect of electron binding energy. Further, anomalous-scattering factors (ASF's), g′(real) and g″(imaginary), were introduced to correct for strong interference of spatial distribution of electrons in the ordered structure at photon

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