ABSTRACT

K-shell fluorescence yields of low, medium Z and rare earth elements were determined using Si(PIN) detector and HPGe detector employing reflection geometry set up. Target atoms were excited using 59.5 keV gamma rays emerging from Am-241 source of strength 300 mCi. Background radiation and multiple scattering effects were minimized by properly shielding the detector. The elemental foils of uniform thickness and 99.9% purity were used in the present investigation. The fluorescent spectra were recorded in an 8K and 16K multi channel analyzer. The data were carefully analyzed and total K-shell fluorescence yields were calculated. The resulting yield values are compared with the available experimental and theoretical values.

Keywords: 8K and 16K Multi Channel Analyzer, Elemental Foils, K-Shell Fluorescence, Rare Earth Elements, Reflection Geometry

INTRODUCTION

K-shell fluorescence yield is one of the important parameters that play a vital role in experimental XRF studies. They connect X-ray production cross sections with the theoretically calculated ionization cross sections and hence are important whenever comparing theory with experiment. The knowledge of fluorescence yields is also required in the solution of many practical problems, such as standardization of radio isotopes, design of many radiation detecting devices and in the design of minimum weight graded or stacked shields for various engineering applications. They are also found extensively useful in nondestructive testing, trace element analysis, analyses of geological samples and in medical research. A detailed
knowledge of fluorescence yields is necessary for the interpretation of a large variety of measurements in atomic and nuclear physics. Some of these measurements include the transition energy in nuclear electron capture decay, the multipolarity of internally converted nuclear gamma transitions, internal ionization and atomic collision cross sections for processes in which inner shells are excited. A literature survey on the K-shell fluorescence yields reveals the fact that there have been a number of theoretical estimations, semi empirical fits (McGuire, 1969; Walters et al., 1971; Kostrum et al., 1971; Bambynek et al., 1972; Krause, 1979; Hubbel et al., 1994) and some experimental investigations to measure these values in all atomic number region in the periodic table (Arora et al., 1987; Al-Naser et al., 1987; Siddu et al., 1988; Pious et al., 1991; Balakrishna et al., 1994; Yashoda et al., 2002). With the advent of super computers and sophisticated computing methods, more and more accurate theoretical data are now available which are to be tested experimentally. Advances made in the field of semiconductors and radiation detection technology culminated in the development of sophisticated and high resolution solid state detectors like Si(Li), Ge(Li) and HPGe. These detectors might enhance the accuracy of the experimental data quite considerably. In the minds of many experimentalists, this rekindled the hope of getting more accurate experimental values with these high resolution and high efficiency detectors. The experimental work embodies the present paper is an attempt in this direction. In the present work a Si(PIN) detector and an HP(Ge) detector are used to detect the fluorescent X-rays coming out from different target materials when they are irradiated with 59.5 keV gamma rays from 300 mCi Am-241 source. Fluorescence Yields corresponding to K shell were measured for elements of atomic number ranging from 26 to 70. The present work also serves as a comparative study of the performance of different detectors to detect photons of different energies coming out from absorbers of different atomic numbers.

Experimental Method

In the present work, K-shell fluorescence yield were determined by employing a straightforward method of measuring K X-ray emission rates and the number of primary K-shell vacancies. The target atoms were ionized using 59.5 keV gamma rays from 300 mCi Am-241 source. Experiments were carried out using reflection geometry setup employing a good collimating and shielding arrangements. The targets employed were pure elemental foils of high purity, greater than 99.9%. The emitted fluorescent X-rays were detected using HPGe detector. The spectra were recorded and analyzed using a 16K multi channel analyzer. The area under the X-ray photo peak which gives \( N_k \) the total number of K X-ray fluorescent radiation is accurately determined and the K X-ray fluorescence yields \( \omega_k \) were evaluated using the expression (Balakrishna, 1989)

\[
w_k = \frac{16\pi^2 N_k r_1^2 r_2^2 [1 + \mu_k / \mu]}{S \varepsilon D \int f_k A A_D [1 - \exp\{-\mu + \mu_k\} t \sqrt{2}]}
\]

where \( r_1 \) is the distance between the source and the target; \( r_2 \) is the distance between the target and the detector; \( S \) is the source strength, \( \varepsilon_D \) is the detector efficiency, \( f_k \) is the fraction of the incident gamma ray flux that ionizes the K shell of the target fluorescer, \( A \) is the area of the target, \( A_D \) is the area of the detector, \( t \) is the thickness of the target. The attenuation coefficients \( \mu \) and \( \mu_k \) were taken from the literature (Hubbell, 1982)

The fraction of the incident gamma ray flux that ionizes the K shell of the target fluorescer is given by \( f_k = (\mu_k - \mu) / \mu \), where \( \mu_k \) and \( \mu \) are the attenuation coefficients immediately above and below the K edge respectively. The values of attenuation coefficients at different energies were taken from the literature (Hubbell, 1982) and a graph of attenuation coefficients versus energy is plotted for all the elements investigated. Then the values of \( \mu_k \) and \( \mu \) were read from this graph corresponding to the K absorption edge.
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