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Measurement of L subshell fluorescence yields of elements in the range $45 \leqslant Z \leqslant 50$ using synchrotron radiation

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Abstract

The L subshell fluorescence yields ω_1, ω_2 and ω_3 have been measured in the range $45 \leqslant Z \leqslant 50$ by exciting the elemental targets with a synchrotron radiation beam at 7 keV. The characteristic L X-ray photons originating from the targets are measured with a Si(Li) detector. The L shell fluorescence yields have been determined using the experimental L_α, $L_{\beta1}$, $L_{\beta2}$, $L_{\gamma1}$ and $(L_{\gamma2} + L_{\gamma3})$ X-ray production cross sections, the theoretical L subshell photoionization cross sections, the Coster–Kronig transitions yields and the fractional X-ray emission rates. The measured values of ω_1, ω_2 and ω_3 are compared with theoretical values and with semi-empirical compilations data.

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Keywords: Fluorescence yields; X-ray; Synchrotron radiation

1. Introduction

X-ray fluorescence parameters such as fluorescence yields and cross sections, are very important in understanding the ionization of atoms as well as for non-destructive elemental analysis in several fields such as material science, medical physics, industry and environmental science. Besides, the accurate values of these parameters are needed to check the atomic physics theory and the validity of models used in predicting fluorescence data.

It is well known that a vacancy created in the inner shell of an atom by primary radiation is filled by radiative or non-radiative process. X-ray fluorescence yield is the probability that a vacancy in the shell or subshell is filled by the radiative process. The Auger and Coster–Kronig transitions are non-radiative transition. In Auger transition a vacancy is transferred between the shells, whereas in a Coster–Kronig transition a vacancy is transferred within the subshell of the same shell. It is well known that the measured K shell fluorescence yields agree well with the values predicted by the theoretical models [1]. In the case of L shell, because of the presence three subshells, the vacancies produced in L_1 and L_2 subshells may be transferred to the higher subshells through the Coster–Kronig transition. Therefore, while comparing the experimental L subshell fluorescence yields with theoretical values, one must take into account the parameters involved in redistribution of vacancies within subshells.

Some researchers have predicted the L shell fluorescence yields using different models. Krause [2] carried out a semi-empirical compilation of atomic L subshell X-ray fluorescence yields ω_i ($i = 1, 2, 3$), the Auger transition yields a_i and the Coster–Kronig transition yields f_{ij} for elements in the range $12 \leqslant Z \leqslant 110$. Chen et al. [3] tabulated the values of L subshell fluorescence yields, ω_i, for elements with $18 \leqslant Z \leqslant 100$ based on relativistic Dirac–Hartree–Slater (RDHS) model. Puri et al. [4] presented theoretical values

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of L subshell fluorescence yields, ω_i, using the radiative emission rates of Scofield [5] and the non-radiative emission rates computed by Chen et al. [6].

Several researchers have measured the L subshell fluorescence yields using electron beam, proton beam, synchrotron radiation, gamma rays from strong radioactive sources and coincidence technique [7–14]. The L subshell fluorescence yields for elements with atomic number $Z \geqslant 70$ have been measured by exciting the target with electron beam and proton beam [7,8]. The L_1 and L_2 fluorescence yields for the elements with $72 \leqslant Z \leqslant 82$ have also been measured by the synchrotron photoionization method [9]. McGhee and Campbell [10] measured ω_2 and ω_3 for high Z elements using K X-ray and L X-ray coincidence technique. Many investigators have also measured L subshell fluorescence yields for high Z elements using 60 keV gamma radiations from ^{241}Am radioactive source [11–14]. The L_1 fluorescence yield ω_1 of bismuth has been recently determined by Campbell [15] using L X-ray photons from ^{210}Pb radioactive source, and recently he has presented a critical review of L X-ray fluorescence yields and the Coster–Kronig transitions [16].

It is interesting to note that only a few researchers have measured L subshell fluorescence yields for the elements in the intermediate Z values and some have observed disagreement between experimental and theoretical values. The L shell fluorescence yields for elements silver and tellurium were measured by Budick and Derman [17]. Markevich and Budick [18] measured L subshell fluorescence yield for rhodium. Xu and Rosato [19] measured L_1 fluorescence yields for the elements around $Z = 50$ by inducing the L X-ray with 2.5 MeV proton beam. In all these experiments, they observed disagreement between theory and experiment. Recently, Jitschin et al. [20] measured L subshell fluorescence yield and other parameters for Ag element by selective photoionization method using synchrotron radiation. However, they observed a good agreement between theory and experiment. From above results, we notice that more data are needed in the intermediate Z region to understand the L shell fluorescence yields using monochromatic X-ray photons. In view of this, we have measured L subshell fluorescence yields for the elements in the range $45 \leqslant Z \leqslant 50$ by exciting the targets with 7 keV synchrotron radiation beam available at National Synchrotron Light Laboratory (LNLS), Campinas, Brazil.

2. Experimental details

The experimental arrangement used in the present work is shown in Fig. 1. It consists of synchrotron storage ring, silicon monochromator, ionization chamber, target chamber and the detector. The polychromatic beam generated from the storage ring operating at 3.7 GeV and nominal current of 10 mA was monochromotized using silicon (1 1 1) channel cut double crystal monochromator. The monochromator could tune the synchrotron energies from 3 keV to 14 keV and the energy resolution was $3–4 \times 10^{-4}$ in the energy region from 7 keV to 10 keV. Computer controlled facility was provided to control horizontal and vertical beam size before and after the monochromator. The ionization chamber was used to measure intensity of the incident beam on the target. The targets were mounted in such way that the incident and take off angles were 45°.

A 7 keV monochromatic beam was incident on target and the characteristic L X-ray photons originating from the target were detected with a high energy resolution Si(Li) detector coupled to multichannel analyzer through electronic modules. The detector was 5 mm diameter, 5 mm thickness and had a beryllium window of thickness 0.0025 cm. The energy resolution of the detector was 165 eV at 5.9 keV.

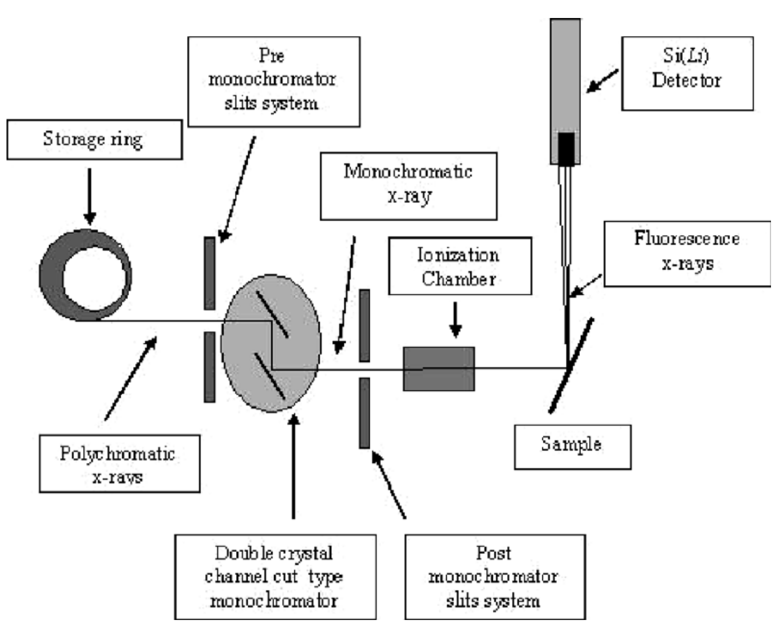

Fig. 1. Experimental arrangement used for measurements of L subshell fluorescence yields.