K- Shell X-ray Intensity Ratios of Fe, Ag and Te following Electron Capture Decay employing 2π geometry

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Introduction

Over the past decades, the studies on nucleus have led to many major developments that have transformed our lives. Even though X-ray fluorescence studies could be traced long back, the topic remains still relevant owing to the increase in the applications of the accurate values of the X-ray fluorescence parameters in various fields. The radioactive decay of the unstable nuclides results in the generation of X-rays. It has been reported that the values of K shell X-ray intensity ratios following electron capture (EC) decay are different from the theoretical values as well as those obtained via photon induced excitations [1]. Several researchers have made attempts to study the K shell intensity ratios by photon excitation methods employing reflection geometries [2]. But there are very few reports on the measurements of K shell X-ray intensity ratios of elements following decay processes, probably due to the difficulty in procuring strong radioactive sources.

The measurement of K shell X-ray intensity ratios of iron, silver and tellurium via electron capture decay of ^{57}Co, ^{109}Cd and ^{125}I is discussed here. Since the electron capture sources themselves will undergo decay to result in emission of X-rays from daughter atoms, the need for separate sources to excite the targets can be eliminated. We have employed 2π geometrical configuration method for the present investigation, which was previously developed by our research group [3]. The method requires only weak EC sources that can be handled safely without any personal radiation hazards. This eliminates the need for heavy shielding materials such as lead. Thus, the method is relatively cost effective and free from radiation hazards compared to all other methods. The obtained results are discussed in the light of the effects of electron capture decay on X-ray emission probabilities.

Experimental

In the present investigation, we have employed an X-ray fluorescence spectrometer consisting of a Si(Li) detector (sensitive surface area 20 mm^2, 3.5 mm thickness, Be window of thickness 12.5 μm, FWHM-140 eV at 5.9 keV), connected to a PC based 8k multichannel analyser. The weak ^{57}Co, ^{109}Cd and ^{125}I EC sources were obtained from Radio Pharmaceuticals Division, Therapeutic and Reference Sources Section, BARC, Mumbai. These sources (2 μCi) were prepared on a plastic disc and covered with aluminised mylar film of thickness 0.7 mg/cm^2. The ^{57}Co source having half-life of 270 days decays by pure EC to the excited state of ^{57}Fe emitting characteristic X-rays of iron and γ rays of 122 keV (85%), 136 keV (11%) and 14.39 keV (8.5%). The ^{109}Cd source having half-life of 453 days decays by pure EC to the isomeric state of ^{109m} Ag which subsequently makes a transition to ground state through the emission of 88 keV γ-ray (5%). Similarly, the ^{125} I source having a half-life of 60 days decays purely through EC to the isomeric state of ^{125m}Te, which subsequently decays to the ground state, either through the emission of a γ-ray of 35.4 keV (7%) or by the emission of internal conversion electron (93%).

The Si(Li) X-ray detector spectrometer was calibrated using various gamma and X- ray sources. Fixing the ^{57}Co source right in front of the face of the detector, a nearly 2π geometrical configuration is adopted and the K X-ray spectra of iron were acquired for the live time of 2000s in four trials. The K X-ray spectra of silver and tellurium were also obtained in the similar way for the live time of 2000s and 3000s respectively. The intensities of K shell X- rays are measured and the detailed analysis of the obtained spectra are done using Origin Pro software. The background subtraction for the obtained intensities is carried out to remove the Compton as well as the internal bremsstrahlung continuum. The intensities are further corrected for the efficiency of the Si(Li) detector, (which includes geometric correction factor, corrections for the attenuation in Be window, Au layer ,Si dead layer and correction due to the absorption in the sensitive volume of the detector) and intensity ratios are estimated. The sum of the intensities of the K_α and K_β X-rays gives the total K X-ray emission probabilities and the intensity ratios gives the relative probabilities of K_α and K_β X-ray emission.

Results and Discussions

The K shell X-ray intensity ratios for iron, silver and tellurium are measured and are presented in Table 1. Present experimental results are compared with theoretical and photoionisation experimental values and are plotted in Fig. 1. The measured K X-ray intensity ratio for iron is lower to about 4% than the theoretical value of Scofield [4]. This may be due to the exchange interactions that occur between the 3p and 3d shell electrons, which reduces the 1s-3p orbital overlap and consequently the K_β X-ray intensity [5]. The measured K_β/K_α intensity ratios for silver and tellurium are showing a respective significant increase of about 8% and 19% than the theoretical values given by Scofield [4]. This may be due to the recoiling motion experienced by the nucleus due to neutrino emission, which results in the electron cloud deformation during EC. This give rise to additional X-ray transitions from the valence band to 1s for K-electron capture, which subsequently increases the K_β/K_α intensity ratios. The recoil effect tends to increase with increasing atomic number (Z), because as Z increases, the atomic orbitals are normally bound strongly enough to their nucleus to immediately follow a recoiling motion [5]. The increasing deviation of the observed values from the theoretical values for silver (Z=47) to tellurium (Z=52) may be due to this phenomena.

Table 1: The measured K_β/K_α intensity ratios

	Present Experiment	Theory	Others' Experimental
Fe	0.116±0.003	0.1208[4]	0.1210±.002[1] 0.1324±.005[6]
Ag	0.212±0.003	0.1964[4]	0.2096±.004[6]
Te	0.254±0.007	0.2132[4]	0.2194±.008[6]

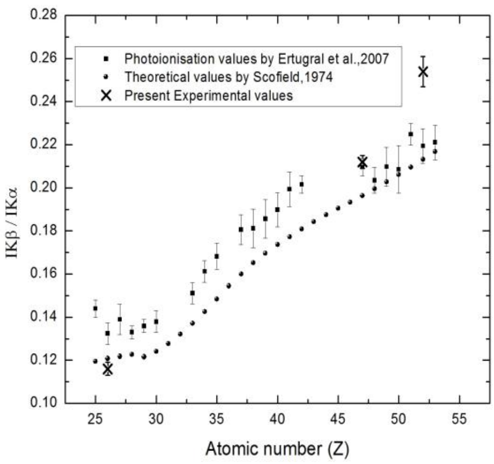

Fig. 1 K_β/K_α intensity ratios versus Z

To study about the variation of the intensity ratios with excitation peculiarities and chemical state, photoionisation experiments and the decay experiments on more elements are in progress. Furthermore, to the best knowledge of the authors, the studies on K X-ray intensity ratios of silver and tellurium following the electron capture decay of ^{109}Cd and ^{125}I are not reported so far.

References

[1]. E. Büyükkasap et al., J. Radioanal. Nucl. Chem. Lett., **186**, 471 (1994).
[2]. K. L. Allawadhi, Ind. J. Phys., **67B**, 555 (1993).
[3]. S. B. Gudennavar et al., Radiat. Phys. Chem., **68**, 745 (2003).
[4]. J. H. Scofield, Atom. Data Nucl. Data Tables, 14, 121, (1974).
[5]. G. Brunner, J. Phys. B: At. Mol. Phys., **16**, 1199, (1983).
[6]. M. Ertugral et al., Radiat. Phys. Chem., **76B**, 15, (2007).