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K_β/K_α X-ray intensity ratios for elements in the range $16 \leqslant Z \leqslant 92$ excited by 5.9, 59.5 and 123.6 keV photons

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Abstract

The K shell intensity ratios K_β/K_α for 59 elements in the atomic region $16 \leqslant Z \leqslant 92$ have been measured at excitation energies of 5.9, 59.5 and 123.6 keV. K X-rays emitted by samples have been counted by a Si(Li) detector with resolution 160 eV at 5.9 keV. The measured values were compared with the theoretical values calculated using Scofield's tables based on the Hartree–Slater and Hartree–Fock theories and available experimental values. Reasonable agreement is typically obtained between present and theoretical values.

Keywords: Intensity ratios; Photoionization; EDXRF

1. Introduction

The knowledge of accurate intensity ratios for elements is important because of their widespread use in the non-destructive elemental analysis of using the energy dispersive X-ray fluorescence (EDXRF) technique. The measurements of K_β/K_α intensity ratios are important for comparison with theoretical predictions based on atomic models in order to test the validity of these models. The K_α X-rays arise from transitions from the L- to the K-shell. The K_β X-rays arise from transitions from the M-, N-, O-, etc. to the K-shell. The K_α and K_β X-rays are described in Table 1.

There have been various investigations on K_β/K_α intensity ratios. Büyükkasap (1997) has measured the thickness effect on the K_β/K_α intensity ratios in Ba, La, Sm, Gd, Dy and Ho. Ertuğrul et al. (2001) have measured K_β/K_α intensity ratios in element range $22 \leqslant Z \leqslant 69$ at 59.5 keV. Ximeng et al. (2001) have reported K X-ray relative transition probabilities for $38 \leqslant Z \leqslant 68$ using 3 MeV photons. Baydas et al. (2003) have measured K_α and K_β X-ray fluorescence cross-sections and the K_β/K_α intensity ratios for elements in the range $22 \leqslant Z \leqslant 29$ by 10 keV photons using a secondary excitation method. Dhal and Padhi (1994) have investigated relative K X-ray intensities on the elements from Mn to Sb using 59.5 keV γ-rays. Similarly, Ertuğrul and Şimşek (2002) have measured K X-ray relative intensities of Tm, Yb, Lu, Ta, W, Re, Au, Hg, Tl, Pb, Bi, Th and U elements. The ^{57}Co radioisotope source has been used for excitation of the elements.

Some workers have studied K X-rays intensity ratios in some compounds and alloys. Bhuinya and Padhi (1992) have measured K_β/K_α X-ray intensity ratios of Ti, Cr and Ni in Ti_xNi_{1-x} and Cr_xNi_{1-x} alloys for different concentrations ($x = 1.0$, 0.74, 0.55, 0.35 and $x = 1.0$, 0.58, 0.20, 0.0, respectively) using 59.5 keV γ-rays. Padhi et al. (1993) have found K_β/K_α X-ray

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intensity ratios of Ti and V in proton-induced X-ray emission (PIXE) and γ-RF studies of the compounds TiB_2, VB_2 and VN. Similarly, K_β-to-K_α X-ray intensity ratios of Ti, V, Cr, Fe, Co (in pure metals and their disilicide compounds), V, Ni (in V_xNi_{1-x} alloys for different compositions ($x = 0.00$, 0.10, 0.20, 0.35, 0.50, 0.75, 1.00)) and Cr, Mn, Co (in CrSe, MnSe, MnS and CoS) have been measured using 59.5 keV γ-rays by Raj et al. (1998, 1999a, b, 2000). K_β/K_α X-ray intensity ratios of some Cr, Mn, Cu, Br and I compounds have been studied by Küçükönder et al. (1992, 2003). These compounds have been excited by 59.5 keV γ-rays emitted from a ^{241}Am radioisotope source. Söğüt et al. (1995) have measured an alloying effect on K_β/K_α intensity ratios in Cr_xNi_{1-x} and Cr_xAl_{1-x} alloys.

Rao et al. (1986) showed that the K_β/K_α intensity ratios depend on the excitation in 3d elements but they could not find such dependence for high-Z elements. Mukoyama et al. (2000, 2001) have calculated for the K_β/K_α X-ray intensity ratios for compounds of 3d elements with the discrete-variational Xα (DV-Xα) molecular orbital method.

In this paper, we report the measurements of K_β/K_α X-ray intensity ratios for some elements from S to U. The targets have been excited with 5.9, 59.5 and 123.6 keV photons from ^{55}Fe, ^{241}Am and ^{57}Co sources. Finally, the measured values of K_β/K_α have been compared with all available experimental data and the theoretical values.

Table 1
Notations for $K_{\alpha,\beta}$ X-ray transitions

K_α	$K_{\alpha1} = L_3$–K	
	$K_{\alpha2} = L_2$–K	
	$K_{\alpha3} = L_1$–K	
K_β	$K'_{\beta1}$	$K_{\beta1} = M_3$–K
		$K_{\beta3} = M_2$–K
		$K_{\beta5} = M_{4,5}$–K
	$K'_{\beta2}$	$K_{\beta2} = N_{2,3}$–K
		$K_{\beta4} = N_{4,5}$–K
		Transitions from higher levels

2. Experimental procedure and calculations

The experimental setup for the annular source in the direct excitation mode used in this study is shown in Fig. 1. In this work, the measurements were performed for 59 elements from sulfur to uranium. The purity of commercially obtained materials was better than 99%. Powder samples were sieved to 400 mesh size and prepared thickness ranging from 15 to 37 mg cm^{-2}. The samples were irradiated by 5.9, 59.5 and 123.6 keV photons emitted by an annular 1.85 GBq ^{55}Fe, ^{241}Am and 0.925 GBq ^{57}Co radioactive sources.

A Si(Li) detector (FWHM 160 eV at 5.9 keV, active area 13 mm^2, thickness 3 mm and Be window thickness 30 μm) was used for the K_α and K_β lines measurement. The output from the preamplifier, with pulse pile-up rejection capability, was fed to a multi-channel analyzer interfaced with a personal computer provided with suitable software for data acquisition and peak analysis. The live time was 5000 s for all elements. The samples were placed at a 45° angle with respect to the direct

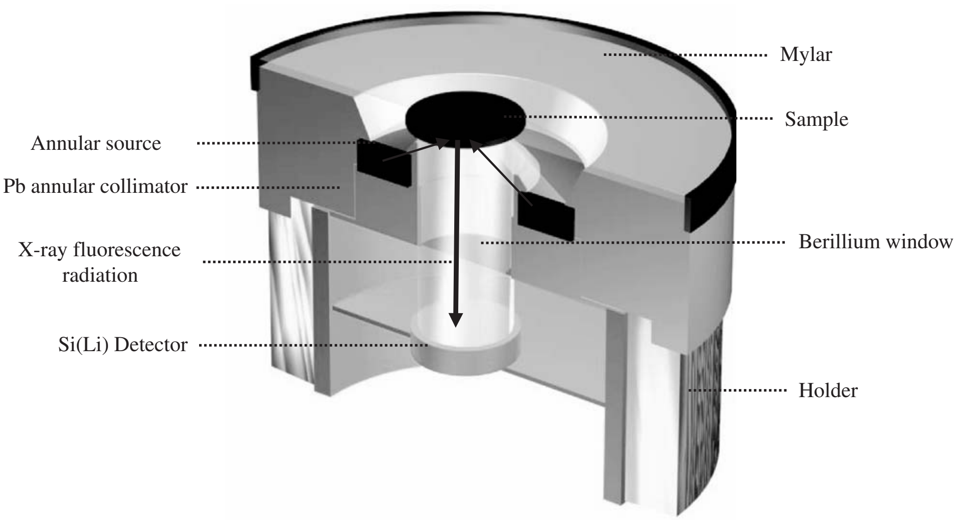

Fig. 1. Geometry of the experimental setup.