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Measurement of Relative K-shell Photoionization Cross-sections of 6-25 keV Photons in S, Ca and V

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In the present work, relative K-shell photoionization cross-sections of 6-25 keV photons in S, Ca and V are measured. Experimental results are found to agree with calculated theoretical values within the experimental uncertainties.

Key Words: Photoionization, Cross-sections.

INTRODUCTION

Present communication is an extension to our earlier measurements[1-3] of K-shell photoionization cross sections down to elements in the atomic number (Z) range 16-25 for the incident photon energies in the range of 6-25 keV. Modified double reflection geometrical set-up[4] has been used in present measurements which provides external conversion fluorescent K X-rays of ten elements in the range of Z = 26 to Z = 50, produced by the interaction of 59.57 keV gamma rays of ^{241}Am annular source. These external conversion K X-rays in the energy range of 6 to 25 keV have been used to photoionize the K shell electrons in S, Ca and V. Fluorescent K X-rays emitted each by S, Ca and V, have been counted by Si(Li) detector. Due to non-availability of low energy (2 to 5 keV) standard photon sources, it is difficult to determine the absolute efficiency of Si(Li) detector and hence relative rather than absolute measurements of photoionization cross sections have been made.

M EXPERIMENTAL

Basic principle of method of measurement used in present measurement is described by Allawadhi *et al.*[2]. Primary targets of Fe, Ni, Zn, Ge, Se, Rb, Zr, Mo, Ag and Sn in the form of circular discs of 4 cm in diameter, were irradiated with 59.57 keV gamma rays emitted from one-Curie ^{241}Am annular source in an experimental arrangement described elsewhere[4]. The radiation emitted from each one of the primary targets was allowed to fall on the secondary circular targets of S, Ca and V of diameter 4 cm each. The K-shell fluorescent X-rays emitted from the secondary targets at 90^0 were counted by a Si(Li)

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energy dispersive X-ray spectrometer procured from EGandG ORTEC USA. The metallic targets of Fe, Ni, Zn, Ge, Se, Zr, Mo, Ag and Sn were purchased from Reactor Experiments Inc. USA. The targets of Ca, V, Rb and S were made from its powders by the technique explained earlier[5]. Si(Li) X-ray detector with active diameter 10mm, sensitive depth 4.66mm of crystal and Be window of thickness 0.0254mm was coupled to ND-600 multi channel analyzer. The resolution of the X-ray spectrometer was found to be *ca.* 170 eV at 5.9 keV.

The K X-rays emitted from secondary target due to coherently and incoherently scattered gamma rays were accounted for by using an equivalent aluminum primary target[4]. The production of secondary target K X-rays by primary target L X-rays of Zr, Mo, Ag and Sn were avoided by absorbing almost complete (*ca.* 99.9%) primary target L X-ray with Al filter of suitable thickness placed between primary and secondary targets. The minimum possible thickness of Al filter was used. Due to wide range of intensities and energies[6] of individual K X-ray photons, calculations shows that weighted mean energy of incident K X-ray photons each of elements Mo, Ag and Sn, increases by very small amount of the order of few electron volts after passing through Al filter. For example, weighted mean energy of Ag K X-ray photons before and after passing through Al filter of thickness 15 mgm/cm^2 is 25.770 and 25.776 keV respectively. Calculated values of K shell photoionization cross-sections[7] in V at 25.770 and 25.776 keV are 621.36 and 620.93 barn/atom. The variation of the order of 0.07% in cross-sections has been neglected in view of experimental error, which is of the order of 5-7%.

For a set of two primary targets P and P_{ref} giving external conversion K X-rays of weighted mean energy E and E_{ref} respectively, the relative K-shell photoionization cross-sections are determined[2] by using eq. 1. The ratio $N_S(P)/N_S(P_{ref})$ was determined by measuring the ratio of the areas under the K X-ray peaks observed in the spectra of radiation emitted from secondary target on irradiation with X-rays from P and P_{ref} targets respectively. A sufficient number of runs for time varying from 10,000 to 50,000 s were taken for each combination of primary and secondary targets so as to achieve the statistical accuracy better than 1% in the counts under the photo peaks. The ratio $N_K(P_{ref})/N_K(P)$ was determined in separate experiment, which consisted of calibrated (Xe + CO_2) filled proportional counter manufactured by Reuter Stokes USA, placed at the position of secondary target. The ratios $\beta(E_{ref})/\beta(E)$ and $\varepsilon(E)/\varepsilon(E_{ref})$ were calculated in a similar way as explained earlier[2] using values of absorption coefficients obtained from standard database[8].

RESULTS AND DISCUSSION

The measured values of the relative K shell photoionization cross-sections in elements S, Ca, and V by fluorescent K X-rays of Fe, Ni, Zn, Ge, Se, Rb, Zr, Mo, Ag and Sn of weighted mean[6] energies 6.47, 7.558, 8.735, 10.005, 11.372, 13.596, 16.035, 17.781, 22.581 and 25.77 keV respectively are shown in Table 1. The overall uncertainties in the results is 5-7% which has been calculated by properly propagating errors in the various measured /computed parameters. The error, in the counts under the photo peaks, is statistical and is < 1%. The errors in the calculation of $\beta(E_{ref})/\beta(E)$ and $\varepsilon(E)/\varepsilon(E_{ref})$ from the known values of absorption coefficients is *ca.* 2% and *ca.* 3% respectively. Since no other experimental data for the set of elements and energies used in the present measurements are available, the results are compared with the calculated values[7] in Tables 1. Within the experimental uncertainties the measured values are found to be agreement with in experimental errors.

TABLE-1

PRESENT MEASUREMENTS OF THE RELATIVE K-SHELL PHOTOIONIZATION CROSS-SECTIONS IN S, Ca AND V COMPARED WITH THE CALCULATED VALUES[7]. THE WEIGHTED MEAN ENERGY[6] OF Zr K X-RAYS IS TAKEN AS REFERENCE VALUE

Energy	S		Ca		V	
	Exp.	Calc.	Expt.	Calc.	Expt.	Calc.
6.47	14.200 ± 0.850	13.86	12.150 ± 0.75	12.54	11.250 ± 0.750	11.68
7.558	8.750 ± 0.550	8.96	8.550 ± 0.550	8.28	7.600 ± 0.500	7.83
8.735	6.150 ± 0.400	5.94	5.450 ± 0.350	5.58	5.150 ± 0.350	5.34
10.005	3.900 ± 0.250	4.02	3.700 ± 0.250	3.84	3.600 ± 0.200	3.71
11.372	2.900 ± 0.180	2.76	2.750 ± 0.200	2.67	2.500 ± 0.150	2.60
13.596	1.700 ± 0.100	1.63	1.550 ± 0.100	1.61	1.650 ± 0.100	1.59
16.035	1.000 ± 0.000	1.00	1.000 ± 0.000	1.00	1.000 ± 0.000	1.00
17.781	0.755 ± 0.040	0.733	0.715 ± 0.045	0.739	0.760 ± 0.048	0.744
22.581	0.370 ± 0.020	0.354	0.380 ± 0.025	0.365	0.360 ± 0.022	0.373
25.77	0.230 ± 0.015	0.237	0.255 ± 0.020	0.246	0.235 ± 0.015	0.253

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