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Variation of CK Enhancement Factors with Energy for Deuterons Induced L subshell X-rays in Ag, Cd, In and Te

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In this paper, the enhancement produced by the Coster Kronig transitions for deuterons induced L subshell X-rays and the variation of the enhancement factors (namely k_l, k_α, k_β and $k\gamma$) with incident deuteron energy and the atomic number has been investigated in Ag, Cd, In and Te. The Coster-Kronig enhancement factors have been observed to be varying with incident proton energy as well as the atomic number. The maximum value of the enhancement factor among elements under investigation has been determined to be about 1.87 for $k_{l,\alpha}$ in Indium-49.

Key Words: Coster Kronig transitions, Deuteron induced, X-rays, Inner shell ionization.

INTRODUCTION

X-rays resulting from the primary vacancies created by various interactions contain information on the concerned process responsible for the creation of the vacancies. The interaction cross-sections and other primary information related thereto can be derived from the emitted inner shell X-rays or Auger electrons resulting from these primary vacancies only. The physical process investigated here takes place between the moment of primary ionization and that of X-ray emission. Different radiative and non-radiative transitions present concurrent channels for the atom to return to the ground state. A special case among these is that of Coster–Kronig transition (In case of L shell, namely L_1 to L_3, L_2 to L_3 and L_1 to L_2). Although, these transitions do not produce X-rays directly, they redistribute the primary vacancies between the different shells and between the different subshells of the same shell. As a consequence, they alter the absolute intensity of the line being analyzed. In nutshell, redistribution of the primary ionizations by the non-radiative transitions causes a significant enhancement in the generated intensity of the L line.

Some researchers have investigated the effect of CK transitions on the average fluorescence yields[1], X-ray production cross sections[2] for ionization by photons. Coster–Kronig enhancement factors of some elements were measured by Oz *et al.*[3, 4] using photons. Chemical effect on the enhancement of the Coster–Kronig transition of L_3 X-rays has been investigated by Sogut *et al.*[5]. It has been concluded that these non-radiative transitions alter the initial emission parameters to a considerable extent. All this work is limited to the photon induced X-ray

emission only, while the alteration brought about by the presence of CK transitions in case of L subshell X-ray emission induced by deuterons still needs to be investigated.

In this paper, we investigated for L lines, the enhancement produced by the Coster–Kronig transitions for deuterons induced L subshell X-rays and the variation of the enhancement factors (namely k_l, k_α, k_β and $k\gamma$) with incident deuteron energy and the atomic number.

Determination of the enhancement factors

The Coster-Kronig enhancement factors for L subshell X-rays induced by deuterons are given by

$$k_l = \frac{(\sigma L_1 + \sigma K\, n_{KL_1})(f_{12}f_{23} + f_{13}) + (\sigma L_2 + \sigma K\, n_{KL_2})f_{23} + (\sigma L_3 + \sigma K\, n_{KL_3})}{\sigma L_3 + \sigma K\, n_{KL_3}} \quad (1)$$

$$k_\alpha = \frac{(\sigma L_1 + \sigma K\, n_{KL_1})(f_{12}f_{23} + f_{13}) + (\sigma L_2 + \sigma K\, n_{KL_2})f_{23} + (\sigma L_3 + \sigma K\, n_{KL_3})}{\sigma L_3 + \sigma K\, n_{KL_3}} \quad (2)$$

$$k_\beta = \frac{\begin{array}{l}(\sigma L_1 + \sigma K\, n_{KL_1})w_{1F_{1\beta}} + [(\sigma L_1 + \sigma K\, n_{KL_1})f_{12} + (\sigma L_2 + \sigma K\, n_{KL_2})]w_2 F_{2\beta} + \\ [(\sigma L_1 + \sigma K\, n_{KL_1})(f_{12}f_{23} + f_{13}) + (\sigma L_2 + \sigma K\, n_{KL_2})f_{23} + (\sigma L_3 + \sigma K\, n_{KL_3})]w_3 F_{3\beta}\end{array}}{(\sigma L_1 + \sigma K\, n_{KL_1})w_{1F_{1\beta}} + (\sigma L_2 + \sigma K\, n_{KL_2})w_2 F_{2\beta} + (\sigma L_3 + \sigma K\, n_{KL_3})w_3 F_{3\beta}} \quad (3)$$

$$k_\gamma = \frac{(\sigma L_1 + \sigma K\, n_{KL_1})w_1 F_{1\gamma} + [(\sigma L_1 + \sigma K\, n_{KL_1})f_{12} + (\sigma L_2 + \sigma K\, n_{KL_2})]w_2 F_{2\gamma}}{(\sigma L_1 + \sigma K\, n_{KL_1})w_1 F_{1\gamma} + (\sigma L_2 + \sigma K\, n_{KL_2})w_2 F_{2\gamma}} \quad (4)$$

The Coster-Kronig enhancement factors for the deuterons induced L subshell X-ray emission in Ag, Cd, In and Te were determined from L sub-shell ionization cross sections (σL_i)[6], L subshell fluorescence yields (ω_i) and Coster-Kronig transition probabilities (f_{ij})[7], K to L_i subshell vacancy transfer probabilities (n_{KLi})[8] and radiative decay rates (F_{ij})[9] using the above method at incident deuteron energies ranging from 100 to 10 MeV.

RESULTS AND DISCUSSION

The results for the L subshell CK enhancement factors *i.e.* k_l, k_α, k_β and k_γ were plotted against the incident deuteron energy for the elements under investigation and the typical plots have been shown in Fig.1. From these plots, it is observed that

1. There exists a particular energy for each element under investigation, where, the CK enhancement factors decrease to a low value. The decrease at low energies has been observed to be quite sharp while the increase towards higher energy side is comparatively gradual.
2. The energy value for which the minimum occurs increases with increase in atomic number and varies from 0.75 MeV to 1.1 MeV for various X-ray groups

3. The values of the enhancement factors k_l and k_α, at all incident deuteron energies, are higher followed by k_β and k_γ.

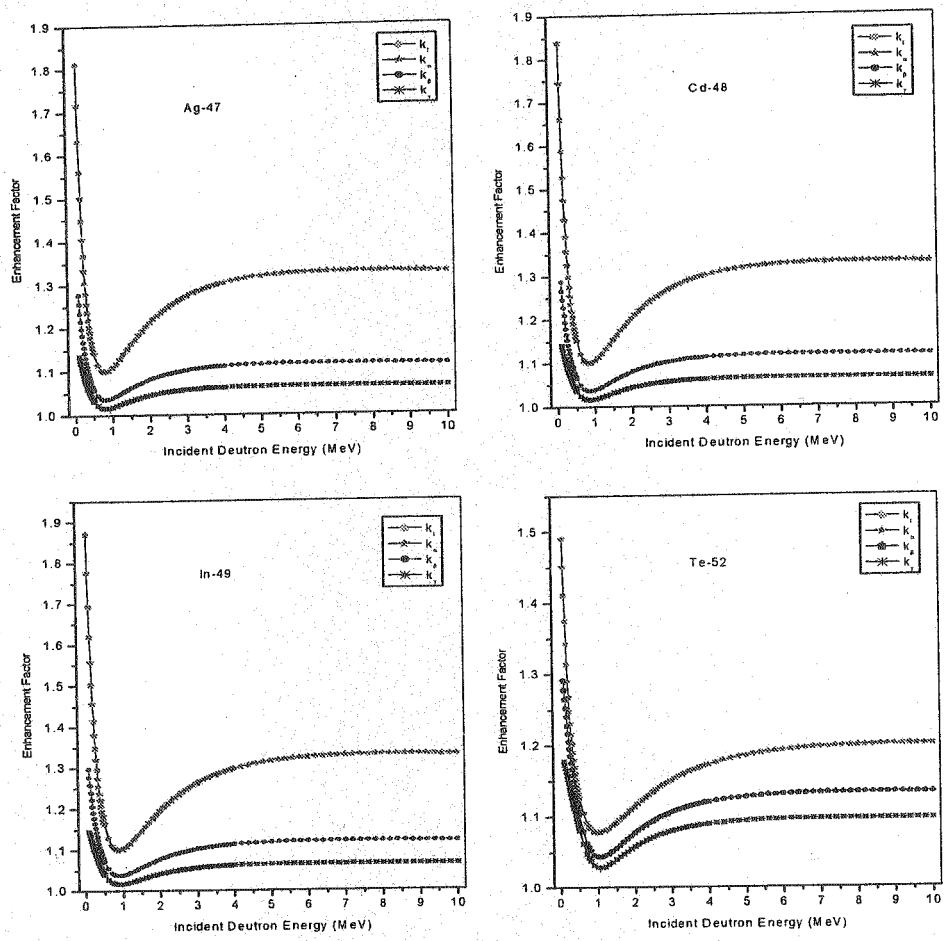

Fig 1. Variation of the L subshell CK enhancement factor with incident Deuteron Energy for Ag, Cd, In & Te

The Coster-Kronig enhancement factors have been observed to be varying with incident deuteron energy as well as the atomic number. The factor k_γ generally shows an increase with atomic number but the variation of k_l, k_α and k_β does not show a regular trend. The maximum value of the enhancement factor among elements under investigation has been observed to be about 1.87 for $k_{l,\alpha}$ in Indium-49.

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