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Energy, Charge and Z Dependence of Carbon (I.E.C+Q Where Q=1,2,3)Projectile Induced L Sub Shell X-Ray Intensity Ratios in Au, Tl, Bi, Th and U Elements

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Energy, charge and Z dependence of L shell X-ray intensity ratios in the energy range 0.9 MeV to 15 MeV has been investigated in Au, Tl, Bi, Th and U for incident carbon (i.e. C^{+q} where q=1,2,3) projectile. The intensity ratios $\frac{I_l}{I_\gamma}$, $\frac{I_\alpha}{I_\gamma}$ and $\frac{I_\beta}{I_\gamma}$ first decreases with increase in energy, attain minimum value and then start increasing. The minimum value of $\frac{I_l}{I_\gamma}$ and $\frac{I_\alpha}{I_\gamma}$ falls in the energy range (0.9MeV to 3MeV) and of $\frac{I_\beta}{I_\gamma}$ in the energy range 6MeV to 15MeV for all elements. It has also been investigated that for a particular energy and Z, values of $\frac{I_l}{I_\gamma}$, $\frac{I_\alpha}{I_\gamma}$ and $\frac{I_\beta}{I_\gamma}$ increases with decrease in value of charge (q). Similarly for particular energy and charge, values of $\frac{I_l}{I_\gamma}$, $\frac{I_\alpha}{I_\gamma}$ and $\frac{I_\beta}{I_\gamma}$ increases with increase in Z value. Also a comparison has been made among the intensity ratios evaluated using two different sets of parameters i.e. (fluorescence yield ω_i where i=1,2,3 for L_1, L_2 and L_3 sub shells and Coster Kronig transitions f_{ij} where i,j=1,2,3 for L_1, L_2 and L_3 sub shells) given by Krause et al and Campbell.

Key Words: Ion atom collision, Intensity ratio, Carbon projectile

INTRODUCTION

The determination of L x-ray intensity ratios produced by the filling of inner shell vacancies has been the subject of extensive study during the last few decades. The x-ray-emission cross-section for charged particle induced emission is approximately proportional[1] to Z^2. So, it is worthwhile to investigate energy, charge and Z dependence of carbon (i.e. C^{+q} where q=1, 2, 3) projectile induced L Sub shell X-ray intensity ratios in Au, Tl, Bi, Th and U elements

In recent past role of Coster-Kronig transitions in emission of L x-ray lines have been investigated by many workers[2,7]. It is concluded from these results that these non-radiative transitions change the initial x-rays emission parameters to a considerable extent. All these works are limited to the photon, proton and deuteron induced X-ray emission only, while the alteration brought about by the presence of CK transitions in case of L sub shell x-rays emission cross- sections induced by heavy ions, particularly carbon projectile still needs to be investigated.

In this communication energy, charge and Z dependence of L sub shell X-ray intensity ratios for incident carbon (i.e. C^{+q} where q=1,2,3) projectile in the energy range 0.9 MeV to 15 MeV has been investigated in Au, Tl, Bi, Th and U. Also a comparison has been made among the intensity ratios evaluated using two different sets of parameters i.e. (fluorescence yield ω_i where i=1,2,3 for L_1, L_2 and L_3 sub shells and Coster Kronig transitions, f_{ij} where i,j=1,2,3 for L_1, L_2 and L_3 sub shells) given by Campbell[8] and Krause et.al[9]

THEORETICAL CALCULATIONS OF INTENSITY RATIOS

The L sub shell X-ray production cross sections σL_l, σL_α, σL_β and σL_γ for carbon projectile (i.e C^{+q} q= 0,1,2,3) can be evaluated by using the following relations :

$$\sigma L_l = \left[\left(\sigma L_1 + \sigma K\, n_{KL_1}\right)\left(f_{12}f_{23} + f_{13}\right) + \left(\sigma L_2 + \sigma K\, n_{KL_2}\right)f_{23} + \left(\sigma L_3 + \sigma K\, n_{KL_3}\right)\right]w_3 F_{3l} \quad (1)$$

$$\sigma L_\alpha = \left[\left(\sigma L_1 + \sigma K\, n_{KL_1}\right)\left(f_{12}f_{23} + f_{13}\right) + \left(\sigma L_2 + \sigma K\, n_{KL_2}\right)f_{23} + \left(\sigma L_3 + \sigma K\, n_{KL_3}\right)\right]w_3 F_{3\alpha} \quad (2)$$

$$\sigma L_\beta = \left(\sigma L_1 + \sigma K\, n_{KL_1}\right)w_1 F_{1\beta} + \left[\left(\sigma L_1 + \sigma K\, n_{KL_1}\right)f_{12} + \left(\sigma L_2 + \sigma K\, n_{KL_2}\right)\right]w_2 F_{2\beta} + \left[\left(\sigma L_1 + \sigma K\, n_{KL_1}\right)\left(f_{12}f_{23} + f_{13}\right) + \left(\sigma L_2 + \sigma K\, n_{KL_2}\right)f_{23} + \left(\sigma L_3 + \sigma K\, n_{KL_3}\right)\right]w_3 F_{3\beta} \quad (3)$$

$$\sigma L_\gamma = \left(\sigma L_1 + \sigma K\, n_{KL_1}\right)w_{1F_{1\gamma}} + \left[\left(\sigma L_1 + \sigma K\, n_{KL_1}\right)f_{12} + \left(\sigma L_2 + \sigma K\, n_{KL_2}\right)\right]w_2 F_{2\gamma} \quad (4)$$

From these relations L sub shell intensity ratios can be calculated as given below:

$$\frac{I_l}{I_\gamma} = I(l,\gamma) = \frac{\sigma L_l}{\sigma L_\gamma}, \quad \frac{I_\alpha}{I_\gamma} = I(\alpha,\gamma) = \frac{\sigma L_\alpha}{\sigma L_\gamma} \quad \text{and} \quad \frac{I_\beta}{I_\gamma} = I(\beta,\gamma) = \frac{\sigma L_\beta}{\sigma L_\gamma}$$

Where σL_l , σL_α σL_β and σL_γ were given by equations (1), (2) ,(3) and (4) respectively. In above equations σL_l , σL_α , σL_β and σL_γ are L shell x-rays production cross-sections. σL_1, σL_2 and σL_3 are L sub shell ionization cross-sections and have been calculated using program developed by S Cipolla[12]. (F_{ij})[10] is the fractional radiative decay rate for the x-ray vacancy in the Li (i=1, 2, 3) sub shell, (n_{KLi})[11] is the K to Li sub shell vacancy transfer probability. The f_{ij}'s ($i \neq j$, i=1,2, j=2,3) are the Coster-Kronig transition probabilities and ω_i's (i=1,2,3) are the L sub shell fluorescence yields. Two alternative sets of fluorescence yields and CK transitions were used in present calculations. The first is widely cited review of Krause et al[9] which has been employed to interpret the great majority of work on light ion-induced x-ray cross sections. The second set is the more recent review by Campbell[8].

RESULT AND DISCUSSION

The intensity ratios have been calculated for incident carbon (i.e. C^{+q} where q=0,1,2,3) projectile at 0.9 MeV to 15 MeV. The typical plot is shown in fig. 1, it is observed that the value of intensity ratio $I(l,\gamma)$ first decreases, attain a minimum value (e.g for Au value is 0.36 and for U value is 0.54) and then starts increasing gradually. Similar trends were seen in case of $I(\alpha,\gamma)$ and $I(\beta,\gamma)$ intensity ratios also. Energy at which Intensity ratio attain minimum value increases with increase in Z value (e.g. for Au minimum value of $I(l,\gamma)$ occur at 0.9 MeV and for U minimum value of $I(l,\gamma)$ occur at 2 MeV). It was observed that the intensity ratios $I(l,\gamma)$, $I(\alpha,\gamma)$ and $I(\beta,\gamma)$,show only small variation if we change the charge of incident projectile(i.e. C^{+q} q=0,1,2, 3).

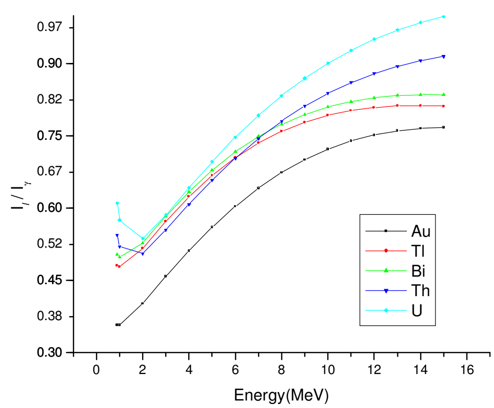

Fig.1. Variation of Intensity ratios $\frac{I_l}{I\gamma}$ with energy (MeV) for Au, Tl, Bi, Th and U for C^{+3} projectile (f's and ω's given by Campbell[8] have been used).

Percentage variation in L shell X-ray intensity ratios were also calculated using the values of CK transition probabilities and fluorescence yields given by Krause et al[8] and Campbell[9]. Typical plot is shown in fig.2. It was observed that there were irregular trends when these results were compared with one another. The maximum percentage deviation observed was around 13% for the intensity ratio $I(\beta,\gamma)$ in Uranium.

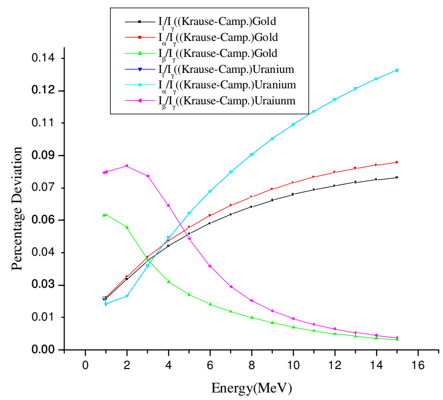

Fig.2. Percentage variation in the value Intensity ratios $\frac{I_l}{I\gamma}$, $\frac{I_\alpha}{I\gamma}$ and $\frac{I_\beta}{I\gamma}$ for Gold and Uranium with carbon(C^{+q} i.e q=0,1,2,3) projectile.

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