EFFECT OF PROCESSES INITIATED AFTER
CREATION OF PRIMARY VACANCIES
ON L AND M SHELL X-RAY EMISSION

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ABSTRACT
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ABSTRACT

The process of X-ray emission follows the various vacancy rearrangement processes within the atomic subshells initiated after the creation of primary vacancies in the inner shells. The X-rays resulting from the primary vacancies contain information on the concerned process responsible for creation of vacancy. However, it is found that in all shells above K shell, some processes faster in time alter the initial primary vacancy distribution in different subshells of a shell before these vacancies are filled either through X-ray emission or Auger process. The processes initiated after the primary vacancy creation, which result in alteration of the primary vacancy distribution in L and higher subshells, include the following.

- The Intra-shell vacancy transfer
- The Inter-shell vacancy transfer

Due to these processes, in measurements involving inner shells, the X-ray energies and intensities do not reveal true characteristics of the primary vacancies and the contribution of processes initiated after the primary interactions have to be properly taken care of.

In the work done in past, these contributions to the primary vacancies have either been eliminated/controlled experimentally or accounted for otherwise, by different workers under their typical experimental conditions only. Very little work has been done for a
detailed insight into the contribution of the vacancies initiated after the primary interaction processes leading to X-ray emission.

The preliminary investigations show that the above mentioned contributions in the primary vacancy distribution result in the change of the spectral distribution of the emitted X-ray line/group resulting in change in the values of different X-ray emission parameters.

The survey of literature shows that little work has been done to investigate the effect of vacancy rearrangement processes on X-ray emission parameters and that too is limited to photon induced L shell X-ray emission only. No systematic and detailed study of the processes initiated after creation of primary vacancies on proton, deuteron and He ion induced X-ray emission parameters for L subshell X-rays and for none of the projectiles on M subshell X-ray emission parameters has yet been undertaken to the best of our knowledge.

Keeping in view the above, the following investigations have been undertaken in the present work.

- An effort has been made to investigate the effect of intra-shell Coster-Kronig transfer among the three subshells of the L shell and that of the inter-shell transfer of K shell vacancies to the three L subshells on the L subshell X-ray production cross-sections for three incident projectiles viz. protons, deuterons and He ions in the energy range 100 keV to 10 MeV in intermediate and high Z elements. The results
indicate that, the intra-shell CK transfer of vacancies contributes towards an increase in the X-ray production cross-sections for different X-ray groups. The contribution of CK transfer is highest for L and L\(\alpha\) group of L X-rays in comparison to L\(\beta\) and L\(\gamma\) groups for all the projectiles and in all elements under investigation. Among the projectiles, the maximum contribution of the intra-shell CK process has been observed for He ion induced X-ray emission (around 53 %) followed by deuteron (around 43 %) & proton (around 27%) induced X-ray emission. In contrast with the observation for intra-shell transfer effect on XRPCS for different projectiles, the maximum inter-shell contribution to the L subshell X-ray production cross-sections is highest (at 0.25 %) in case of proton induced X-ray emission followed by deuteron (at 0.08%) and He ion (0.02 %) induced process and is found to increase with the projectile energy for all the targets under investigation. With CK transitions playing the major role, the contribution of all the secondary vacancy creating processes to the L subshell XRPCS follows the trend observed for the contribution of intra-shell transfer alone.

- The variation in L subshell X-ray intensity ratios due to Coster-Kronig and inter-shell vacancy transfer has been studied for the X-rays induced by protons, deuterons and He ions with energies ranging from 100 keV to 10 MeV in elements with 40 \(\leq\) Z \(\leq\) 92. Both the intensity ratios I(L\(\alpha\))/I(L\(\beta\)) and I(L\(\alpha\))/I(L\(\gamma\)), in general, are found to
be higher in presence of CK transition than in their absence, while
the intensity ratio $I(L_\alpha)/I(L)$ does not show any dependence of the CK
transitions. There exists a particular energy for all the elements, where, the effect of CK transitions and hence the percentage
deviation decreases to a very low value. The contribution of CK
transfer is as high as about 50 % in case of the intensity ratio
$I(L_\alpha)/I(L_\gamma)$ for He ion induced X-ray emission in $^{41}$Nb. The inter-K-to-L-
shell transfer of vacancies is not found to contribute much for the all
the L subshell X-ray intensity ratios. The contribution of this process
goes as high as up to 0.03 % in case of X-ray emission induced by
protons in $^{42}$Mo.

- The formulation to calculate the different charged particle induced M
subshell production cross-sections has been worked out and the
contribution of vacancy transfer by the M subshell Coster-Kronig
transitions has been studied for elements with $70 \leq Z \leq 90$ for proton
induced X-rays. For a comparative study among the proton induced
M subshell XRPCS based on different models, a classification of data
was made depending upon the availability of values of different
parameters based on various theoretical models. The results show
that the production cross-sections for different X-ray lines/groups
display strong projectile energy dependence in the lower energy
region i.e. up to 1-2 MeV. The production cross-sections for all the M
X-ray lines/groups have been found to decrease with increase in
atomic number of the target element. It is interesting to note that the estimated CK modification in $M_{\zeta_1}$ and $M_\alpha$ X-ray production cross-sections falls abruptly from about 44 % for $^{73}$Ta to about 32 % for $^{74}$W and other higher Z elements. This large change is perhaps due to the Cut-off of a strong $M_{4-5}N_{6,7}$ Coster-Kronig transition for the element W. A similar abrupt decrease, going up to 23 %, in the CK contribution for the $M_{2O1,4}$ group of X-rays has been observed as we move from $^{88}$Ra to $^{89}$Ac; apparently due to cut-off of $M_{1-2}N_{6,7}$ Coster-Kronig transition for Actinium and higher Z elements. In the typical case of $^{73}$Ta, the estimated CK modification in $M_{1O2,3}$, $M_{2O1,4}$, $M_\gamma$, $M_\alpha$ and $M_{\zeta_1}$ X-ray production cross-sections comes out to be 0, 10.9, 21.3, 44.3 and 44.3 % respectively for 7 MeV protons.

- The dilution in $L_3$ subshell vacancy alignment by processes initiated after primary ionization by protons has been estimated by calculating the Dilution Factors for some elements with $45 \leq Z \leq 53$. The dilution factors for $L_3$ subshell vacancy alignment caused by the shift of unaligned vacancies from lower shells/subshells show a variation both with energy and atomic number. The $L_3$ subshell alignment of vacancies has been found to be most affected by the processes initiated after primary ionization for $^{45}$Rh target ($D.F. = 0.2574$) at the incident proton energy of 5.2 MeV. The minimum dilution (0.1232) has been observed for the $^{51}$Sb target at 1.6 MeV.