O4 Key experimental M subshell line X-ray production cross sections for slow light ions on high atomic number targets compared with ECUSAR theory

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The x-ray production cross sections for dominant lines in each of the five M subshells have been measured for slow proton and helium ion impact on selected high atomic number targets from tungsten to uranium. Proton energies between 0.5 and 3 MeV and helium ion energies between 0.5 and 2 MeV were used providing M subshell cross sections for $0.3 < \xi_{Mi} < 3$, where $\xi_s = v_1/(\theta_s v_{2s})$, as defined by Brandt and Lapicki 1979, distinguishes between slow ($\xi_s < 1$) and fast ($\xi_s > 1$) collision regimes.

Ion energies and targets over these ranges cover the commonly used PIXE range for M subshell x-ray production on heavy targets across the x-ray energy range 1.3-6 keV, which has a strong overlap with key common K shell elements from Al to Fe. Hence it is important for frequently used PIXE analysis programs like GUPIX and GEOPIXE to have a consistent set of M subshell cross sections together with subshell parameters, like fluorescence yields and Coster-Kronig transition rates, which will precisely and accurately predict M shell line intensities over this low energy X-ray region of interest.

We compare our experimental x-ray production cross sections for the $M\alpha$, $M\beta$, $M\gamma$, M2-N4 and M1-O23 lines, (together with their overlaps) representing all five M subshells with the theoretical cross sections obtained from the ECUSAR theory of Lapicki 2002. We use the DHS fluorescence yields and emission rates of Puri 2007 and the Coster-Kronig rates of Chauhan and Puri 2008 to convert the theoretical ionisation cross sections to x-ray production cross sections for each resolved x-ray line. The experiment-theory comparison was done against the velocity parameter ξ_{Mi} for each of the five Mi subshells. The ratios of the experimental values to the ECUSAR theoretical values (R_i) were fitted to a 5^{th} order polynomial whose coefficients are presented for each subshell as a function of ξ_{Mi}.

We found for the ECUSAR comparisons with experiment; R_{tot}=(0.96±0.12), R_5 =(0.96±0.13), R_4 =(0.83±0.19), R_3 =(1.35±0.23), R_2 =(0.91±0.21) and R_1 =(1.03±0.56) for reduced velocities above $\xi_{Mi} > 0.7$. For $\xi_{Mi} < 0.7$, these ratios R_i increase rapidly with decreasing collision speed for each of the 5 subshells, with the experimental values being 3 to 6 times higher than the ECUSAR predictions for these slower ions on high atomic number targets.

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