

SUB-SURFACE NEUTRALIZATION OF HIGHLY-CHARGED, SLOW RECOIL IONS

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K X rays from target-recoil atoms produced in collisions with high-energy heavy-ions exhibit rich satellite structure indicating significant target multiple ionization. Recoil velocities are 10^5 - 10^6 cm/sec. For third row elements, K-shell radiative lifetimes are $\sim 10^{-15}$ sec. Combining these gives translational distances between ionization and X-ray emission of only ~ 0.1 - 1 Å. Therefore, recoiling ions do not significantly depart from their initial lattice sites before K-X-ray relaxation. L-shell vacancy distributions inferred from K-X-ray satellites ($K_{\alpha}L^n$) follow approximately binomial distributions, with average numbers of L-vacancies $\langle N \rangle$ accompanying the K-shell ionization varying for different targets, depending on the electronic environment surrounding the recoiling ion. The explanation lies in the potential for rapid refilling of the L-shell vacancies by transfer of electrons from the surrounding medium, i.e., neutralization by inter-atomic transfer which competes with radiative stabilization. K X rays provide a clock against which refilling of L-shell (and M-shell) vacancies may be studied. We have measured K X rays from chlorine and argon, excited by 2-MeV/u O^{q+} and 0.9-MeV/u Si^{q+} ion impact at the EN Tandem using the ORNL high-resolution von Hamos spectrometer. Spectra from Ar and HCl gas targets, where refilling is avoided, are compared with similar data for chlorine and argon atoms implanted in the upper surface (1500 Å) of thin nickel foils, and for chlorine compounds. From differences in the areas of the $K_{\alpha}L^n$ satellites, we derive gross L-shell refilling rates. From shifts in the peak energies, we derive M-shell vacancy distributions at the time of K-shell radiative relaxation. Spectra of $K_{\alpha}L^n$ X rays show significant differences in gas-solid comparisons for argon versus chlorine. The argon implanted in nickel spectra essentially mimic the argon gas spectra, indicating the effective insolubility of noble gases in metals. Such an effect has been observed in TEM studies of implanted metals and, recently, in K X-ray emission of neon implanted in solids. Future studies will investigate L-shell and M-shell refilling rates for Ar and Cl implanted in semiconductor (Si) and insulator (SiO_2) environments. The goal of this research is to understand the processes important in very rapid sub-surface neutralization of highly charged, low-energy atoms.