Triply Excited States in Three-Electron Ions

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Theoretical and experimental investigations of triply excited states of three-electron atoms and ions are of fundamental interest to the atomic physics of the ideal four-body Coulomb system. The symmetries of preferred excited states and their decay modes are dominated by electron-electron correlation. A wealth of experimental information about these states has come from the study of Li atoms excited by synchrotron radiation. The excitation of triply excited Li by synchrotron radiation is limited to $^2P^o$ excited resonances. Laser excited $1s^2 2p\ ^2P^o$ targets can be used to produce $^2S^e$, $^2P^e$ and $^2D^e$ states, but this method poses experimental challenges. Theoretical investigations of triply excited states include saddle-point complex-rotation, R-Matrix, Dirac-Fock, and a systematic classification of these states using the hyperspherical approach by Morishita and Lin.

The study of triply excited states of three electron ions with Z > 3 using synchrotron radiation is difficult due to insufficient fluxes of high photon energies required for the excitations. Theoretical studies of the isoelectronic sequences of such states have been done, however, by Safronova *et al.*, using the perturbative 1/Z-expansion method, and by Madsen *et al.*, and Conneely *et al.* using configuration interaction models.

Doubly and triply excited states of atoms and ions can be studied by ion-atom interactions. Early work by Rodbro *et al.* investigated optically inaccessible states of Li and Be by observing the forward emitted projectile Auger electron emission spectra from slow ion-atom/molecule collisions. These spectra are very rich, and are dominated by single excitation states, but contain doubly excited two- and three-electron states with 2sn*l* and $2s^2 nl$ configurations, respectively. Selective excitation of doubly excited two-electron states can be achieved in fast ion-atom collisions by observing the projectile Auger decay. One process that selectively excites these states is the e-ion excitation of the projectile [e.g. $F^{8+}(1s) + e^- \rightarrow F^{7+}(2p^2,{}^1D^e)$]. This process has been called resonance transfer excitation. We have studied the He-like isoelectronic sequence C^{4+}, N^{5+}, O^{6+}, and F^{7+}. Measured Auger rates were obtained using the electron scattering model and compare exceedingly well with R-Matrix theory calculations.[1] We have extended the method to the excitation of Li-like triply excited states by using well characterized metastable-ion beams. For example, we can reach hollow ionic states by the reaction $F^{7+}(1s2s,{}^3S) + e^- \rightarrow F^{6+}(2s2p^2,{}^2D^e)$.[2]

The newest method that we employed to study multiply excited states is triple electron capture in high velocity bare-ion + argon collisions. We observed triple capture to *1s2l2l'* configurations in C^{6+} + Ar collisions.[3a] At the suggestion of C. D. Lin, we looked for a favorable system for capturing to higher n-levels. We found that F^{9+} + Ar provides a favorable level matching. We observed the following: $F^{9+} + Ar \rightarrow F^{6+}(2s2p^2,{}^2S^e\ {}^2P^e\ {}^2D^e$ and $(2p)^3$, $^{2,4}P^o$ and $^{2,4}D^o$ states) + Ar^{3+}.[3b] These are ideal three electron states to test existing theories. The experiments are made possible by the use of a high efficiency, high-resolution zero-degree off-axis hemispherical spectrometer.[4] Differential cross sections, Auger energies, and Auger branching ratios are determined. The results are compared with available theoretical calculations.

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