Influence of metastable states in ionic beams colliding with atomic targets[†]

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Synopsis The role of 1s2s ^{1,3}S metastable states ion beams in collision dynamics investigations is examined. We report on the production of 1s2s(^{3}S)nl ^{2,4}L and 2s2p ^{1,3}P doubly excited states in collisions of 6-18 MeV C^{4+}(1s^2 ^{1}S, 1s2s ^{1,3}S) mixed-state beams with gas targets. Our data are accompanied with semi-classical three-electron atomic orbital coupled channel calculations (AOCC). In particular, our calculations and measurements indicate cascade feeding effects for the population of the 1s2s2p ^{4}P state need to be considered.

The use of mixed-state (1s^2 ^{1}S, 1s2s ^{1,3}S) He-like ion beams in collision dynamics investigations is examined. The 1s2s ^{1,3}S metastable beam components offer the opportunity of investigating dynamic collision processes in ionic environments having an initial K-shell vacancy [1]. Such states have been successfully used in studies of single and double electron transfer, excitation, transfer-excitation, the production of triply-excited states and superelastic scattering. Using high resolution Auger projectile spectroscopy the contributions of the 1s2s ^{3}S metastable beam component can be effectively separated. This is accomplished with a technique that exploits two independent spectrum measurements under the same collision conditions, but with ions having quite different metastable fractions [2].

Based on this method [3], we investigate the production of Li-like 1s2s(^{3}S)nl ^{2,4}L states, by direct nl transfer and transfer-excitation, as well as the production of 2s2p ^{1,3}P hollow states, by excitation processes in collisions of 6-18 MeV C^{4+}(1s^2 ^{1}S, 1s2s ^{1,3}S) with gas targets. Our experimental data are accompanied by theoretical three-electron AOCC calculations using the semi-classical close-coupling approach [4].

In particular, the Li-like 1s2s2p ^{2,4}P states offer the possibility to also investigate cascade feeding effects in single electron transfer. So far, the effect of this mechanism was related to the ratio of cross sections for the production of ^{4}P and ^{2}P states, $R_m=\sigma(1s2s2p\ ^4P)/\sigma(1s2s2p\ ^2P)$, via its departure from its spin recoupling value of 2 [5]. Previous measurements, as well as theoretical calculations including cascade feeding [6-8], have found much higher values, in disagreement with our recent experimental results of $R_m \simeq 2$.

However, recently, our AOCC calculations predict the ratio R_m to be closer to 1.2, an unexpected result implying that the population of the states are not in accord with the spin recoupling scheme results [5]. As a consequence, our experimental value of $R_m \simeq 2$ is about 60% higher than the AOCC results, allowing for considerations of additional candidate mechanisms to fill in the difference. We attribute this difference to the population enhancement of the 1s2s2p ^{4}P state afforded from higher lying quartet states through the *selective cascade* feeding mechanism [7,8]. Experimental evidence based on the observed population of 1s2s(^{3}S)nl ^{2}L states with n>2, further corroborate this argument.

References

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