Transfer-excitation in fast ion-atom collisions: A coherent treatment

E. P. Benis[1], T. J. M. Zouros[2,3], A. Laoutaris[2,3], I. Madesis[2,3], S. Nanos[1,3], S. Passalidis[4] and A. Dubois[4]

[1]*Department of Physics, University of Ioannina, GR-45110 Ioannina, Greece*
[2]*Department of Physics, University of Crete, GR-70013 Heraklion, Greece*
[3]*Tandem Accelerator Laboratory, Institute of Nuclear and Particle Physics, NCSR "Demokritos", GR-15310 Ag. Paraskevi, Greece*
[4]*Sorbonne Université, CNRS, Laboratoire de Chimie Physique-Matière et Rayonnement, F-75005 Paris, France*

A non-perturbative, multi-electron treatment of the process of transfer-excitation in energetic collisions of He-like ground state projectile ions with helium targets is presented. For the first time, all possible pathways to populate the same final doubly-excited states of the projectile, are included in a coherent treatment using a three-electron close-coupling approach [1,2]. We focus on the production of the $C^{3+}(1s2p^2\ ^2D)$ state, where our theoretical single differential cross sections (SDCS) show a distinctive two-peak structure as a function of the collision energy. Corresponding experimental SDCS for the production of the $C^{3+}(1s2p^2\ ^2D)$ state are also determined for the high-energy peak, by detecting the emitted Auger electron at $\theta=0^o$ with respect to the beam direction. Our recently proposed *in situ* "two-spectra measurement" technique [3] was applied to separate the $C^{4+}(1s^2)$ ground state contributions from the typically delivered mixed-state $C^{4+}(1s^2,\ 1s2s\ ^3S)$ ion beam.

For the high-energy peak, experiment and theory are in excellent agreement. In addition, using simplifying two-level models, we have also exposed the underlying mechanisms essentially responsible for both peaks. The high-energy peak is thus found to arise primarily from a two-centre electron-electron interaction at large impact parameters, validating our present understanding of its resonant nature known as RTE (Resonant TE). The low-energy peak, however, was not found to be due to a two-step non-resonant mechanism, but to arise mainly from a *novel one-step* mechanism, never considered before. This new mechanism - called NCTE (non-resonant correlated TE) - is mediated by a single electron-nucleus interaction responsible for projectile excitation and is correlated to an electron transfer at small impact parameters (i.e., head-on collisions), where the target and projectile electronic clouds largely overlap. Thus, NCTE is completely different from the process of NTE (non-resonant TE) traditionally thought to lead to the production of the low-energy TE peak.

The present, first fully coherent, many-body treatment [4] provides an important advance in the modelling and understanding of multi-electronic processes in quantum systems under strong and ultra-fast perturbations.

References

[1] J.W. Gao, Y. Wu, J.G. Wang, A. Dubois, and N. Sisourat, Phys. Rev. Lett. **122**, 093402 (2019).
[2] I. Madesis, A. Laoutaris, T.J.M. Zouros, E.P. Benis, J.W. Gao, and A. Dubois, Phys. Rev. Lett. **124**, 113401 (2020).
[3] E.P. Benis and T.J.M. Zouros, J. Phys. B **49**, 235202 (2016).
[4] A. Laoutaris, S. Nanos, I. Madesis, S. Passalidis, E.P. Benis, A. Dubois, T.J.M. Zouros, Phys. Rev. A, accepted for publication.