

Merged beam studies of mutual neutralization at subthermal collision energies

X. Urbain¹, N. de Ruelle^{2,3}, A. Dochain¹, T. Launoy⁴, R.F. Nascimento², M. Kaminska², M.H. Stockett², J. Loreau⁴, J. Liévin⁴, N. Vaeck⁴, R.D. Thomas², H.T. Schmidt² and H. Cederquist²

¹*Institute of Condensed Matter and Nanosciences, Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium*

²*Department of Physics, Stockholm University, Stockholm, SE-106 91, Sweden*

³*European Spallation Source ESS AB, P.O. Box 176, SE-211 00 Lund, Sweden*

⁴*Laboratoire de Chimie Quantique et Photophysique, Université Libre de Bruxelles, B-1050 Brussels, Belgium*

We have measured the total cross sections and kinetic energy distributions for the mutual neutralization of a large ensemble of atomic anions (H^- , C^- , O^- , Si^- , P^- and S^-) and cations (H^+ , He^+ , Li^+ , C^+ , N^+ , O^+ , Ne^+ , Na^+ , H_2^+ and CO^+). Cation and anions are accelerated to equal velocities in a merged beam setup, enabling measurements at collision energies as low as 5 meV. Three-dimensional momentum imaging is performed with two position sensitive detectors located several meters downstream from the few centimeter long region where the A^+ and B^- beams overlap. An unprecedented resolution in the kinetic energy release (KER) spectra allows us to identify the states of both reactants and products down to their fine structure. Knowing the angular distribution of the products in the laboratory and center-of-mass frame, allows for total, partial, and differential cross sections to be retrieved.

A recent study dealing with MN in collisions with O^- [1] has revealed the contribution of two-electron processes for N^+ as a cation. The population of core-excited configurations was qualitatively accounted for by including configuration mixing in the asymptotic treatment of electron transfer via the Firsov-Landau-Herring method [2] dealing with electron transfer to an excited state of the neutralized cation. KER spectra recorded for Na^+ and Ne^+ colliding with O^- and S^- demonstrate instead electron capture to the ground state, leaving the electron donor in an excited state (Fig. 1). Such a two-electron, two-center process is beyond the applicability of the Firsov-Landau-Herring approach, calling for new theoretical developments.

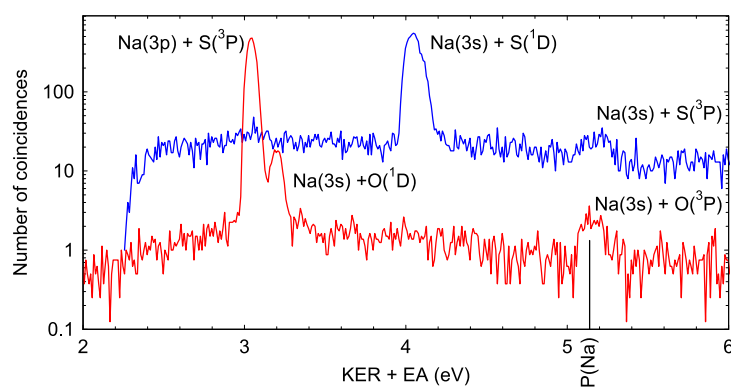


Figure 1: Raw experimental KER spectra shifted by the electron affinity (EA) of the anion. Top: $\text{Na}^+ + \text{S}^-$ reaction (blue curve). Bottom: $\text{Na}^+ + \text{O}^-$ reaction (red curve).

- [1] de Ruelle N, Dochain A, Launoy T, R. F. Nascimento RF, Kaminska M, Stockett MH, Vaeck N, Schmidt HT, Cederquist H and Urbain X 2018 *Phys. Rev. Lett.* **121** 083401
 [2] Chibisov MI and Janev RK 1988 *Phys. Rep.* **166** 1