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The "Negative Ion Cookbook" Viewed through Neutral Resonant Ionization

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The Middleton-type cesium sputter ion source (CSIS) is the foundation of negative ion sources for atomic and nuclear physics and for accelerator mass spectrometry (AMS). Middleton's "Negative Ion Cookbook" remains a reference in anion laboratories. [1] In the introduction, he admitted that "..., there are other effects that we don't presently fully understand. For example, the negative ion currents and ionization efficiencies are very dependent upon the creation of a deep sputter crater and the formation of an intense plasma ball." He argued in his final publications that anions formed in the plasma but was still unsure of the mechanism: "Presumably conditions in these plasmas are similar to the conditions in alkali-vapor charge-exchange canals. The major difference is that the charge-changing collisions in the plasma regions in sputter sources occur at energies of a few eV rather than a few keV typical in adder canals."[2] In the mid-1980's, Barbier et al. [3] showed that resonant electron transfer occurred between atoms at high rates at eV energies. This confirmed cross sections near resonance that rise as the inverse square of the energy deficit: the difference between electron affinity of the receptor and the ionization potential of a donor in an excited state.

We used a collision-radiation model of Cs plasma in mm-sized recesses to explore the creation of excited states in a neutral Cs plasma. The ionization potential of these states were compared to the pattern of electron affinities to understand the elemental anion currents found in the Cookbook and through AMS experience. The Cs state populations vary with primary Cs+ currents, but the greatest effect on these populations is with pre-drilled recess diameters. These state populations are further modified by ionization competition from the Cu sample holders and/or elements added for thermal, electrical, or chemical stability. Few of the molecular ions in the Cookbook have known electron affinities, but most elemental behaviours, even ones that puzzled Middleton, are explainable by production of or competition for the modeled excited states.

References

1. R. Middleton, University of Pennsylvania: Philadelphia Unpublished (1989).
2. R. Middleton, and J. Klein, Phys. Rev. A 60, 3786 (1999).
3. L. Barbier, M.T. Djerad, and M. Chéret, Phys. Rev. A 34, 2710 (1986).