§11. Two-Electron Transitions in Slow Collisions of Ions with Helium

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In slow collisions between an ion and an atomic target, transfer transitions of one electron from the target to the ion are very common. A simultaneous transition of a *second* electron, on the other hand, is generally rare. A notable exception is the case of double-transfer in the symmetric He^{2+} – He system.

Very recently, it was found [1] that in slow He^{2+} – He collisions, the cross section for single electron transfer is of a very similar magnitude as the cross section for *simultaneous transfer and excitation* of the two He electrons. Such unusual phenomenon has been interpreted as caused by the symmetry of this collision system. Transitions are initiated mainly by a rotational coupling between two molecular *ungerade* states, and hence the population of two final configurations is equally likely if these final configurations are the same except for an exchange between the labels "projectile" and "target". This result is of considerable interest for diagnostics purposes at fusion facilities, it is confirmed for the population of n=4 He^{+} states in a companion experimental study [2].

For the more general case of an asymmetric collision system, it is still to be expected that transfer-excitation cross sections are appreciable if the energy defect between the initial state and some given final state is favourable. In order to investigate this effect we have determined transfer-excitation cross sections in Be^{4+} – He and in C^{6+} – He collisions, along with single-capture cross sections into, respectively, the n=2-6 and the n=3-7 shells of the projectile, and single excitation cross sections. Again, there is considerable interest in such detailed cross sections for fusion plasma diagnostics.

The cross sections for one-electron transitions show qualitatively the expected behaviour [3]. The transfer-excitation cross sections from this and earlier work is displayed in figure 1, for references see our ealier discussion [5] and references cited therein. We have adopted [5] a scaled plot in which the transfer-excitation cross section is divided by the cross section $\sigma_{transfer}$ for total transfer, as suggested by work [4] on low-energy transfer-*ionization* cross sections. Surprisingly,

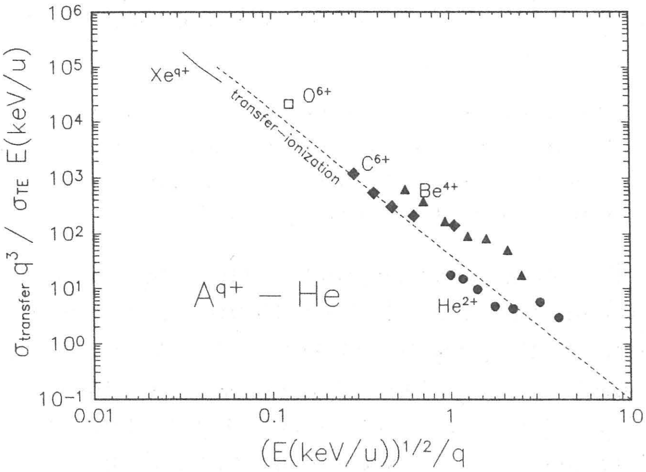

Figure 1: Plot of scaled transfer-excitation (TE) cross sections from this (He^{2+}, Be^{4+}, C^{6+}) and earlier (Xe^{q+}, O^{6+}) work, cf. text.

the scaled transfer-excitation cross sections lie close to a common curve, which in turn happens to be the curve which represents [4] a large body of experimental transfer-ionization cross sections. Deviations from a common curve are expected because of shell effects at low energies and because of missing transfer-excitation configurations at higher energies.

The calculated transfer-excitation cross sections at low energies are distinctively larger than cross sections for single excitation. This shows that a model of "independent" electron transitions would not hold for transfer-excitation, as it does not hold for double-electron transfer. Both electrons appear to move jointly in the collision, in what would appropriately be called a "correlated" transition. Unlike in collisions at higher energies, the electron-electron interaction *alone* cannot be held responsible for such correlated transition. It rather cooperates with the nucleus-electron interaction in intricate ways, to produce final two-electron configurations which, through their energies, are preferably populated.

[1] Fritsch, W., J. Phys. B 27 (1994) 3461.

[2] Folkerts, H.O., *et al.*, J. Phys. B 27 (1994) 3475.

[3] Fritsch, W., in Proc. Int. Conf. on the Physics of Highly Charged Ions, Vienna 1994, in press.

[4] Tanis, J.A. *et al.*, Nucl. Instr. Meth. B 23 (1987) 167.

[5] Fritsch, W., Phys. Lett. A 192 (1994) 369.