A.3. Electron Capture and Transfer Ionization in Ion-Atom Collisions

A.3.1. COLTRIMS Measurements of Low Energy Capture from He--*M. Abdallah, H. Wolf, W. Wolff, E. Kamber, M. Stöckli and C.L. Cocke*

The capture of electrons from multielectron neutral targets by slow-moving highly charged ions is well established to be primarily an over-barrier sequential capture process [3]. The major processes are rather well understood, and theoretical details, even including impact-parameter (or angular scattering) dependences, are well described by coupled channel calculations for up to two electron transfer and modestly charged projectiles (less than about 6+). For larger numbers of active electrons and for higher projectile charges the number of states which must be included in the basis set becomes so large that coupled channel treatments become impractical and model descriptions remain necessary. Such questions as the role of transfer excitation in capture are also very poorly understood and are only crudely described within the context of any model calculation.

When applied to the capture of electrons from neutral targets by slow-moving highly charged ions, COLTRIMS allows the simultaneous measurement of the final state populated and the transverse momentum transferred to the projectile. The latter can be interpreted in terms of an impact parameter for the collision in simple cases, or can be used to deduce the trajectory, which the collision has followed in "molecular orbital space" in more complex ones. The technique also allows us to examine the capture over a much larger range of projectile velocity than is possible with older translational energy spectroscopic and angular scattering techniques.

We have applied COLTRIMS to the study of the capture of one and two electrons from He by Ar^{8+} and Ar^{16+}. Although this work was reported in our last progress report, the publications appear on the present progress report. The major findings were:

1. Contrary to expectations based on simple (Landau-Zener, LZ) models, the major effect of raising the projectile velocity is to spread, rather than shift, the reaction window. The higher density of states for larger n of the final electron leads to heavier population of LOWER Q value channels, just the opposite of what the LZ model predicts.

2. For single capture by Ar^{8+} both the angular distributions and Q values are well accounted for by coupled channel calculations.

3. For single and double capture by Ar^{16+}, coupled channel calculations are not practical, but both the Q value spectrum and the angular distributions are in general agreement with the

predictions of the Niehaus [3] model. The spreading of the Q window with increasing projectile velocity is found to follow the expectations of a general but previously untested model based on the uncertainty principle. These results are reported in Publications #36 and 46.

During the last two years, we have carried out COLTRIMS measurements on single capture from He by C^{5+} and Ar^{6+} projectiles over a substantial range of projectile velocities. For C^{5+} on He, the translational energy spectra for single-electron capture show that capture into the C^{4+} n=3 state is the dominant reaction channel observed over the entire collision energy region studied, in agreement with close-coupling calculations. Transfer excitation processes contribute only very weakly to the total cross sections for single-electron capture ~2–4%. Figure 1 shows the Q value spectrum for several values of transverse momentum transfer for which the close-coupling prediction of Fritch and Lin [4] predicted the TE contribution to be appreciable, comparable in total cross section to double capture. The measured TE contribution is considerably smaller than predicted. This is a remarkable failure of the calculation, since the same calculation has done an excellent job in the past at predicting all other characteristics of this type of collisions sytem, even including the transverse momentum dependences. In addition to the TE result, we also measured the double capture channel. The autoionizing double-electron-capture transfer ionization spectrum clearly shows that C^{3+} (*2l*, *2l´*) states are populated at the lowest impact energy, whereas contributions from capture into C^{3+} (*2l*, n*l*) states with n>3 increase as the impact energy is increased and become the dominant process at higher velocity. Apart from the TE results, the experimental results are in rather good agreement with close-coupling and multichannel Landau-Zener calculations. This work is described in Publications #71 and 84.

A similar study of Ar^{6+} on He has revealed a strong contribution of TE to the reaction. The general reason for this result is that the reaction window includes no natural single electron capture states for this case, and thus the system is forced to seek core excited states within the favored Q (or R) window. Theoretical analysis on this system is being performed by J.P. Hansen (U. Bergen).

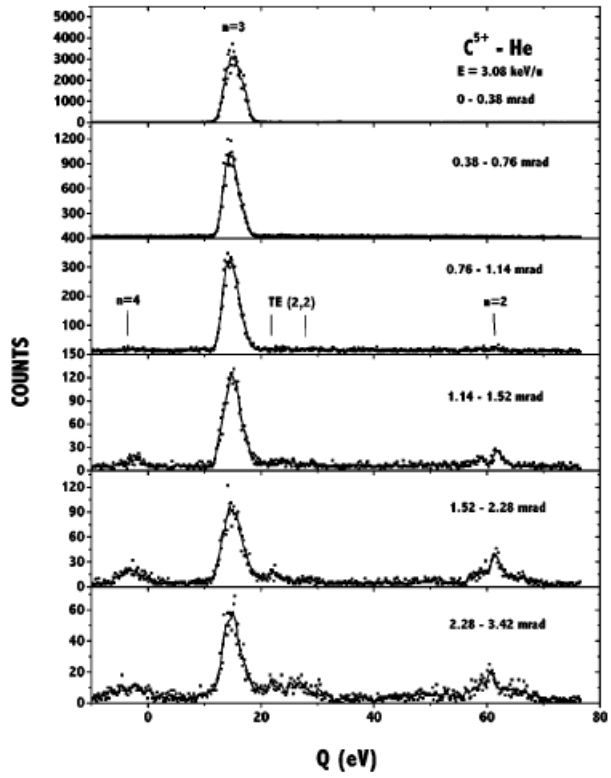

Figure 1. Translational energy-gain spectra for single-electron capture by C^{5+} ions from He at an impact energy of 3.08 keV/u and different projectile laboratory scattering angles. This figure is from Publication #84.