State-Selective Electron Capture Studied for U^{90+} Ions in Collisions with Gaseous Targets

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In relativistic collisions involving high-Z projectiles and heavy target atoms, non-radiative electron capture (NRC) is a very important charge exchange process [1], a process mediated by three-body interaction. In general, a precise theoretical treatment of this process is very difficult to achieve since the Coulomb field of the fast moving projectile leads to distortions of the atomic target wave functions even at infinite distances. For high-Z ions and relativistic energies the experimental information about NRC is restricted to total cross sections which are quite insensitive to the details of this process. An experiment aiming at a study of state-selective electron capture was conducted at the gas-jet area of the ESR, by utilizing the spectroscopy of projectile x-ray transitions following electron capture into excited projectile states. This method benefits in particular from the large fine structure splitting present in such heavy ion systems. In the experiment, the Balmer radiation produced by electron capture in collisions of 223 MeV/u U^{90+} ions on N_2, Ar, Kr, and Xe targets have been measured in coincidence with the down-charged uranium ions (here *Balmer* transition refers to the transitions from higher levels to n=2 states). The recorded x-ray spectra are shown in figure 1. As the target varies from light to heavy atoms, the relative intensities of the *Balmer* lines exhibit a significant change. This feature already indicates a strong influence of the target charge on the relative population of the various (n, l, j) projectile sublevels by electron capture.

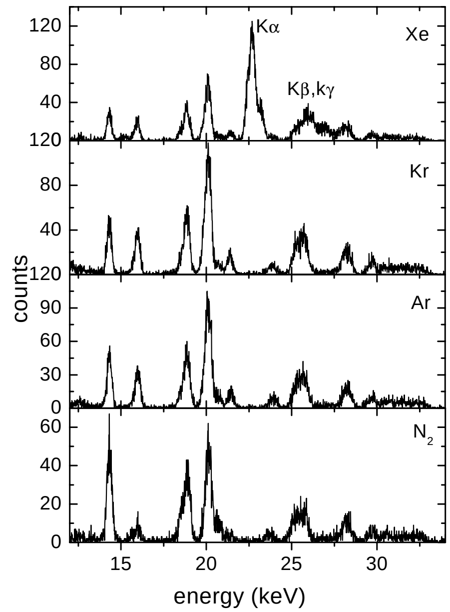

Figure 1: *Balmer* spectra measured in 223 MeV/u U^{90+} impinging on N_2, Ar, Kr, and Xe targets. For the case of Xe, also characteristic target transitions (Kα,Kβ,Kγ) are observed.

The intensity pattern of the multitude of well-resolved *Balmer* transitions was used to obtain the j-selective cross section data as a function of target Z_T. For this goal a spectrum analysis and simulation code has been developed where electron cascades originating from states up to n=40 are considered. The latter was accomplished by using the individual decay rates and transition energies of all states involved. In the spectra simulation, both the NRC and the radiative electron capture (REC) were taken into account. The CDW theory was used to calculate the NRC cross sections. To obtain experimental information on the j-sensitive population for electron capture, a fit to the measured spectra was carried out by setting the relative cross sections as fitting parameters. From this procedure, the information on relative populations to the different j-sublevels has been deduced [2]. For N_2, where the cross sections for REC are a factor of 10 larger than for NRC, good agreement with theory is obtained. Here, the captured electrons mainly populate the s and p states where the $s_{1/2}$ levels are more favored which is in agreement with REC theory and the j-substate distribution behaves non-statistically. For the heavier targets (Ar, Kr, and Xe), NRC is the most important capture process. This process leads to a n, l, j-distribution which differs markedly from the one observed in the case of the N_2-target (REC). Here, our data analysis shows that NRC seems to favor the population of states with angular momentum l=1 which appears to be only in rough agreement with the CDW approach applied. The discrepancies between our data and the latter approach are in particular evident with respect to the j-dependency. For CDW a statistical j-distribution had to be assumed since we are dealing with a non-relativistic theory. For the case of high-Z projectiles, however, this assumption is questionable (see e.g Ichihara[3]). The systematic deviations between the experimental data and the theoretical calculations for the j-subshell cross sections indicate that a relativistic approach is needed for an appropriate description of NRC in the high-Z domain.

References

[1] J. Eichler and W. E. Meyerhof, Relativistic Atomic Collisions (Academic press, San Diego, 1995).

[2] X. Ma et al., Physica Scripta (in print).

[3] A. Ichihara, T. Shirai, and J. Eichler, At. Data and Nucl. Data Tab. 55 63 (1993).