INNER SHELL IONIZATION WITH HIGH VELOCITY POSITIVE IONS

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Although the past few years have seen a tremendous growth in the study of inner-shell ionization phenomena there has been relatively little work done with high velocity heavy particles. A primary reason for this was the belief that in this domain the Plane-Wave-Born Approximation (PWBA) would give an adequate description of the data so that no useful information would result. Recently however, Reading and his collaborators have published a series of papers[1] calling this assumption into question. These papers suggest that a test of their new theories would come from a study of the ratio of alpha particle and deuteron induced ionization at equal projectile velocities. In order to test these predictions we have begun a study of inner shell ionization with these projectiles.

Self-supporting targets of Cr, Mn, Fe, Ni, Cu, Zn, Mo, Ag, Sn, Ta, Pt, and Au, all approximately 1 mg/cm^2 thickness were bombarded with 66 MeV deuterons and 132 MeV α - particles in the low intensity cave of the Indiana University Cyclotron. Characteristic K- and L- shell x-rays were detected, at 90° to the beam direction, with a Ke-Vex Si(Li) x-ray detector. The data were stored on magnetic tape and analyzed at Ohio State, using Gaussian peak-fitting routines to extract K_α and K_β yields, as well as L-subshell yields for the heavier elements. The specific method for obtaining cross sections from the x-ray yields has been described before.[2]

The total K and L shell cross sections were considerably larger than available theoretical estimates used to design the experiments. Hence, the counting rate was much higher than anticipated, necessitating the use of very low beam currents (≃ 100 pa) to obtain low count rates and high resolution. This makes the charge integration very suspect and hence only ratios of values can be taken with any assurance. We have still been able to extract significant new information from the data. Studies are currently underway to overcome this integration problem.

The data has already provided several new results. For the heavy elements, Ta, Au, and Pt, one can obtain individual L subshell cross sections. One can then form the ratio $4\,\sigma^{d}_{Lj}/\sigma^{\alpha}_{Lj}$. If one forces this ratio to be one for the L_1 subshell (the PWBA value) the effects of beam integration are removed. Having done this, we find that the ratios for L_2 and L_3 show significant (≃ 10%) departures from the PWBA predictions, which are yet unexplained. Reading's theory[1] is, unfortunately, not yet formulated for the L-shell.

Another interesting area of study is the $K\alpha/K\beta$ ratios for various targets. Within the statistics of the experiment (usually < 2%) we find the $K\alpha/K\beta$ ratios to be the same for alpha and deuteron induced ionization but to show a significant systematic departure from ratios measured by electron and photon induced ionization, as well as theoretical calculations.[4] In particular the heavy particle induced ratios are much higher in the vicinity of $Z = 24$-30 and gradually go over to the photon results near $Z = 46$-50. This suggests that a process like multiple ionization is affecting the heavy particle results in the lighter atoms.

In the future we hope to improve the charge integration, to be able to directly compare alpha and deuteron results at the same velocity, and to measure more elements in the $Z = 30$ to 40 region to study the systematics of the $K\alpha/K\beta$ results.

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1) J.F. Reading and E. Fitchard, Phys. Rev. A10, No. 8 (1974).

2) C.N. Chang, J.F. Morgan, S.L. Blatt, Phys. Rev. A11, 607 (1975).

3) G.D. Nelson, B.G. Saunders, and S.J. Salem, Atomic Data Tables 1, 377 (1970).

4) J.H. Scofield, Phys. Rev. 179 9 (1969).