BNL--32343

DE83 005799

SIMULTANEOUS ELECTRON CAPTURE AND EXCITATION IN ION-ATOM COLLISIONS

BNL-32343
Conf-821123--33

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Summary

A review of recent efforts to observe simultaneous electron capture-and-K-shell excitation in ion-atom collisions is presented. This process which has been referred to as resonant-transfer-and-excitation (RTE), is qualitatively analogous to dielectronic recombination (inverse Auger transition) in free-electron-ion collisions, and, hence, is expected to be resonant. Experimentally, events having the correct signature for simultaneous capture-and-excitation are isolated by detecting projectile K x rays in coincidence with ions which capture a single electron. In a recent experiment involving 70-160 MeV S^{13+} ions incident on Ar, a maximum was observed in the yield of projectile K x rays associated with electron capture. This maximum is attributed to simultaneous capture-and excitation. The position (120 MeV) and width (60 MeV) of the observed maximum are in good agreement with theoretical calculations. The data indicate that RTE is an important mechanism for inner-shell vacancy production in the energy range studied.

Introduction

In MeV/amu heavy ion-atom collisions several fundamental inner-shell processes such as excitation, ionization, and charge transfer occur. To date, most inner-shell atomic collision experiments have been limited to measurements of total cross sections which include an unknown mixture of contributions from these various mechanisms. In order to probe individual inner-shell processes in the interaction of a highly charged ion with a neutral target atom under single collision conditions, it is necessary to associate particular inner-shell transitions with specific projectile charge-changing events. Experimentally, such information can be obtained by measuring coincidences between x rays (emitted from either the projectile or target) and the outgoing projectile charge state of interest.

A mechanism of particular interest is that of electron capture accompanied by simultaneous K-shell excitation of a projectile. In recent experiments[1-3], this process has been recognized as a possible contributor to K vacancy production in ion-atom collisions and may account for as much as 25% of the total K vacancies for lithium-like projectiles in the velocity range studied. Simultaneous capture-and-excitation, which is due to the Coulomb interaction of the projectile with the target electrons, is qualitatively analogous to an inverse Auger transition and is expected to be resonant for projectile velocities corresponding to the energy of an exiting electron in the Auger process. Since the captured electron is initially bound in the target, the width of the resonance should be reflective of the distribution of electron momenta in the target, i.e., the Compton profile of the target electrons. The simultaneous electron-capture-and-excitation process has recently been referred to as resonant-transfer-and-excitation (RTE).[4]

In the case of free-electron recombination, dielectronic recombination occurs when a highly stripped ion captures a continuum electron and simultaneously excites an electron from the ground-state configuration of the ion. Dielectronic recombination is the dominant recombination mechanism in high temperature fusion plasmas for ions with three or more bound electrons.[5] Although dielectronic recombination has been identified in plasmas, cross sections for this process have not been successfully measured in laboratory experiments.[?]

In the case of RTE in an ion-atom collision, the captured electron is supplied by the neutral target atom. The signature for either dielectronic recombination or RTE is the emission of a K x ray in coincidence with a single capture event. Absolute cross sections may be obtained by measuring these coincidences. For a free electron incident on a highly stripped ion, the resonant width is very narrow (< 1 eV). However, for ion-atom collisions, calculations by Brandt,[6] which include the effect of the Compton profile of the target electrons, indicate that the width of the resonance is sufficiently wide (tens of MeV) so as to be easily observable.

A process which can compete with RTE is one-electron capture following excitation (by the target nucleus or target electrons) in the same collision with one target atom. Since RTE is a resonant process, observation of resonant behavior in the x-ray yield associated with capture would identify the mechanism and distinguish it from competing channels.

Three reported investigations of RTE involving the coincidence technique have been performed to date. These works are described in Refs. 1-3.

In another type of experiment, the group at Kansas State has recently tried to observe the RTE process using a high resolution Bragg crystal spectrometer.[7] In this work, a search was made for x-ray transitions associated with the formation of specific intermediate RTE states for F^{6+} ions incident on several target gases. No definite conclusion concerning RTE was obtained from these measurements.

In Ref. 1, 70 MeV S^{q+} ions (q=13-16) were incident on an argon gas target. While coincidence events were observed, the data obained was not sufficient to identify the mechanism involved.

In the experiment of Ref. 2, 160 and 180 MeV Ar^{q+} (q=14, 15 and 17) were incident on Xe. Cross sections for the various projectile processes which were measured are shown in Fig. 1 for 180 MeV Ar^{q+} ions. It should be noted that the relatively large cross section for projectile K x rays associated with single electron capture σ_x^{q-1} for Ar^{17+} (hydrogenlike) ions