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RESONANCE INTERFERENCE AND ABSOLUTE CROSS SECTIONS IN NEAR-THRESHOLD ELECTRON-IMPACT EXCITATION OF MULTICHARGED IONS

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Strong resonance features were observed in near-threshold excitation of $^1S \rightarrow {}^3P$ intercombination transitions in Si^{2+}, Ar^{6+}, and Kr^{6+}. Such resonances are predicted to dominate over direct excitation by more than an order of magnitude in the threshold region. Absolute cross sections were measured by using the merged electron-ion beams energy loss technique. The results are compared with R-matrix close-coupling (CCR) theory for all of the ions. Several discrepancies in resonance positions and magnitudes exist between experiment and theory for these spin-forbidden transitions.

Cross sections for electron-impact excitation of ions can be dominated by dielectronic resonances, particularly for forbidden transitions. Interference between nearby resonances through direct configuration interaction (CI) and through indirect interactions with a common continuum has been shown [1] to have a strong effect on the resonant contributions to the cross sections as calculated in the close-coupling formulation. In addition, it was found [1] that the resonance structure is sensitive to the exact positions of the individual resonances. Experiments can provide important benchmarks for these predictions.

The JILA/ORNL merged electron-ion beams energy-loss (MEIBEL) technique [2] employs trochoidal analyzers with crossed magnetic and electric fields to merge and demerge an electron beam with ion beams extracted from an electron-cyclotron resonance (ECR) source. The demerger acts as an energy analyzer, separating inelastically scattered electrons from unscattered or elastically scattered electrons. The unscattered primary electrons and those elastically scattered at small angles are collected in a Faraday cup since they are deflected less than inelastically scattered electrons that are deflected onto a position sensitive detector (PSD). Electrons elastically scattered through large enough angles to reach the PSD are blocked by a series of apertures at the

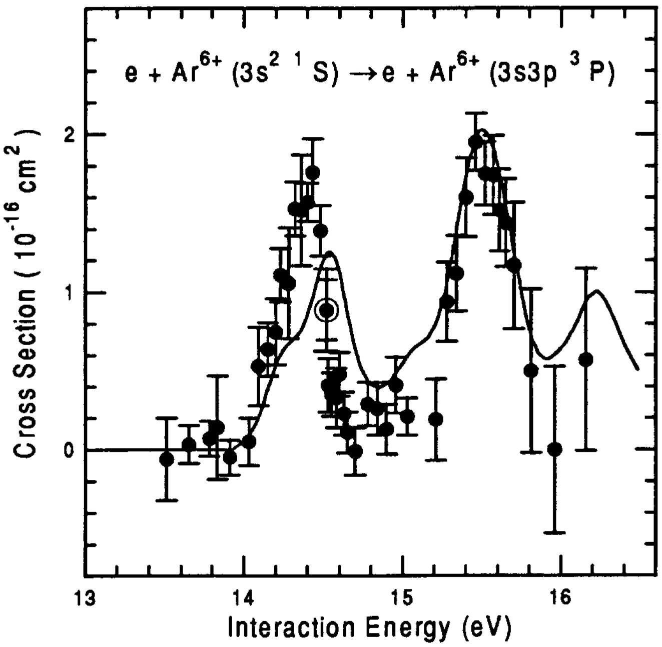

Figure 1: Excitation cross sections for Ar^{6+}. The error bars are relative uncertainties at a 90% confidence level. The bars on the point at 14.52 eV shown as an open circle represent the expanded combined absolute uncertainty. The solid curve is a convolution of a Gaussian (0.24 eV FWHM) with CCR theory from Ref. 6.

entrance of the demerger. By measuring the beam overlaps at several points along the merge path using a two-dimensional video beam probe,[3] the cross sections are put on an absolute scale. The measured cross sections at higher interaction energies may be corrected for backscattering losses by using a three-dimensional trajectory modeling program.[4]

Experimental excitation cross sections[5] for the $3s^2\ {}^1S \rightarrow 3s3p\ {}^3P$ transition in Ar^{6+} are shown in Fig. 1 along with results of CCR calculations[6] (solid line) convoluted with a Gaussian of 0.24 eV FWHM representing the experimental energy resolution. The energy resolution and contact potential of the electron gun were determined using cross sections measured for the optically-allowed $3s^2\ {}^1S \rightarrow 3s3p\ {}^1P$ transition in Ar^{6+}. The calculation agrees very well with the experiment for the resonance feature near 15.5 eV. The agreement for the peak near 14.4 eV is not good, indicating that the theory has diffi-

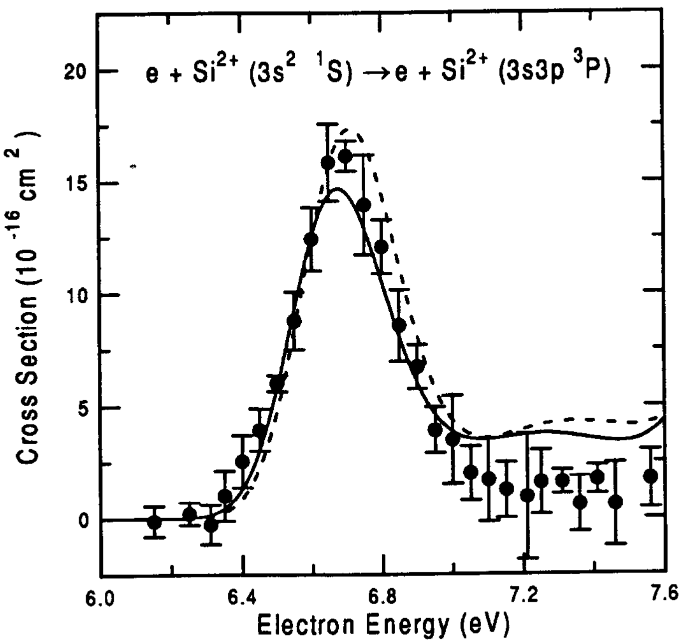

Figure 2: Excitation cross sections for Si^{2+}. The error bars are relative uncertainties at a 90% confidence level. The curves are convolutions of a Gaussian (0.24 eV FWHM) with CCR calculations from Ref. 6 (solid) and Ref. 10 (dashed).

culty calculating the precise energies of the contributing resonances and their interference. A similar situation exists for experimental cross sections[7] for the $4s^2$ $^1S \rightarrow 4s4p$ ^3P transition in Kr^{6+}. Guided by the measurements, Gorczyca et al.[8] refined their R-matrix calculations on Kr^{6+} by including a Breit-Pauli Hamiltonian to achieve fairly good agreement, although there remains a noticeable discrepancy for one of the two measured resonance features.

Experimental excitation cross sections[9] for the $3s^2$ $^1S \rightarrow 3s3p$ ^3P transition in Si^{2+} are also dominated by a dielectronic resonance, with a measured cross section of about 16×10^{-16} cm^2 just above threshold, in excellent agreement with two separate CCR calculations[6,10] as shown in Fig. 2. Ion energy limitations prevented measurements beyond 7.6 eV in the range of a second predicted[6,10] resonance peak. Measured cross sections for the optically-allowed $3s^2$ $^1S \rightarrow 3s3p$ ^1P transition in Si^{2+} are in fair agreement with the CCR calculations, with the experimental data showing a sharper drop from the peak cross section, perhaps due to a resonance just above threshold not predicted by theory.

The MEIBEL technique is a powerful tool[11] for investigating near-threshold electron-impact excitation of ions, particularly for forbidden transitions which are commonly dominated by dielectronic resonances. The present experimental cross sections serve as crucial benchmarks for the close-coupling R-matrix theory and indicate that some refinements are required for the calculations to accurately reproduce the resonance positions and cross section contributions.

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