Coherent Excitation of Autoionizing Resonances

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DOE Patent Clearance Granted

11-27-02
Date

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An electron-electron coincidence [or $(e, 2e)$] technique was used to investigate atomic ionization by electron impact in the neighborhood of autoionizing resonances. Differing binary (I^+) and recoil (I^-) lobe intensities in coplanar $(e, 2e)$ ejected-electron angular distributions were analyzed in terms of interference cross-terms, between opposite parity final-state continua, that change sign when $\theta_{ej} \rightarrow \theta_{ej} + 180^\circ$ in the angular distributions. The magnitude of these cross-terms varies rapidly with ejected-electron energy across overlapping autoionizing resonances. The energy variation in the interference terms may be examined by obtaining the sum ($I^+ + I^-$) and difference ($I^+ - I^-$) of $(e, 2e)$ energy spectra measured at ejected-electron angles 180° apart.

Cadmium $(e, 2e)$ interference experiments

Comprehensive sets of cadmium $(e, 2e)$ measurements and their analysis were completed at up to eight scattering angles between 2° and 18° , corresponding to values of momentum transfer 0.2 to 1 a.u.. The sum and difference spectra have been compared with calculations that included $J = 0 \rightarrow 7$ partial waves with phases for $J = 0, 2$ shifted by the amounts found for the small angle experiments. The shape of the calculated sum and difference spectra then agrees well with the experimental results for all scattering angles; the magnitudes of the calculated difference spectra (normalized to the sum spectra) differ considerably from the experiments [1-3].

Exchange effects in Cd $(e, 2e)$ energy spectra

As the scattering angle was increased from 2° to 15° the relative peak intensities of the 3P_1 and 1P_1 $4d^9 5s^2 5p$ autoionizing resonances in the Cd $(e, 2e)$ sum spectra changed by a factor of three. This is due to electron-impact exchange processes and has been explained in terms of a semi-empirical model which seeks to parameterize all the data in terms of a single constant [4].

Cd $J = 3$ autoionizing levels

A by-product of the $(e, 2e)$ experiments was the observation at $\theta_{sc} = 18^\circ$ of previously undetected $4d^9 5s^2 5p$ $J = 3$ levels. The parity favored/unfavored nature of the autoionizing process for these levels resulted in striking intensity variations within the momentum-transfer and P_3 spectra [5].

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Cd photoelectron experiments

In a collaboration with researches from ORNL and UCF, electric dipole-quadrupole interference effects in cadmium photoelectron spectra were measured [6]. As well as being of interest in their own right, these experiments are the direct photon analogue of the $(e, 2e)$ experiments and provide valuable information for the analysis of the $(e, 2e)$ experiments. The experiments represent the first observation of interference between dipole and quadrupole amplitudes for the photoexcitation of autoionizing levels of different parity. Furthermore, for the cadmium target used, these levels correspond to extremely low photon energies (< 15 eV) for which the non-dipole effect is a fraction of 1% of the dominant dipole amplitude. Such tiny effects may be detected because of the rapid variation of the interference amplitude σ_{12} as the photon energy is swept through an autoionizing resonance. Thus the experiment and the data analysis closely follow the techniques used in the $(e, 2e)$ experiments. The photoelectron experiment detected the dipole-quadrupole interference between $4d^9 5s^2 5p$ $J = 1$ and $5p6p$ 3P_2 autoionizing resonance.

Selected Publications

- [1] N.L.S. Martin, D.B. Thompson, R.P. Bauman and M. Wilson, "Determination of Complex Ionization Amplitudes by $(e, 2e)$ Spectroscopy", *Phys.Rev.Lett* **72**, 2163 (1994).
- [2] N.L.S. Martin, D.B. Thompson, R.P. Bauman, M. Wilson, "Investigation of Complex Ionization Amplitudes in Cadmium by $(e, 2e)$ Phys. Rev. A **50**, 3878 (1994).
- [3] N.L.S. Martin, R.P. Bauman, M. Wilson, "An $(e, 2e)$ study of cadmium ionization in the $4d^9 5s^2 5p$ autoionizing region", *Phys. Rev. A.* **59**, 2764 (1999).
- [4] N.L.S. Martin, R.P. Bauman, M. Wilson, "The Observation of exchange scattering effects in cadmium $(e, 2e)$ energy spectra", *Phys. Rev. A.* **57**, 1827 (1998).
- [5] N.L.S. Martin, R.P. Bauman, M. Wilson, "The observation of Cd $4d^9 5s^2 5p$ $J = 3$ autoionizing levels in $(e, 2e)$ energy spectra", *Phys. Rev. A.* **57**, 4346 (1998).
- [6] N.L.S. Martin, D.B. Thompson, R.P. Bauman, C.D. Caldwell, M.O. Krause, S.P. Frigo, and M. Wilson, "Electric Dipole-Quadrupole Interference of Overlapping Autoionizing Levels in Photoelectron Energy Spectra", *Phys. Rev. Lett.* **81**, 1199 (1998).