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COHERENT EXCITATION OF AUTOIONIZING RESONANCES BY ELECTRON IMPACT

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Coherent Excitation of Autoionizing Resonances

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Experimental investigations are being carried out into interference effects, in the Group II B transition metal atoms Zn, Cd, and Hg, caused by the coherent excitation, by electron impact, of autoionizing levels of differing total angular momentum and parity. The work will provide information on both the excitation mechanism by charged particle impact and the spectroscopy of autoionizing levels.

The experimental technique being used is electron-electron coincidence spectrometry. Differing binary and recoil peak intensities in coplanar $(e, 2e)$ ejected-electron angular distributions are caused by interference cross-terms, between opposite parity levels, that change sign when $\theta_{ej} \rightarrow \theta_{ej} + \pi$ 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 isolated by subtracting an $(e, 2e)$ spectrum taken in the recoil peak from one taken in the binary peak.

The results of initial experiments in cadmium,[1,2] at small scattering angles (*i.e.* in the plane wave Born approximation (PWBA) limit), are in quite good agreement with a model calculation that assumes that the important levels are the (well known) odd parity Cd $4d^9 5s^2 5p$ $J = 1$ and the (previously undetected) even parity Cd $5pnp$ $J = 0, 2$ $(n = 5, 6, 7)$. In order to obtain respectable coincidence count rates, the energy resolution (0.15 eV) in these experiments was insufficient to resolve details of the resonant structure predicted by the calculation to occur in the interference spectrum. It was therefore not possible to verify the ***ab initio*** calculated positions of the $5pnp$ levels that had been used in the model.

This year we have therefore concentrated on a major experimental upgrade to improve both the energy resolution and the effective coincidence count rate. The work falls naturally into two parts: optimization of the existing apparatus, and the installation of a resistive anode (RA) based position sensitive detector (PSD) on the ejected-electron channel.

Improvements in the apparatus have resulted in an energy resolution of 0.05 eV with the same coincidence count rate obtained with the previous resolution of 0.15 eV. Figure 1 shows binary and recoil spectra with the improved energy resolution (unpublished). Note the sharp feature at ~4.2 eV in the recoil peak; in Ref(2), Fig (4), this was imperfectly resolved and appeared as a shoulder on the main peak.

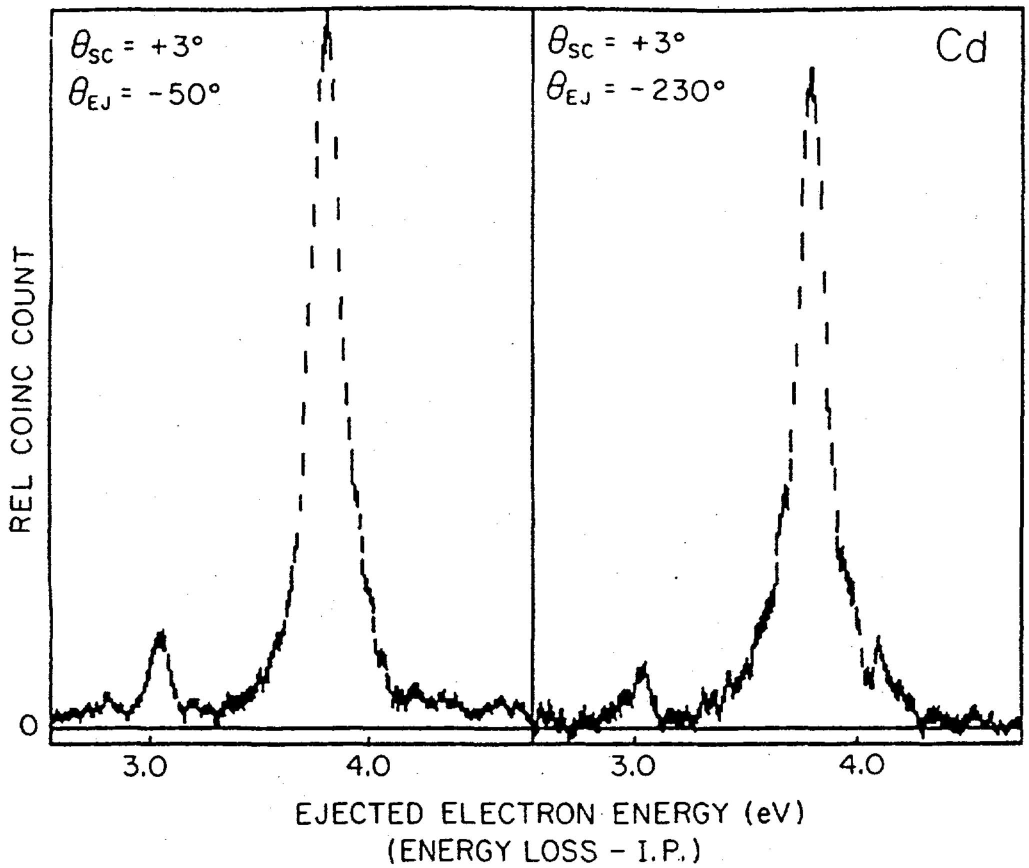

Figure 1. Cd coincidence spectra for $\theta_{ej} = -50°$ (binary peak) and $-230°$ (recoil peak), with $\theta_{sc} = +3°$, 150 eV incident energy. The resolution (FWHM) is 0.05 eV. The data have been three point averaged.

At the time of writing, the PSD system has been installed and initial tests are being carried out. Both non-coincident and coincident ejected-electron spectra are taken simultaneously; the former may be used for energy alignment of the binary and recoil $(e, 2e)$ spectra. Figure 2 shows an example of a non-coincident ejected-electron spectrum with energy resolution 0.05 eV. The spectrum was taken by ramping the PSD energy window (0.28 eV) through the energy range of interest (2 eV); thus each data point is the sum of data taken at each of the 77 PSD digital channels. The peaks at 3.3 eV and 4.15 eV are Auger peaks that do not appear in the coincidence spectrum.

On the theoretical front, as a result of β parameter measurements,[3] the P.I. has recently collaborated with M. Wilson in a calculation of the Cd $4d^9 5s^2 5p$ region that includes the optically allowed, but weakly excited, Cd $5p6s$ $J = 1$ levels.[4] Inserting the results into the model calculation of the interference spectrum shows that these levels have a noticeable effect. A more complete calculation is planned that will include more $5pns$ and $5pnd$ levels. It is also hoped to carry out some

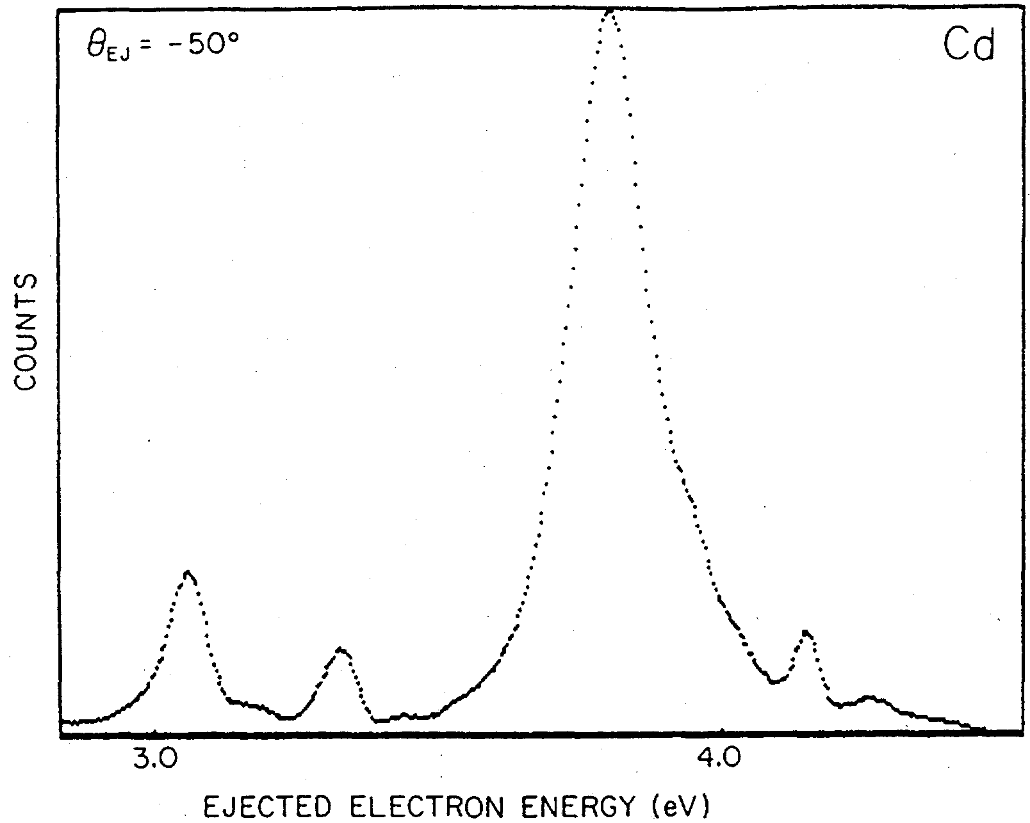

Figure 2. Cadmium non-coincident ejected-electron spectrum taken with the PSD system. The energy resolution is 0.05 eV.

PWBA calculations for the even parity 5*pnp* levels; the present calculated interference spectrum contains some fairly drastic approximations.

References

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2. N. L. S. Martin and D. B. Thompson, "Coherent Excitation of Cadmium $J = 0, 1, 2$ Autoionizing Levels by Electron Impact," Phys. Rev. A **43**, 2281 (1991).

3. N. L. S. Martin and D. B. Thompson, "A Measurement of the Cd Photoelectron Asymmetry Parameter Using $(e, 2e)$ Spectroscopy," J. Phys. B. **25**, 115 (1992).

4. N. L. S. Martin and M. Wilson, "The 5*p*6*s* Autoionizing Levels of Cadmium," J. Phys. B Letters (submitted June 1992).

Summary of Research Plans for 1993

In 1992 the $(e, 2e)$ spectrometer was optimized and a position sensitive detector (PSD) fitted to the apparatus. In 1993 the PSD will be fully operational. The Cd experiments into the coherent excitation of $J = 0, 1, 2$ autoionizing levels will continue. $(e, 2e)$ spectra will be taken with the improved energy resolution for the same scattered and ejected electron angles as before. A new experiment will then be carried out where spectra will be taken for a scattering angle of 2 degrees and ejected electron angles of 90 and 270 degrees. These ejected electron angles correspond, for this scattering angle, to a "magic angle" displacement from the momentum transfer direction. Because the $J = 2$ terms depend on a second order Legendre polynomial, they vanish. Under these circumstances the interference spectrum, found from the difference between the two spectra, isolates the $J = 0, 1$ cross-terms. An analysis of these two experiments should help with the spectroscopy of the presently uncertain $J = 0, 2$ autoionizing levels. Depending on the quality of the data obtained using the PSD system on the ejected electron detector, a second system (and accompanying monochromator) may be purchased and fitted to the scattered electron channel.

On the theoretical front, plans are underway to perform *ab initio* calculations, in collaboration with M. Wilson, of PWBA amplitudes for the autoionizing levels. These calculations will include $J = 1$ two-electron excited autoionizing levels previously omitted from the model calculations. This work will greatly aid analysis of the experimental spectra, and will promote the next experimental phase of spectra taken at larger scattering angles.