ON THE QUENCHING OF SINGLE EXCITATION CHANNELS IN THE INNER SHELL SPECTRA OF CERTAIN ELEMENTS

By

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The collaboration between the University of Bonn and Imperial College on the use of synchrotron radiation for the observation of atomic absorption spectra (1,2) has yielded much new data since IAU Colloquium No.27 (see also E. Radtke's paper in the present meeting). Among recently observed spectra are those of Tl I (3), In I (4), Ga I (5), Pb I (6), Sn I and Ge I (7), while earlier data on Zn I and Cd I (8) have been extended to include double excitations (9). The first evidence of strong mixing between the d-np channel and double excitations at the same energy has come for Tl I (3) where some of the expected d-np series are absent and, instead, other additional series appear. These converge on experimentally known limits and can only arise by double excitation, The explanation seems to be that the double excitation channel acquires oscillator strength at the expense of the single excitation channel, with consequent quenching of the latter. The clearest instance is afforded by the In I spectrum (4), where high members of several double excitation series overlap 4d-5p in energy (see Fig.2). The double excitations are observed when they occur at the same energy as 4d-5p single excitations, but their oscillator strengths fall to very low values away from the 4d-5p transitions. In the spectra of Zn I, Cd I and Hg I, where the double ionization threshold lies well above the outermost d-subshell spectrum, well developed d-np,nf series are found (8). In Tl I (3), where the double ionization threshold lies just above the d subshell spectrum, only some of the expected d-np,f series occur.

In Figs.3 and 4, we show how the energies of the double and triple ionization thresholds compare with inner shell ionization energies for the elements adjacent to Ga I and In I in the Periodic Table (10). Quenching of the single excitation channels is found where the curves cross (see Fig.1) as the double ionization threshold is passed towards higher energies.

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In Sn I (7) where the double ionization threshold is well below the d-np spectrum, the single excitations become very diffuse, with no surviving series and no sign of the normally sharp (8) d-nf transitions.

These observations have been discussed (10) in terms of a possible enhancement of double photoionization by quenching of inner shell excitation, a process resulting from inter-subshell correlations (4,11). Our present experiments do not enable double ionization rates to be measured directly. Recent studies of post-collision interactions for 4d ionization of Xe I (12) independently suggest that 4d-p,f oscillator strength can be transferred to the double photoionization continuum.

1. Connerade, J.P., Tracy, D.H., Mansfield, M.W.D. and Thimm, K. 1974. Proceedings IVth VUV Conference Pergammon Vieweg, p.99.

2. Connerade, J.P., Tracy, D.H., Mansfield, M.W.D. and Thimm, K. 1974. Proceedings IVth VUV Conference Pergammon Vieweg, p.243.

3. Connerade, J.P., Garton, W.R.S., Mansfield, M.W.D. and Martin, M.A.P. 1975. Proc.Roy.Soc. A350, 47.

4. Connerade. J.P. 1977. Proc.Roy.Soc. A352, 561.

5. Connerade, J.P. 1977. Proc.Roy.Soc.A. (In the Press).

6. Connerade, J.P., Garton, W.R.S., Mansfield, M.W.D. and Martin, M.A.P. 1977. (To be published).

7. Connerade, J.P. and Martin, M.A.P. 1977. Proc.Roy.Soc.A. (In the Press).

8. Garton, W.R.S. and Connerade, J.P. 1969. Astrophys.J. 155, 667. (Zn I, Cd I, Hg I) sharp d-nf transitions are also prominent in Tl I: Connerade, J.P. 1972. Astrophys.J. 172, 213.

9. Mansfield, M.W.D., Connerade, J.P. 1977. Proc.Roy.Soc.A. (In the Press).

10). Connerade, J.P. 1977. Phys.B.(Letters). 10, L239.

11). Wendin, G. and Ohno, M. 1976. Physica Scripta 14, 148.

12). Wight, G.R. and Van der Wiel, M.J. 1977. J.Phys.B. 10, 601.

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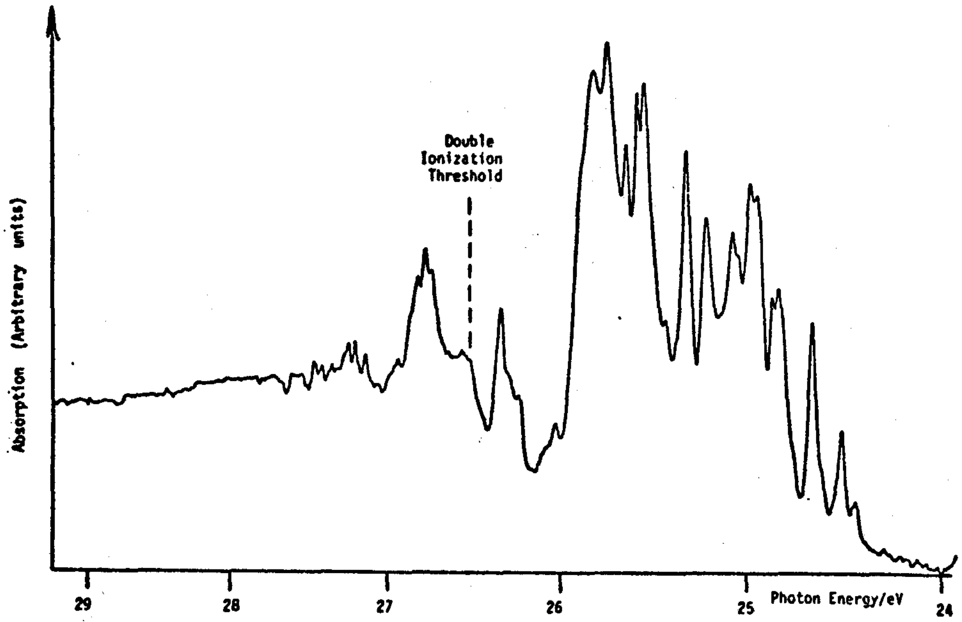

FIG.1. Showing the 'quenching' of 3d — np transitions as the double ionization threshold is passed towards higher energies in Ga I.

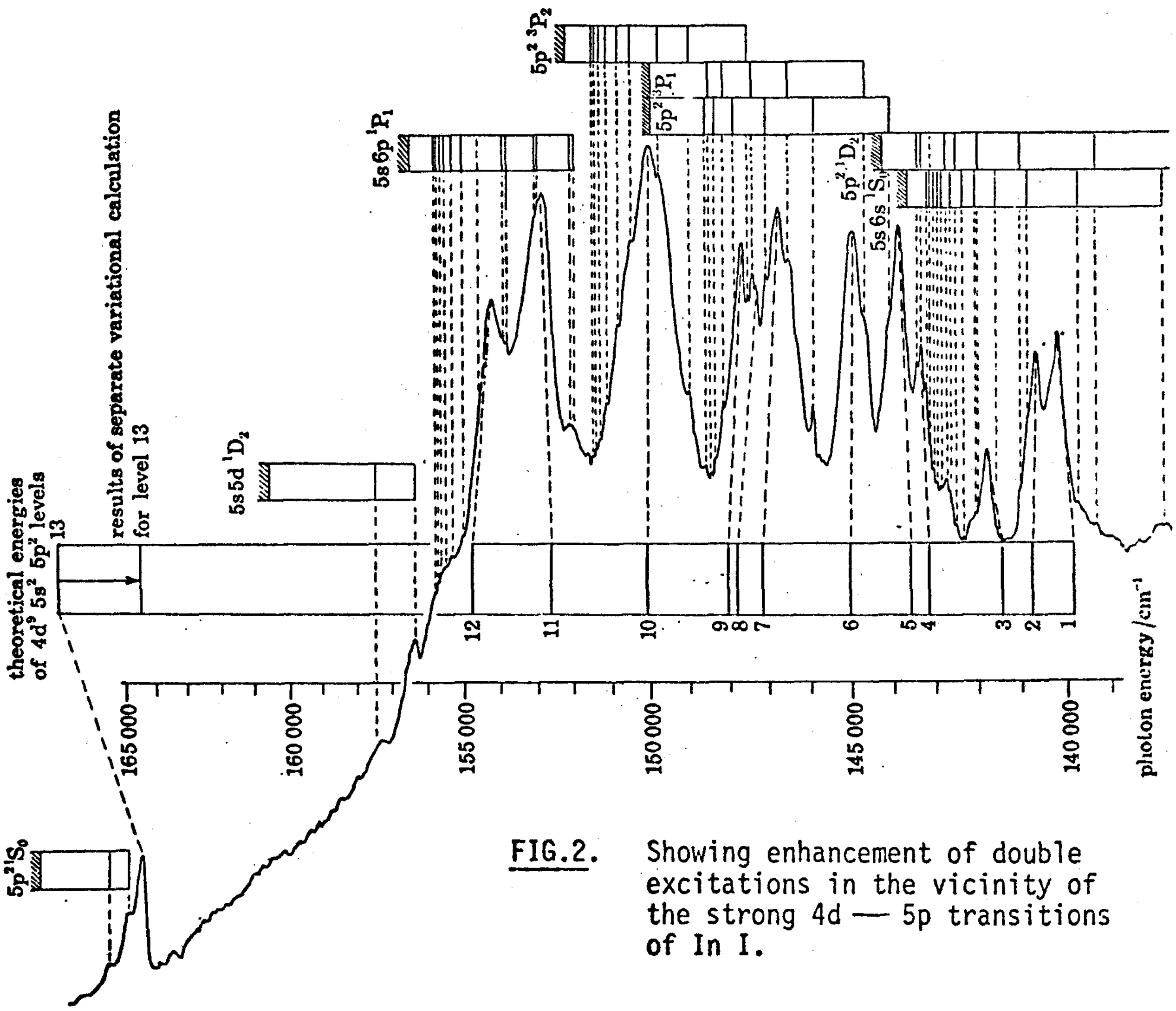

FIG.2. Showing enhancement of double excitations in the vicinity of the strong 4d — 5p transitions of In I.

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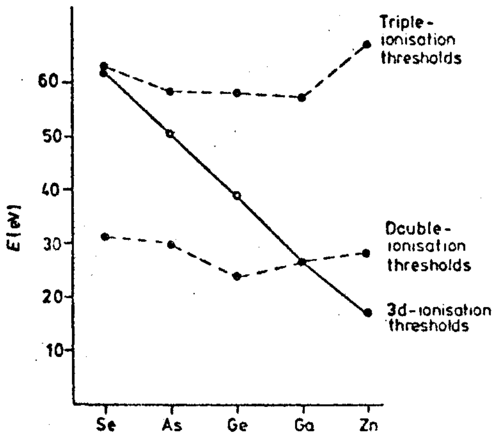

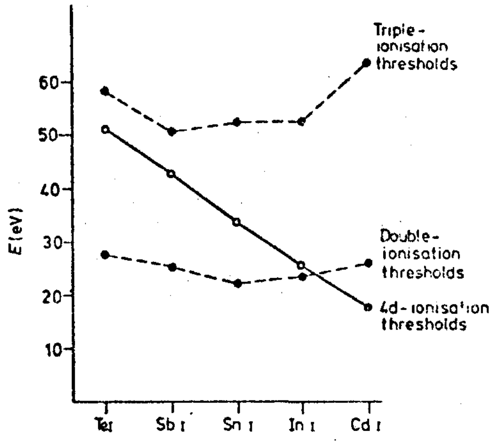

Fig.3 - Plot of the double- and triple-ionization thresholds and of the 3d-ionization threshold against Z from Z = 34 to Z = 30. Note the crossing at Ga. Experimental ● o adjusted Hartree-Fock (see text).

Fig.4 - Plot of the double- and triple-ionization thresholds and of the 4d-ionization threshold against Z from Z = 48 to Z = 52. Note the crossing at In I. Experimental o adjusted Hartree-Fock.