

# Electron Excitation of Heavy Elements in Planetary Nebulae

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Modern observational equipment makes it possible to identify extremely weak metal lines in deep surveys of the optical and near-IR region of the electromagnetic spectrum. In particular, collisionally excited lines from heavy ions ( $Z > 30$ ) have been recently identified in the spectrum of NGC 7027 (Péquignot & Baluteau 1994). However, detailed quantitative analyses of the observed lines have not been feasible due to the lack of accurate collisional data for the heavy elements.

Meanwhile, electron excitation collision strengths have been calculated for the ions Kr III,IV,V, Xe III,IV,VI and Ba II,IV, the most convincing cases for line identification (Schöning 1996a,b). In these papers the scattering problem has been solved using a full intermediate coupling Breit-Pauli R-matrix approach (Hummer et al. 1993: The IRON Project). Test calculations with the Dirac R-matrix method (see Norrington & Grant 1987) have demonstrated the applicability of the Breit-Pauli method to the computation of electron excitation rates of heavy elements to serve as diagnostics for highly excited nebular spectra. Furthermore for Kr ions we have pointed out that the semi-relativistic R-matrix approach, essentially an algebraic recoupling technique using term-coupling coefficients (Saraph 1978), is an adequate alternative to the computationally expensive Breit-Pauli calculations.

Our results will have important implications for abundance determinations of heavy trace elements in gaseous nebulae. We have shown that the effective collision strengths of Kr and Xe ions are similar in magnitude to those of the lighter noble gas ions and thus cannot account for the anomalous intensities of the collisionally excited lines in NGC 7027. Future needs for reliable collisional data of heavy elements can be foreseen since observations based on recent high-tech instrumental developments will enable the resolution of lines of heavy ions with unprecedented accuracy even in the spectra of fainter planetary nebulae.

## REFERENCES

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