Measurement of Absolute Electron Excitation Cross Sections in Multiply-Charged Ions Using Electron Energy-Loss Methods

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Electron-collision excitation rates and cross sections in multiply-charged positive ions are one of the more important quantities required to analyze optical-emission spectra from astrophysical objects. These data are needed to both test theoretical methods (such as close-coupling and distorted-wave methods), and to provide benchmark laboratory data for the infrared to x-ray transitions observed in stellar, pulsar, nebular, etc. emission spectra. Within the appropriate models, the data provide estimates of electron and ion densities and temperatures in these high electron temperature objects. Past, present and future NASA flight missions include HUT, EUVE, ORFEUS, STIS/HST, FUSE, and AXAF.

The experimental program at JPL addresses two important phenomena involving multiply-charged ion collisions in astrophysics: collisional excitation and emission lifetimes (for obtaining f-values). JPL pioneered the use of the electron energy-loss method in collisional excitation of ions. This technique has several major advantages over more conventional optical-emission measurements. First, optically-forbidden transitions (forbidden by spin or g,u/+,- symmetry) as well as optically-allowed transitions are routinely detected. Second, there is no "wavelength barrier" to the measurements: a transition in the infrared, at 1μ, corresponds to an electron energy loss of 1.2 eV; while a transition in the X-ray region, at 10 nm, corresponds to an energy loss of 124 eV. Both extremes are accessible by the energy-loss technique in one experimental apparatus!

We have recently placed on line a new, state-of-the-art electron-cyclotron resonance ion source ("Caprice"). The source operates in the Ku band, and has produced ample currents of, for example, O III-V, Mg III-VIII, and Fe III-XIII, all in low-power ($\leq$ 100 watts microwave power) operation. Higher charge states are obtained at 500- and 1000-watt operation. Two beam lines have been constructed, with allowance for a third. Using the old source and beam line, absolute collision cross sections have been most recently reported for O II [1], C II [2], S II [3]; and cross sections in S III have been measured using the new Caprice source [4]. Near-term measurements are planned for the ions C III, N V, Si III and Fe X.

References:

[1] S. J. Smith, A. Chutjian, R. J. Mawhorter, I. D. Williams and D. E. Shemansky, J. Geophys. Res. 98, 5499 (1993); M. Zuo, S. J. Smith, A. Chutjian, I. D. Williams, S. S. Tayal and B. M. McLaughlin, Ap. J. 440, 421 (1995).
[2] M. Zuo, Steven J. Smith, A. Chutjian, S. S. Tayal and I. D. Williams, Ap. J. 463, 808 (1996).
[3] C. Liao, Steven J. Smith, D. Hitz, A. Chutjian and S. S. Tayal, Ap. J. 484, 979 (1997).
[4] J. G. Greenwood, Steven J. Smith, and A. Chutjian, unpublished results.

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