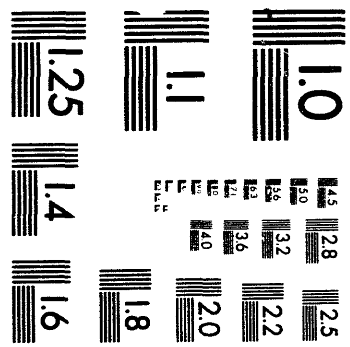

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PROGRESS REPORT FOR 1990-1991 ON

THE INVESTIGATION OF ELECTRON-ION RADIATIVE AND DIELECTRONIC RECOMBINATION IN HIGH-TEMPERATURE PLASMAS

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PROGRESS REPORT

The unified description of radiative and dielectronic recombination, which we have developed to provide corrections to the conventional independent-processes approximation, has been generalized to self-consistently incorporate the effects of charged-particle collisions and plasma electric fields. A manuscript on the general formulation is in the final stages of preparation for submission to the Physical review A. This generalization provides a self-consistent description of relaxation phenomena in a diverse class of atomic radiative transitions involving autoionizing resonances, and this important milestone has been reached as a result of a close collaboration with J. Cooper, at the Joint Institute for Laboratory Astrophysics, and S. L. Haan, at Calvin College. Specific calculations are in progress for K-shell dielectronic satellite transitions in the He-like and Li-like ions of Fe and Ar, using the autoionization and radiative transition rates that have been provided by M. Chen, at the Lawrence Livermore National Laboratory. Comparisons will be made between the predictions of the conventional and unified theories. The Ar satellite spectra is of particular interest for diagnostic studies on the MIT Tokamak, and a collaboration on the modeling of the relevant spectra has been planned with E. Marmar, at the MIT Plasma Fusion Center. The Fe satellite spectra has been the subject of extensive experimental investigations at the Princeton Plasma Physics Laboratory, and a collaboration with members of the PPPL group on the simulation of the Fe K_{α} satellite spectra is in progress, as described in detail in the following paragraph.

The K_α model for the dielectronic satellite spectra of highly-charged Fe ions, which we have developed based on the conventional theory of dielectronic satellite line intensities, has been incorporated into the muti-ion-species transport code MIST, which has been developed at the Princeton Plasma Physics Laboratory. This project is being carried out in collaboration with M. Bitter of PPPL and P. Beiersdorfer of LLNL. Excellent agreement has been obtained between the simulated spectra and the observed Fe K_α spectra from PLT and TFTR. A manuscript on this work is nearly ready for submission to the Physical Review A, entitled "High-Resolution Measurements, Line Identifications, and Spectral Modeling of K_α Transitions in Fe XVIII - Fe XXV", by P. Beiersdorfer, T. Phillips, V. L. Jacobs, K. W. Hill, M. Bitter, S. Von Goeler, and S. M. Kahan. The satellite spectra can be employed to provide a very detailed investigation on the nature of the various plasma transport processes, both collisional and anomalous. Future extensions of this collaboration may be focused on the intimate coupling between the impurity-ion transport and radiative cooling problems, which we believe to be an important aspect in the realistic investigation of atomic processes in Tokamak plasmas.

A detailed investigation has been completed on the dielectronic recombination satellite spectra in the presence of a distribution of plasma electric microfields. A manuscript has been published in the Physical Review **A 44**, 1281 (1991), entitled "Effects of Electric Microfields on Argon Dielectronic Satellite Spectra in Laser-Produced Plasmas", by L. A. Woltz, V. L. Jacobs, C. F. Hooper, Jr., and R. C. Mancini. This investigation utilizes the conventional theory of dielectronic satellite intensities due to both radiationless electron capture and inner-shell electron excitation, but it is based on a self-consistent treatment of the level-population and line broadening phenomena associated with autoionization processes, radiative transitions, electron collisions, and the quasi-static action of the ion-produced electric microfields. The calculations have been carried out for the lowest-lying $n = 2$ satellites, which are affected by the electric fields only in high-density laser-produced plasmas. For application to the lower-density conditions in Tokamak plasmas, in which the electron density is about ten orders of magnitude smaller, a number of alternatives are under consideration for evaluating the recombination rates associated with the Rydberg autoionizing states corresponding to large values of n. This collaborative investigation has resulted in the development of a model for the effects of electric fields which is more detailed than the original description presented in 1976 by V. L. Jacobs. We are now extending this investigation to incorporate an explicit calculation for the populations of the $n = 2$ autoionizing levels in the presence of an electric microfield, and detailed calculation will be carryed out for the $n = 3$ states using the autoionization and radiative decay rates supplied by M. H. Chen, at LLNL. Finally, a highly successful workshop was held at JILA on "Autoionization Resonance Phenomena in Electric Fields". This workshop provided a unique opportunity for a comprehensive review of this area of atomic physics by many of the leading research workers.

A manuscript entitled "Observation of Density-Enhanced Dielectronic Satellite Spectra Produced During Subpicosecond Laser-Matter Interactions" has been submitted for publication in the Physical Review A, in collaboration with A. Zigler, P. G. Burkhalter, and D. J. Nagel and with T. S. Luk and C. Rhodes (University of Illinois at Chicago) This work provides a convincing experimental verification of the theoretical predictions, which were published in Phys. Rev. **A 21**, 525 (1980) in collaboration with M. Blaha, on the density sensitivity of diagnostically-important dielectronic satellite spectra in dense plasmas. Although the subject of this investigation is also restricted to the $n = 2$ autoionizing levels, the experimental confirmation of the theoretically-predicted density enhancement of dielectronic satellite spectra has obvious implications for the realistic modeling of the dielectronic recombination rates associated with the higher values of n, which usually provide the dominant contributions to the recombination rates of low- and medium-Z ions for plasma electron densities in the Tokamak regime.