conference report

FIELD EFFECTS ON RYDBERG ATOMS

During the past decade the use of lasers to do detailed spectroscopic studies has led to an increased interest in the physics of atoms in which one electron is at a large distance from the atomic core. These "Rydberg atoms" are often extremely sensitive to applied electric (Stark effect) and magnetic (Zeeman effect) fields and field free spectroscopic studies have been complemented by investigations of the effects of such fields on Rydberg atoms. Basic research in this area has important practical applications. In particular, the process of dielectronic recombination, in which a free electron is captured by an atomic ion to form a Rydberg state which then emits radiation, is an important loss mechanism in fusion plasmas and is responsible for satellite lines observed in emission from astrophysical plasmas. The first laboratory measurements of cross sections for this important process have been made during the past several years, and the results of these measurements are apparently affected by the small fields present in the laboratory environment.

A two-day workshop on "Atomic Spectra and Collisions in External Fields" held at NBS on October 22-23, 1984 focused on recent experimental and theoretical developments in the general area of field effects on atomic systems and their importance in fusion research and astrophysics. The meeting was sponsored by the National Measurement Laboratory, the Department of Energy, the National Science Foundation, and the University of Illinois, and was international in scope with 14 of the 70 attendees from laboratories outside the United States.

The first day of the workshop included reviews of our current understanding of the Zeeman and Stark effects on Rydberg atoms presented by C. W. Clark (NBS) and D. A. Harmin (University of Colorado). New theoretical developments in Zeeman spectroscopy and in crossed field spectroscopy; i.e., with both electric and magnetic fields present, were discussed by H. S. Taylor (University of Southern California) and M. G. Littman (Princeton University). J. C. Gay (Ecole Normale Superieure, France) presented new results on group theoretical approaches to field effects on Rydberg atoms.

On the experimental side, new results on electric field effects on hydrogen, the atom for which the most extensive theoretical calculations are available, were discussed by M. H. Nayfeh (University of Illinois) and K. Welge (Universitat of Bielefeld, Fed. Rep. of Germany). Recent work on Stark effect measurements made at high fields using relativistic beams at the Los Alamos "Meson Factory" (LAMPF), as well as earlier measurements on negative hydrogen ions, were reported by W. W. Smith (University of Connecticut) and H. C. Bryant (University of New Mexico). Measurements on helium and sodium were described by P. Koch and H. Metcalf (both of State University of New York at Stony Brook) and S. Liberman reported on recent field effect studies and their interpretation at Laboratoire Aime Cotton (Paris, France). T. F. Gallagher (University of Virginia) discussed recent work on autoionizing states of barium reached by multi-step processes and their relationship to dielectric recombination, and R. Hulet (Massachusetts Institute of Technology) reported on the excitation of Rydberg atoms to states with large azimuthal quantum numbers using microwave techniques to produce atoms with practically circular orbits. J. P. Grandin (Universite de Caen, France) reported experimental results on the effect of strong magnetic fields on autoionizing states.

The second day of the workshop was devoted to applications, dielectronic recombination and concluding remarks by the participants. R. C. Isler (Oak Ridge National Laboratory) and R. Hulse (Princeton Plasma Physics Laboratory) stressed the importance of laboratory measurements of cross sections and theoretical calculations to the modeling of fusion plasmas. W. D. Watson (University of Illinois) reported on the importance of high Rydberg states and dielectronic recombination in providing an interpretation of spectral lines observed in the radio frequency range from interstellar gas and also gave several other examples of the relevance of the topics discussed at the workshop to various topics in astrophysics.

The two sessions on dielectronic recombination (experiment and theory) were particularly timely since most of the experimental groups who have performed measurements of the cross sections for this process were represented as well as a majority of the theorists who have provided detailed calculations.

The recent experiments on dielectronic recombination are of two types: coincidence measurements, where the process is labeled by detecting

photons and neutrals as the final state products of a crossed electron and ion beam configuration; and merged beam techniques, in which electron and ion beams are made to follow parallel paths in the interaction region and ions of a lower charge state (or neutrals) are detected. Electric fields are present in all of these experiments and the large discrepancies between measured and calculated cross section are at present attributed to the presence of these fields. Current experimental efforts are aimed at exploring the field effects in more detail.

A summary of recent work on coincidence measurements for magnesium and calcium was given by G. H. Dunn (Joint Institute for Laboratory Astrophysics) and details of a proposed new crossed beam experiment were discussed by J. L. Kohl (Harvard-Smithsonian Center for Astrophysics). Merged beam experiments on carbon were reviewed by J. B. A. Mitchell (University of Western Ontario) and work on lithium and sodium isoelectronic sequence ions was presented by P. F. Dittner (Oak Ridge National Laboratory). J. A. Tanis (Western Michigan University) presented the results of recent measurements on the closely related process of resonant transfer and excitation in atom-ion collisions.

The theoretical session focused on recent attempts to include electric field effects in calculations of dielectronic recombination. V. L. Jacobs (Naval Research Laboratory) gave a summary of the basic theoretical model which is currently being used for this purpose. Recent calculations as well as summaries of the basic theory were presented by Y. Hahn (University of Connecticut) and by D. C. Griffin (Rollins College, FL). The final talk of the session was by J. Dubau (Observatoire de Paris) who discussed the use of dielectronic recombination calculations in modeling dilute high temperature plasmas. This was of special interest since the agreement of these calculations with the results obtained from solar spectra is an important test of the basic theory of dielectronic recombination which complements the recent measurements.

The workshop closed with summary remarks by U. Fano (University of Chicago), A. L. Merts (Los Alamos National Laboratory) and K. T. Lu (Academia Sinica, Beijing, China), and a discussion of future directions led by remarks from the chairpersons of the various sessions. Some of the key observations of the summary session were the following:

1. Our basic understanding of the theory of the Stark effect on Rydberg atoms has advanced to a stage where many of the new experimental results reported could be understood and detailed calculations made to compare with the experimental results. The same is not true for the Zeeman effect or for cases where crossed fields are applied.

2. The effects of electric fields on dielectronic recombination is currently a topic of great interest and the various experiments have not reached a stage where definitve statements could be made as to the adequacy of our current theoretical understanding. Coupled with this was uncertainty of the applicability of calculations with time-independent fields to real plasma-like environments where the fields fluctuate.

3. Exciting new possibilities exist for studies of Rydberg atoms prepared in specific orientations by application of electric and magnetic fields and by controlling their orientation via various experimental techniques.

The above remarks represent only a brief synopsis of the interesting ideas that emerged from the workshop. Those who wish more information should consult the conference proceedings, which has been published as *Atomic Excitation and Recombination in External Fields*, ed. M. H. Nayfeh and C. W. Clark (Gordon and Breach, New York, 1985).

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