COLLISION CROSS SECTIONS AND EQUILIBRIUM FRACTIONS OF IONS AND ATOMS IN METAL VAPOR TARGETS

Project Progress Report for the Period
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A B S T R A C T

The objective of this program is to measure atomic collision cross sections and equilibrium fractions of ions and atoms in metal vapor targets. The goal is to obtain experimental information on atomic collision processes relevant to the Magnetic Fusion Energy Program. In particular, in connection with the development of double charge exchange D^- ion sources, we are measuring D^- formation cross sections in alkaline-earth metal vapor targets. During the period covered in this report we have measured electron transfer cross sections for 3-40 keV D^+ ions and D^o atoms in collision with calcium vapor.

DISCLAIMER

Discussion of Activities

We have completed modifications to the apparatus to allow for the production of a ground state H^o atom beam. This was accomplished by fabricating and installing a neutralizer chamber and pumping station. We also have installed on the apparatus a 60 cm drift section (with its own pumping station) between the neutralizer and target. In order to produce a ground state H^o atom beam, gas is admitted into the neutralizer and electron capture collisions occur between the neutralizer gas and the fast H^+ ion beam. An electric field of up to 8 kV/cm is applied over 40 cm in the drift region in order to sweep the remaining protons out of the beam and to quench the H(2s) component in the beam. The electric field also serves to field-ionize highly excited states in the beam before entry into the target. In this way a beam of essentially all ground state atoms is produced. An extensive series of experimental tests demonstrated that the remaining small excited state population in the atom beam did not affect the measured cross sections. These tests included varying by up to 50% the fractional population of excited states in the beam by changing both the pressure and type of gas in the neutralizer and by varying the electric field in the drift region.[1]

In order to check-out the new apparatus, measurements were made of the cross sections for

$$H^+ \rightarrow H^o,\ H^-,\ H(2s),$$

and

$$H^o \rightarrow H^+,\ H^-,\ H(2s)$$

in both argon and hydrogen gas, over the energy range from 2-90 keV.

It was decided to use two gaseous test-targets and to take extensive data over a broad energy range since, for incident H^o atom beams, there is meager information available, and where independent measurements overlap there are some inconsistencies.[2]

After completing the cross section measurements in gaseous targets we returned to the alkaline earth metal vapors and decided to study calcium first. The choice of calcium was motivated by not only its interesting negative-ion-equilibrium-fraction properties (which we recently measured in this laboratory[3]) but also by the fact that at the present time, collision properties of calcium targets are being studied by others. Dr. R.E. Olson (SRI International) has recently calculated configuration interaction potentials for several molecular states of both charged and neutral calcium hydride[4] (CaH^+, CaH^o, CaH^-). Also, Dr. F. Schlachter (Lawrence Berkeley Laboratory) is presently setting-up to measure low energy H^- equilibrium fractions using a calcium target.[5]

As of June 1, 1980 we had measured the cross sections for

$$H^+ \rightarrow H^o,\ H^-,\ H(2s),$$

and

$$H^o \rightarrow H^+,\ H^-,\ H(2s)$$

in calcium over the energy range 3-40 keV. We are presently completing the calcium measurements by extending both the high and low energy ranges and checking the reproducibility of the data. The calcium measurements, taken over an energy range from 2 to 90 keV, as well as measurements in strontium metal vapor over the same energy range, will be finished by the end of the current contract period (September 30, 1980). The results will be presented at the Second Symposium on the

Production and Neutralization of Negative Ions and Beams, Brookhaven National Laboratory (October 1980).

During the period covered by this progress report a new experiment has been built and installed on the other beam-line coming from the accelerator bending magnet. As part of this new experiment in our laboratory, which is funded by the National Science Foundation, we have purchased an IBM 7406 Device Coupler.[6] The coupler is used to interface the experimental instrumentation with the new Digital Electronic Corporation DEC-20 University computer (which began operation on May 15, 1980) via a computer terminal already present in the laboratory. This system, apparatus → coupler → terminal → computer, will provide interactive computer-assisted experimentation. With this new capability in the laboratory we have decided to computer-interface the Department of Energy metal vapor project as well as the National Science Foundation work. The system will soon be working and will provide an important instrumentation up-grade at no cost to the Department of Energy.

The H^- negative ion collaboration between Dr. T.J. Morgan and Drs. Carmen Cisneros and Ignacio Alvarez (University of Mexico), discussed in our last project progress report, is working very well. During the period covered by this report I have made two trips to Mexico City. In August 1979, I spent three weeks at the Institute of Physics, University of Mexico (funds for this visit were supplied by Wesleyan University and the University of Mexico). During this visit I participated in an experiment to measure the differential

scattering cross section $d\sigma(\theta)/d\Omega$ for H^- formation in 200 to 5000 eV H^+ and H^o collisions with magnesium metal vapor. Data on H^- angular scattering below about 5 keV is important to the design and development of atomic neutral beam sources, and consequently, the results of this collaboration are of value to the neutral injection program. The results are quite interesting and show oscillatory structure in the H^- differential cross section for energies below about 800 eV. An interpretation in terms of molecular curve crossing effects in being pursued. Professor A. Russek (University of Connecticut) also is involved in the data interpretation.[7]

In January 1980, I visited the University of Mexico to confer with Drs. Cisneros and Alvarez concerning future collaborative research and possibilities for a joint U.S. — Mexico workshop in the field of negative ions. This visit was supported by funds made available through the award of a NSF International Cooperative Science Program travel grant. During this visit a workshop proposal was formulated and subsequently written and submitted to the NSF on April 25, 1980. The coorganizers of the workshop are Drs. T.J. Morgan and C. Cisneros, and it is planned for January 1981 near Mexico City. The workshop will deal primarily with the physics of light negative ions e.g. H^-, He^-, Li^- — both their collisional formation and destruction mechanisms as well as their structure. The workshop will be of great value to the Magnetic Fusion Energy Program.

Finally, it should be noted that the principal investigator, Thomas J. Morgan, has been promoted to Associate Professor of Physics with tenure.

References

1. R.H. McFarland and A.H. Futch, Jr., Phys. Rev. A2, 1975 (1970).
2. Atomic Data for Controlled Fusion Research, C.F. Barnett et. al, Oak Ridge National Laboratory (1977).
3. T.J. Morgan, J. Stone, M. Mayo, and J. Kurose, Phys. Rev. A20, 54 (1979).
4. R.E. Olson and B. Liu, Chem. Phys. Letts. (submitted).
5. A.S. Schlachter, private communication.
6. A.A. Guido, H. Cole, and L.B. Kreighbaum, Proc. IEEE 63, 1509 (1975).
7. C. Cisneros, private communication.

Travel During Contract Period

1. University of Mexico, August 1979. Travel not supported by present contract.
2. American Physical Society Meeting, Houston, December 1979. Travel supported by present contract.
3. University of Mexico, January 1980. Travel not supported by present contract.

Personnel Involved with Project

1. T.J. Morgan, Principal Investigator
2. Jack Stone, Postdoctoral associate supported by present contract.
3. Marguerite Mayo — graduate student.

Relevant Papers Published

1. Single and Double Electron Capture by 1-100 keV Protons in Collisions with Magnesium and Barium Atoms, Phys. Rev. A19, 1448 (1979).
2. Formation of Metastable Hydrogen Atoms by Charge Exchange of Fast Protons in Magnesium and Barium Vapors, Phys. Rev. A19, 2185 (1979).
3. D^- Production by Multiple Charge Transfer Collisions in Alkaline-Earth-Metal Vapors, Phys. Rev. A20, 54 (1979).
4. Investigation of Nonadiabatic Effects in Molecular Hydrogen Rydberg States by Electric Field Ionization, Phys. Rev. A20, 1062 (1979).