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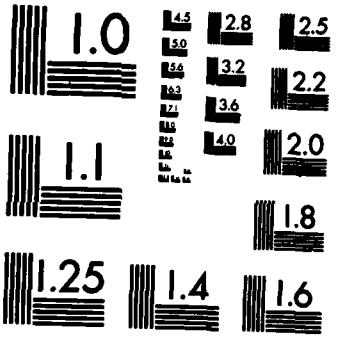

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FINAL REPORT

OF

MOLECULAR BEAM STUDIES OF LOW ENERGY REACTIONS

PERIOD: 1 FEBRUARY 1981 - 31 JANUARY 1983

ONR CONTRACT NO. N00014-81-K-0255

PRINCIPAL INVESTIGATOR: R. H. NEYNABER

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March 31, 1983

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A summary of the research performed under ONR Contract No. N00014-81-K-0255 is given. The contract covered the period 1 Feb. 1981-31 Jan. 1983. The report describes merging-beams studies of charge-transfer reactions. Included are investigations of the Cl^+-Xe, He^+-$He(2^3S)$, and Ar^{2+}-Ar systems.

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Final Report
of
Molecular Beam Studies of Low Energy Reactions
Period: 1 February 1981 - 31 January 1983
ONR Contract No. N00014-81-K-0255
Principal Investigator: R. H. Neynaber

1. Contract Description

Chemi-ionization and ion-molecule reactions involving metastable and ground-state atoms are studied by merging beams at low relative energies (i.e., 0.01 to 10 or 20 eV).

2. Scientific Problem

Some theories exist for chemi-ionization involving collisions of metastable and ground-state rare gases. There is very little experimental data to test these theories over a range of relative kinetic energy from 0.01 to 10 or 20 eV. We will supply such data. Theoretical work for collisions between two metastables is almost non-existent, and experimental data are scant. We will supply experimental information such as absolute and relative cross sections and branching ratios for associative to Penning ionization. This information should establish patterns to test those calculations that do exist and will stimulate further theory. Our chemi-ionization data also will produce some information on unknown potentials for the systems A^*B and C^*D, where A, B, C, and D are atoms and asterisks denote metastables. This information includes well depths and the dependence of the long range potential on internuclear separation.

The composition of keV neutral rare gas beams formed by charge transfer of the rare gas parent ion beam in alkalis is unknown. The beams consist of rare gas metastables (generally in two states) and ground-state atoms. The technique for generating such beams is common, and information on the composition is needed in analyzing data obtained through their use. We have developed a method for obtaining the fraction of ground-state

atoms in such beams by studying appropriate ion-molecule reactions. We will apply this method to determine unknown compositions.

No experimental information exists on low-energy resonant or near-resonant charge-transfer reactions between rare gas ions and metastables. Our experiments will supply such information. The data can be used to see if existing theories for charge transfer between ions and ground-state atoms can be extended to this case. We also will investigate energy distributions of product ions from which information on the reaction kinetics can be obtained.

Charge-transfer studies of special interest to the Navy will also be conducted.

3. Scientific and Technical Approach

Merging-beams techniques will be used for the studies. The two reactants of the process under investigation will be merged. Their velocities will be adjusted with respect to each other so that the desired relative energy in the center-of-mass system will be obtained. Product ions resulting from the reaction will be collected to give relative and absolute cross sections, and branching ratios will be obtained when appropriate.

4. Results

We have obtained the following results during the contract period.

a) A study was made of the charge-transfer reaction $Cl^+ + Xe \rightarrow Cl + Xe^+$ in the relative energy range of 1-900 eV. The reaction is asymmetric with cross sections increasing with increasing collision energy. At 20 eV the cross section is about 1.9×10^{-16} cm^2. The studies are of interest because (1) the reaction is associated with rare-gas halide excimer lasing action in a mixture of HCl and Xe and (2) relatively few charge-transfer processes have been investigated over the wide range of collision energy used in this experiment. The results have been published.

b) Absolute and relative cross sections were obtained for the charge transfer between ground-state helium ions and helium atoms in the first metastable state. The reaction is $He^+(1^2S) + He(2^3S) \rightarrow He(2^3S) + He^+(1^2S)$. The studies were made for a relative collision energy of 0.01 to 1289 eV. Resonant charge transfer (RCT) preceded by capture, or orbiting, collisions occurs for $W \leq 0.04$ eV, whereas RCT without capture occurs at higher W. A recent theoretical prediction by J. N. Bardsley shows good agreement over the entire energy range. The results have been published and presented at the XII International Conference on the Physics of Electronic and Atomic Collisions at Gatlinburg, Tenn. in 1981.

c) Studies were made of the charge transfer reaction $Ar^{2+} + Ar \rightarrow Ar + Ar^{2+}$ at relative energies from 2 to 1000 eV. Reasons for conducting this experiment were that other experimental results did not agree with each other or with theory and only one previous experiment obtained cross sections below 40 eV. Our results show an increasing cross section with decreasing energy and fair agreement with the theory of Fetisov and Firsov. A paper has been published of the results.

5. Publications

a) R. H. Neynaber and S. Y. Tang, "Charge Transfer of Cl^+ in Xe," J. Chem. Phys. 75, 2469 (1981).

b) R. H. Neynaber and S. Y. Tang, "Charge Transfer between Helium Ions and Metastable Helium," Chem. Phys. 69, 213 (1982).

c) R. H. Neynaber and S. Y. Tang, "Symmetric-Resonance Charge Transfer of Ar^{2+} in Ar," Chem. Phys. Lett. 92, 556 (1982).

6. Extenuating Circumstances

None.

7. Funds

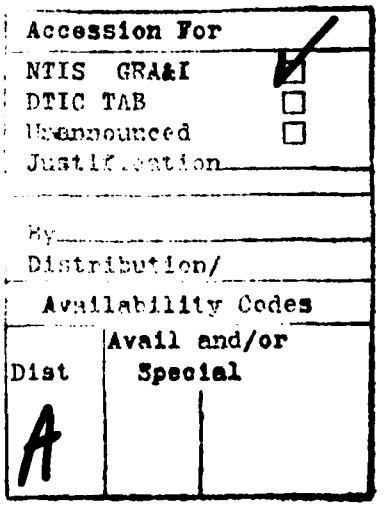
There are no unspent funds in the contract.

8. Graduate Students

No graduate students received their degrees during this contract.

9. Other Support

R. H. Neynaber has received partial support from the Air Force Office of Scientific Research, Contract No. F49620-82-K-0023, since 1 May 1982.

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