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

The annual summary of the research performed under ONR Contract No. N00014-74-C-0011 is given. The report describes merging and crossed-beam studies of chemi-ionization and/or ion-molecule reactions. Included are investigations of the Ne^*-He^*, He^*-He^*, He^*-D, Ne^*-Xe, He^+-Na, and He^+-Ne^* systems. A description is also given of how this research helps resolve unknown aspects of the areas investigated.

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Annual Summary

of

Molecular Beam Studies of Low Energy Reactions

ONR Contract No. N00014-74-C-0011

1. Contract Description

Chemi-ionization and ion-molecule reactions involving metastable and ground-state atoms are studied by both crossed and 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 is 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.

3. Scientific and Technical Approach

Merging-beams techniques will be used for most of 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.

Some crossed-beams measurements will be made of the ion-molecule reactions at relative energies above 1 eV. Again product ions will be measured to obtain cross sections.

4. Progress.

We have made the following progress during the past contract period.

a) Chemi-ionization studies have been made for the Ne^*-He^* and He^*-He^* systems, and the results have been published.

b) Chemi-ionization studies of the He^*-D system have been repeated. The new work covers a wider energy range and has produced more accurate results. Comparisons with current theory are made.

c) We have determined that the fraction of ground-state atoms is 0.06 in composite helium beams generated by charge transfer of He^+ in Na at ion energies of 1100 and 4000 eV.

d) Experimental and theoretical cross sections were obtained for the charge-transfer reaction $He^+(1S) + Ne^* \rightarrow He^{\ddagger} + Ne^+$ where Ne^* in a composite of the $^3P_2$ and $^3P_0$ states and $He^{\ddagger}$ represents a variety of excited states of He.

e) We have modified the detector magnet in our merging-beams apparatus in order to study the chemi-ionization of the Ne^*-Xe system. Previously the magnet could not be used to mass analyze ions as heavy as Xe^+ and $NeXe^+$ at the desired energies.

5. Publications

a) R. H. Neynaber and G. D. Magnuson, "Chemi-ionization in Collisions of Metastable Argon with Sodium," J. Chem. Phys. 67, 430 (1977).

b) R. H. Neynaber and S. Y. Tang, "Chemi-ionization in Collisions of Metastable Helium with Metastable Neon," J. Chem. Phys. 67, 5619 (1977).

c) R. H. Neynaber, G. D. Magnuson, and S. Y. Tang, "Chemi-ionization in Collisions of Metastable Helium with Metastable Helium," J. Chem. Phys. 68, 5112 (1978).

6. Extenuating Circumstances

None.

7. Investigators

Dr. R. H. Neynaber was the Principal Investigator during the past contract period. Dr. S. Y. Tang was also associated with the project.