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ANNUAL SUMMARY
OF
MOLECULAR BEAM STUDIES OF LOW ENERGY REACTIONS

ONR CONTRACT NO. N00014-80-C-0149

PRINCIPAL INVESTIGATOR: R. H. NEYNABER

OCTOBER 31, 1980

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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. N00014-80-C-0149 is given. The report describes merging-beams studies of chemi-ionization and ion-molecule reactions. Included are investigations of the Ne^*-Ar^*, He^*-Ne^*, and HCl^+-Xe 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. N00014-80-C-0149

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 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 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. Progress

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

a) Our results for chemi-ionization in the Ne^*-Ar^* system have been published. A paper on the subject was presented at the 11th Annual Meeting of the American Physical Society, Division of Electron and Atomic Physics, 10-12 December 1979, Rice University.

b) A study was made of the Penning ionization of He^* by Ne^* over a range of relative kinetic energy of the reactants from 0.01 to 10 eV. Both absolute and relative cross sections were obtained and the results compared with our previous results of Penning ionization of Ne^* by He^* and associative ionization of He^* and Ne^* as well as with chemi-ionization in other systems of two colliding metastables.

c) A review of some merging-beams studies at IRT Corporation was presented at the XIth International Conference on the Physics of Electronic and Atomic Collisions in Kyoto, Japan, 29 August-4 September 1979. The subject was associative and Penning ionization involving a metastable rare gas atom and a ground-state atom or two metastable rare gas atoms. The review was also published (see Section 5).

d) Absolute and relative cross sections were obtained for the charge transfer reaction $HCl^+ + Xe \rightarrow HCl + Xe^+$. The reaction appears to be exothermic but, in fact, proved to be near-resonant. The near resonance is apparently fostered by the matching of electronic-vibrational-rotational energy levels of the entrance and exit channels. This results in the conversion of internal energy of HCl^+ into internal energy of HCl.

5. Publications

a) R. H. Neynaber and S. Y. Tang, "Chemi-ionization in the Metastable Neon-Metastable Argon System," J. Chem. Phys. 72, 6176 (1980).

b) R. H. Neynaber and S. Y. Tang, "Penning Ionization of Metastable Helium in the Metastable Helium-Metastable Neon System," J. Chem. Phys. 72, 5783 (1980).

c) R. H. Neynaber, "Merging-Beams Experiments with Excited Atoms," Electronic and Atomic Collisions, North-Holland Publishing Company, Amsterdam, pp. 287-300 (1980).

6. Extenuating Circumstances

None.

7. We do not expect any unspent funds remaining at the end of the current contract period.

8-9. No graduate students or postdoctoral personnel have been associated with the contract.

10. R. H. Neynaber has received partial support from the Air Force Office of Scientific Research, Grant No. AFOSR-80-0244, but this support terminated 30 September 1980.

June 1978

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