(2)

AD-A204 586

DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

ECTE
FEB 16 1988
D

1b. RESTRICTIVE MARKINGS

DTIC FILE COPY

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)
AFOSR-TR- 89-0196

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
The Regents of the University of Colorado		AFOSR/NC

6c. ADDRESS (City, State, and ZIP Code)	7b. ADDRESS (City, State, and ZIP Code)
Campus Box 019 University of Colorado Boulder, CO 80309	Bolling Air ForceBase, Washington, D.C. 20332

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
Airforce Office of Scientific Research	NC	AFOSR-86-0018

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO
Bolling Air Force Base, Washington, D.C. 20332	61102F	2303	B1	

11. TITLE (Include Security Classification)
State-Resolved Dynamics of Ion-Molecule Reactions in a Flowing Afterglow (unclassified)

12. PERSONAL AUTHOR(S)
Stephen R. Leone and Veronica M. Bierbaum

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM 10/1/85 TO 10/31/88	1988 November 30	15

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Ion-molecule reactions
Flowing afterglow
Laser-induced fluorescence
Rotational alignment
Velocity distribution
Penning ionization

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

The dynamics and kinetics of ion-molecule collision processes have been explored in flowing afterglow, flow-drift and single collision instruments using laser-induced fluorescence and Doppler resolved laser probing. The rate coefficients and branching ratio for the atmospherically important reaction, N_2^+ + O, have been studied. The rotational alignment of N_2^+ induced by collisions with helium has been characterized in uniform electric drift fields; a theoretical treatment has been developed to relate the observed alignment to the individual tensor cross sections in the collisions. The mobility and velocity distribution of Ba^+ drifted in helium have been determined using single frequency laser-induced fluorescence. The vibrational and rotational product state distributions of the Penning ionization reaction, Ne^* + N_2, have been characterized under single collision conditions.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Francis J. Wodarczyk	(202)767-4963	NC

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

COMPLETED PROJECT SUMMARY

1. TITLE: State-resolved Dynamics of Ion-molecule Reactions in a Flowing Afterglow

2. PRINCIPAL INVESTIGATORS: Dr. Stephen R. Leone
Dr. Veronica M. Bierbaum
Department of Chemistry and Biochemistry,
University of Colorado
Joint Institute for Laboratory Astrophysics
University of Colorado and
National Institute of Standards and Technology
Boulder, Colorado 80309

3. INCLUSIVE DATES: 1 October 1985 - 31 October 1988

4. CONTRACT NUMBER: AFOSR-86-0018

5. COSTS AND FY SUPPORT: $150,577, FY86; $154,337, FY87; $164,994, FY88.

6. SENIOR RESEARCH PERSONNEL: Dr. D. M. Sonnenfroh
Dr. R. A. Dressler
Dr. H. Meyer
Dr. J. P. M. Beijers
Dr. S. M. Penn

7. JUNIOR RESEARCH PERSONNEL: K. Knutsen

8. PUBLICATIONS:

"A rotationally resolved LIF study of the N_2^+ products of the thermal energy Penning ionization reaction: Ne^* ($^3P_2$) + N_2", D. M. Sonnenfroh and S. R. Leone, J. Chem. Phys. 87, 504(1987).

"Optical studies of product state distributions in thermal energy ion-molecule reactions," V. M. Bierbaum and S. R. Leone, in "Structure/Reactivity and Thermochemistry of Ions," ed. P. Ausloos and S. G. Lias, Reidel, Boston, 23 (1987).

"Direct observation of Ba^+ velocity distributions in a drift tube using single frequency laser-induced fluorescence," R. A. Dressler, H. Meyer, A. O. Langford, V. M. Bierbaum, and S. R. Leone, J. Chem. Phys. 87, 5578 (1987).

"Laser probing of the rotational alignment of N_2^+ drifted in helium," R. A. Dressler, H. Meyer and S. R. Leone, J. Chem. Phys. 87, 6029 (1987).

"Laser probing of product state distributions in thermal energy ion-molecule reactions," S. R. Leone and V. M. Bierbaum, Disc. Faraday Soc. 84, 253 (1987).

"Bimodal rotational distributions of N_2^+ produced in the thermal energy Penning ionization of N_2 by Ne^* ($^3P_2$)", D. M. Sonnenfroh and S. R. Leone, Int. J. Mass Spectrom. Ion Proc. 80, 63 (1987).

"Steady-state model for the collision induced rotational alignment of molecular ions in electric drift fields," H. Meyer and S. R. Leone, Molec. Phys. 63, 705 (1988).

"Remeasurement of the rate constant and branching ratio for the $N_2^+ + O$ reaction," K. Knutsen, V. M. Bierbaum and S. R. Leone, Planet. Space Sci. 36, 307 (1988).

"Laser probing of ion velocity distributions in drift fields: Parallel and perpendicular temperatures and mobility for Ba^+ in He," R. A. Dressler, J. P. M. Beijers, H. Meyer, S. M. Penn, V. M. Bierbaum and S. R. Leone, J. Chem. Phys. 89, 4707 (1988).

9. ABSTRACT OF OBJECTIVES AND ACCOMPLISHMENTS:

The dynamics and kinetics of ion-molecule collision processes have been explored in flowing afterglow, flow-drift and single collision instruments using laser-induced fluorescence and Doppler resolved laser probing. The thermal energy rate coefficient and branching ratio for the atmospherically important ion-molecule reaction:

$$N_2^+ + O \rightarrow NO^+ + N$$
$$O^+ + N_2$$

were determined to be $k = 1.8(\pm 0.7) \times 10^{-10}$ cm^3 s^{-1} and $NO^+ : O^+ = 90\ (\pm 3) : 10\ (\pm 3)$, respectively. The good agreement with previous measurements suggests that this reaction rate coefficient is not the source of the discrepancy between measured and predicted densities of N_2^+ in the E and F regions of the earth's atmosphere.

The rotational alignment of N_2^+ induced by collisions with helium was probed with laser-induced fluorescence in the uniform electric field of a flow-drift tube. The ions are found to be aligned preferentially with rotational angular momentum vectors perpendicular to the electric field vector. The observed alignment is associated with the considerable repulsive anisotropy and the relatively small well depth of the N_2^+-He interaction potential with respect to the collision energies of this experiment. A theoretical treatment was developed to relate the observed alignment to the individual tensor cross sections in the collisions.

The mobility and velocity distribution for Ba^+ drifted in helium under well-characterized conditions have been determined using single frequency laser-induced fluorescence. The reduced mobility decreases monotonically with increasing E/N, suggesting that the repulsive part of the Ba^+-He interaction potential is probed predominantly. The velocity profiles are characterized by shifted elliptical Maxwellian distributions. The parallel and perpendicular ion temperatures are in excellent agreement with both a repulsive Maxwell model and a parametrized version of the three temperature theory.

The vibrational and rotational product state distributions of the Penning ionization reaction:

$$Ne^* (^3P_2) + N_2(X^1\Sigma_g) \rightarrow Ne(^1S_o) + N_2^+ (X^2\Sigma_g) + e^-$$

have been determined in a flowing afterglow coupled with a jet expansion and laser-induced fluorescence detection. The rotational distribution in each vibrational state shows evidence for multiple pathways in the reaction, displaying both a highly excited (220-490K) and a very low excitation (45-60K) component. The results may be explained in terms of the location on the potential surface at which electron transfer occurs.

AFOSR Program Manager: F. J. Wodarczyk

Table of Contents

A. OBJECTIVES OF THE RESEARCH

This research has been directed toward a detailed understanding of the dynamics and kinetics of a wide variety of ion-molecule collision processes. The experimental methods make use of flowing afterglow technology, flow-drift techniques and jet expansions coupled with laser-induced fluorescence and Doppler resolved laser probing. Research objectives include studies of the kinetics of atmospheric ion-molecule reactions, characterization of the alignment and velocity distribution of ions in uniform electric drift fields and determination of the vibrational and rotational product state distributions of Penning ionization processes.

B. STATUS OF THE RESEARCH EFFORT

1. Atmospheric Ion-Molecule Reactions

Published results: "Remeasurement of the Rate Constant and Branching Ratio for the $N_2^+ + O$ Reaction", K. Knutsen, V. M. Bierbaum and S. R. Leone, Planet. Space Sci. 36, 307 (1988).

Summary of Research:

We have recently redetermined the rate coefficient and branching ratio of the atmospherically important ion-molecule reaction, N_2^+ with O atoms. This reaction is important in the balance of atmospheric ions and has been implicated in the discrepancy between the measured and predicted density of N_2^+ in the E and F regions at an altitude of 200-400 km. The predicted ion densities are 1.5-2 times greater than the observations, and a higher rate coefficient for the reaction of $N_2^+ + O$ would bring the results into better agreement. Our redetermination at 300K, $k = 1.8\ (\pm 0.7) \times 10^{-10}\ cm^3\ s^{-1}$, shows no significant difference with the previous determinations, and thus the thermal energy rate coefficient cannot be the source of the discrepancy. In addition, our measurement of the product branching ratio of $NO^+ : O^+ = 90(\pm 3) : 10(\pm 3)$ is in good agreement with earlier results. There are speculations that the rate of reaction for vibrationally excited ions may be significantly different than unexcited ions, and future work in our laboratory will attempt to address this issue.

2. Rotational Alignment of Ions in Well-characterized Drift Fields

Published results: "Laser probing of the rotational alignment of N_2^+ drifted in helium", R. A. Dressler, H. Meyer and S. R. Leone, J. Chem. Phys. 87, 6029 (1987).

Summary of Research:

We have studied the rotational alignment of N_2^+ induced by collisions with helium in the uniform electric field of a flow-drift tube. Our results indicate that ions are aligned preferentially with rotational angular momentum vectors perpendicular to the electric field vector in analogy to observations made for neutral molecules in molecular beam expansions. At a drift field of 14 Td, corresponding to a center-of-mass collision energy of 52 meV, a quadrupole moment $A_o^{(2)} = -0.11 \pm 0.03$ is determined for the N=10 rotational state. This indicates that approximately 1.5 times as many molecules have their plane of rotation preferentially parallel to the drift field as perpendicular. The observed alignment is associated with the considerable repulsive anisotropy and the relatively small well depth of the N_2^+-He interaction potential with respect to the collision energies of this experiment.

The substantial alignment observed for N_2^+ strongly suggests that larger ions may be aligned to a higher degree when drifted in an inert buffer gas. This alignment may strongly affect ion mobilities as well as the kinetic energy dependence of site-specific ion-molecule rates measured in drift-tubes. Experiments to determine the alignment of larger ions, such as the 1,3,5-trifluorobenzene cation, are currently in progress.

Published results: "Steady state model for the collision induced rotational alignment of molecular ions in electric drift fields", H. Meyer and S. R. Leone, Molec. Phys. 63, 705 (1988).

Summary of Research:

We have developed a theoretical treatment to describe the rotational alignment of molecular ions induced by collisions in electric drift fields. We have derived a relationship between the state multipole moments which characterize the deviation in an ensemble of rotors from an isotropic M_J distribution and the microscopic state multipole cross sections for rotational energy transfer in an atom-diatom system. Steady state conditions and cylindrical collision symmetry are assumed. We allow for the possibility that the velocity distribution, which is used to calculate the rates, is dependent on the rotational angular momentum quantum numbers J and M_J. Using an approximate velocity distribution, we have related the rotational alignment of molecular ions colliding with a buffer gas in an electric drift field to the zeroth and second order tensor cross sections.

3. Velocity Distributions of Ions in Well-Characterized Drift Fields

Published results: "Direct observation of Ba^+ velocity distributions in a drift tube using single frequency laser-induced fluorescence", R. A. Dressler, H. Meyer, A. O. Langford, V. M. Bierbaum and S. R. Leone, J. Chem. Phys. 87, 5578 (1987).

"Laser probing of ion velocity distributions in drift fields: Parallel and perpendicular temperatures and mobility for Ba^+ in He", R. A. Dressler, J. P. M. Beijers, H. Meyer, S. M. Penn, V. M. Bierbaum and S. R. Leone, J. Chem. Phys. 89, 4707 (1988).

Summary of Research:

We have probed the ion velocity distributions for Ba^+ drifted in helium under well characterized conditions using single-frequency laser-induced fluorescence detection. We have determined the reduced mobilities and the Doppler profiles parallel and perpendicular to the electric field vector as a function of the field strength (E) to the buffer gas density (N) up to 33.5 Td. The reduced mobility decreases monotonically with increasing E/N from the zero field value of 16.7± 0.4 $cm^2 V^{-1} s^{-1}$ at 313K. This suggests that the repulsive part of the Ba^+-He interaction potential is probed predominantly. The Ba^+ velocity distributions in the drift tube are characterized by a shifted, elliptical Maxwellian at electric fields up to 33.5 Td. The parallel and perpendicular ion temperatures are in excellent agreement with both a repulsive Maxwell model and a parametrized version of the three temperature theory.

In recent experiments we have extended these studies to include accurate measurements of the Ba^+ velocity distributions, both parallel and perpendicular to the field with a variety of heavier, more polarizable buffer gases. For argon as a collision partner the velocity distributions take on a substantial asymmetry, in which the distribution in the parallel direction is skewed to higher velocities in the forward direction. Such skewing has been predicted in collisions that are governed by an r^{-4} potential.

4. Vibrational and Rotational Product State Distributions of Penning Ionization Reactions

Published results: "A rotationally resolved LIF study of the N_2^+ products of the thermal energy Penning ionization reaction; Ne^* ($^3P_2$) + N_2", D. M. Sonnenfroh and S. R. Leone, J. Chem. Phys. 87, 5041 (1987).

"Bimodal rotational distributions of N_2^+ produced in the thermal energy Penning ionization of N_2 by Ne^* ($^3P_2$)", D. M. Sonnenfroh and S. R. Leone, Int. J. Mass Spectrom. Ion Proc. 80, 63 (1987).

Summary of Research:

We have studied the thermal energy Penning ionization of N_2 by Ne^* ($^3P_2$), using laser-induced fluorescence probing of the N_2^+ products under single collision conditions. In each vibrational state, bimodal rotational populations are observed which can be fit by a two-component Boltzmann distribution with a low (45-60K) and a high (220-490K) temperature element. Several mechanisms are presented to account for the observed bimodal rotational distributions. The most intriguing involves possible dynamical effects of the structure known to exist in the repulsive wall of the entrance surface. This structure may make possible ionizing transitions to two distinct regions of the exit surface resulting in collisions of different inelasticity with the repulsive wall of that surface. We have also measured the N_2^+ product vibrational distribution and found that it closely matches photoionization distributions obtained at similar energies. The vibrational results confirm the essential Franck-Condon nature of the Penning ionization process. In contrast, the rotational results provide a valuable extension to the traditional Penning ionization model for repulsive systems.

C. PUBLICATIONS

1. "Vibrational chemiluminescence from ion-molecule reactions: $O^- + CO \rightarrow CO_2 + e^-$," V.M. Bierbaum, G.B. Ellison, J.H. Futrell and S.R. Leone, J. Chem. Phys. 67, 2375 (1977).

2. "Direct detection of the product vibrational-state distribution in the associative detachment reaction $Cl^- + H \rightarrow HCl(v) + e$," T.S. Zwier, M.M. Maricq, C.J.S.M. Simpson, V.M. Bierbaum, G.B. Ellison, S.R. Leone, Phys. Rev. Lett. 44, 1050 (1980).

3. "Vibrational product state distributions of ion-molecule reactions by infrared chemiluminescence: $Cl^- + HBr, HI \rightarrow HCl(v) + Br^-, I^-$," V.M. Bierbaum, G.B. Ellison, and S.R. Leone, J. Chem. Phys. 72, 5426 (1980).

4. "Vibrational product states from reactions of CN^- with the hydrogen halides and hydrogen atoms," M.M. Maricq, M.A. Smith, C.J.S.M. Simpson and G.B. Ellison, J. Chem. Phys. 74, 6154 (1981).

5. "Nascent product vibrational state distributions of ion-molecule reactions: The proton transfer reactions $F^- + HX \rightarrow HF(v) + X^-$, X = Cl, Br, and I," J.C. Weisshaar, T.S. Zwier and S.R. Leone, J. Chem. Phys. 75, 4873 (1981).

6. "Nascent product vibrational state distributions of ion-molecule reactions: The $H + F^- \rightarrow HF(v) + e^-$ associative detachment reaction," T.S. Zwier, J.C. Weisshaar and S.R. Leone, J. Chem. Phys. 75, 4885 (1981).

7. "Infrared fluorescence: A versatile probe of state-selected chemical dynamics," S.R. Leone, Acc. Chem. Res. 16, 88 (1983).

8. "Product vibrational state distributions in thermal energy associative detachment reactions: $F^- + H,D \rightarrow HF(v), DF(v) + e^-$," M.A. Smith and S.R. Leone, J. Chem. Phys. 78, 1325 (1983).

9. "Product vibrational analysis of ion-molecule reactions by laser-induced fluorescence in a flowing afterglow: $O^- + HF \rightarrow OH(v=0,1) + F^-$," C.E. Hamilton, M.A. Duncan, T.S. Zwier, J.C. Weisshaar, G.B. Ellison, V.M. Bierbaum, and S.R. Leone, Chem. Phys. Lett. 94, 4 (1983).

10. "Infrared chemiluminescence from vibrationally excited NO^+: Product branching in the $N^+ + O_2$ ion-molecule reaction," M.A. Smith, V.M. Bierbaum, and S.R. Leone, Chem. Phys. Lett. 94, 398 (1983).

11. "Laser-induced fluorescence studies of ion collisional excitation in a drift field: Rotational excitation of N_2^+ in helium," M.A. Duncan, V.M. Bierbaum, G.B. Ellison, and S.R. Leone, J. Chem. Phys. 79, 5448 (1983).

12. "Flowing afterglow studies of ion reaction dynamics using infrared chemiluminescence and laser-induced fluorescence," V.M. Bierbaum, G.B. Ellison, and S.R. Leone, Gas Phase Ion Chemistry, Vol. 3, "Ions and Light," ed. M.T.Bowers (Academic Press, Orlando, 1984), pp. 1-39.

13. "Vibrational energy disposal in polyatomic ion-molecule reactions: SF_6^- + H,D -> SF_5^- + HF(v), DF(v)," C.E. Hamilton, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 80, 1831 (1984).

14. "State-resolved molecular reaction dynamics," S.R. Leone, Ann. Rev. Phys. Chem. 35, 109 (1984).

15. "Laser probing of chemical reaction dynamics," S.R. Leone, Science 227, 889 (1985).

16. "Product vibrational state distributions of thermal energy charge transfer reactions determined by laser-induced fluorescence: N^+ + CO -> CO^+ (v=0-2) + N," C.E. Hamilton, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 83, 601 (1985).

17. "Product vibrational state distributions of thermal energy charge transfer reactions determined by laser-induced fluorescence in a flowing afterglow: Ar^+ + CO -> CO^+(v=0-6) + Ar," C.E. Hamilton, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 83, 2284 (1985).

18. "Flowing afterglow infrared chemiluminescence studies of vibrational energy disposal in the ion-molecule reactions F^- + HBr, DBr -> HF,DF + Br^-," A.O. Langford, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 83, 3913 (1985).

19. "Auroral implications of recent measurements on O(^{1}S) and O(^{1}D) formation in the reaction of N^+ with O_2," A.O. Langford, V.M. Bierbaum, and S.R. Leone, Planet. Space Sci., 33, 1225 (1985).

20. "Branching ratios for electronically excited oxygen atoms formed in the reaction of N^+ with O_2 at 300 K," A.O. Langford, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 84, 2158 (1986).

21. "A rotationally resolved LIF study of the N_2^+ products of the thermal energy Penning ionization reaction: $Ne^*(^3P_2) + N_2$", D. M. Sonnenfroh and S. R. Leone, J. Chem. Phys 87, 504 (1987).

22. "Optical studies of product state distributions in thermal energy ion-molecule reactions," V.M. Bierbaum, and S.R. Leone, in "Structure/Reactivity and Thermochemistry of Ions," ed. P. Ausloos, S.G. Lias, Reidel, Boston, 23 (1987).

23. "Direct observation of Ba^+ velocity distributions in a drift tube using single frequency laser-induced fluorescence," R.A. Dressler, H. Meyer, A.O. Langford, V.M. Bierbaum, and S.R. Leone, J. Chem. Phys. 87, 5578 (1987).

24. "Laser probing of the rotational alignment of N_2^+ drifted in helium," R.A. Dressler, H. Meyer, and S.R. Leone, J. Chem. Phys. 87, 6029 (1987).

25. "Laser probing of product state distributions in thermal energy ion-molecule reactions," S.R. Leone, and V.M. Bierbaum, Disc. Faraday Soc. 84, 253 (1987).

26. "Bimodal rotational distributions of N_2^+ produced in the thermal energy Penning ionization of N_2 by $Ne^*(^3P_2)$", D.M. Sonnenfroh and S.R. Leone, Int. J. Mass Spectrom. Ion Proc. 80, 63 (1987).

27. "Steady-state model for the collision induced rotational alignment of molecular ions in electric drift fields," H. Meyer and S.R. Leone, Molec. Phys. 63, 705 (1988).

28. "Remeasurement of the rate constant and branching ratio for the $N_2^+ + O$ reaction", K. Knutsen, V.M. Bierbaum and S.R. Leone, Planet. Space Sci. 36, 307 (1988).

29. "Laser probing of ion velocity distributions in drift fields: Parallel and perpendicular temperatures and mobility for Ba^+ in He", R.A. Dressler, J.P.M. Beijers, H. Meyer, S.M. Penn, V.M. Bierbaum and S.R. Leone, J. Chem. Phys. 89, 4707 (1988).

D. PROFESSIONAL PERSONNEL ASSOCIATED WITH THE RESEARCH

Stephen R. Leone: Co-principal Investigator. Adjoint Professor, Department of Chemistry, University of Colorado. Staff Physicist, Quantum Physics Division, National Institute of Standards and Technology.

Veronica M. Bierbaum: Co-principal Investigator. Senior Research Associate, Special Member of the Graduate Faculty, Department of Chemistry, University of Colorado.

David M. Sonnenfroh: Postdoctoral research associate. Presently Research Associate, Argonne National Laboratory, Argonne, IL.

Rainer A. Dressler: Postdoctoral research associate. Presently Staff Member, Air Force Geophysics Laboratory, Bedford, MA.

Henning Meyer: Postdoctoral research associate. Presently Assistant Professor, Max Planck Institute für Strömungsforschung, Gottingen, West Germany.

Johannes P.M. Beijers: Postdoctoral research associate.

Stephen M. Penn: Postdoctoral research associate.

Karen Knutsen: Graduate research associate.

E. PROFESSIONAL INTERACTIONS

S. R. LEONE - Seminars and Conferences

"State-selected ion-molecule chemistry and energy transfer," Chemistry Department Colloquium, University of California, Davis, January 1986.

"Laser probing of energy transfer and chemical reaction dynamics," Physical Chemistry Seminar, Stanford University, January 1986.

"Laser studies of chemical reaction dynamics," Chemistry Department Colloquium, University of Kansas, Lawrence, March 1986.

"Product states and alignment effects in chemical dynamics," American Chemical Society Local Section, University of Wisconsin, Madison, April 1986.

"Dynamics of ion-molecule reactions," Sanibel Symposium, Snowbird, UT, April 1986.

"Optical studies of product state distributions in thermal energy ion-molecule reactions. I. Infrared chemiluminescence," NATO meeting on Ion-Molecule Chemistry, Les Arcs, France, July 1986.

"Optical studies of product state distributions in thermal energy ion-molecule reactions. II. Laser induced fluorescence," NATO meeting on Ion-Molecule Chemistry, Les Arcs, France, July 1986.

"Infrared probing of chemical dynamics," University of Bern, Bern Switzerland, July 1986.

"Laser probing of chemical reaction dynamics," Institute for Space and Astronautical Research, Tokyo, Japan, October 1986.

"Laser probing of chemical reaction dynamics," Chemistry Department, University of Tokyo, Hongo, Japan, October 1986.

"Laser probing of chemical reaction dynamics," Tokyo Institute of Technology, Tokyo, Japan, October 1986.

"Laser and infrared probing of the thermal energy ion molecule reactions," Nagoya Meeting - Symposium on New Techniques in Reaction Dynamics, Japan, October 1986.

"Laser probing of chemical reaction dynamics," Institute for Molecular Science, Okazaki, Japan, October 1986.

"Laser probing of chemical reaction dynamics," Keio University, Yokohama, Japan, October 1986.

"Laser probing of chemical reaction dynamics," Kyushu University, Kyushu, Japan, November 1986.

"Product state analysis of chemical reaction dynamics," Chemistry Department Colloquium, Washington University, St. Louis, MO, December 1986.

"Laser probing of state-selected dynamics in the gas phase and on surfaces," University of California, Santa Barbara, CA, April 1987.

"Laser probing of product state distributions in thermal-energy ion-molecule reactions," Faraday Discussion No. 84 on Dynamics of Elementary Gas Phase Reactions, Birmingham, England, September 1987.

"Laser probing of alignment and velocity effects in collision dynamics," Chemistry Department, University of Minnesota, Minneapolis, MN, October 1987.

"Laser probing of alignment and velocity effects in atomic collision physics," Georgia Institute of Technology, Atlanta, GA, March 1988.

Kaufman lectures, University of Pittsburgh, Pittsburgh, PA, September, 1988.

<u>V. M. BIERBAUM - Seminars and Conferences</u>

"Energy Disposal in the Reaction of $N^+ + O_2$," Western Regional Conference on Gaseous Ion Chemistry, University of California Conference Center, Lake Arrowhead, California, January 1986.

"State Resolved Dynamics of Thermal Energy Ion-Molecule Collisions in the Gas Phase," AFOSR Molecular Dynamics Conference, AFGL, Bedford, Massachusetts, October 1986.

"Gas Phase Studies of Ion-Molecule Chemistry and Dynamics," Chemical Physics Seminar, University of Southern California, Los Angeles, California, October 1987.

J. P. M. BEIJERS - Seminars and Conferences

"Laser probing of ion-velocity distributions of Ba^+ drifting in helium," Chemical Physics after Dark seminar, JILA, December 1987.

"LIF probing of the velocity distribution of Ba^+ drifted in He," DAMOP Meeting, Baltimore, MD, April 1988.

"Laser probing of ion collisions in drift fields: velocity distributions, state excitation and alignment effects," SUNY, Stony Brook, NY, May 1988.

"Laser probing of ion collisions in drift fields: velocity distributions, state excitation and alignment effects," KVI, University of Grominger, The Netherlands, July 1988.

"Non-Gaussian velocity distributions of ions in a drift tube," GEC meeting, Minneapolis, MN, October 1988.

S.M. PENN - Seminars and Conferences

"Laser Probing of Ion Velocity Distributions in Drift Fields: Parallel and Perpendicular Temperatures and Mobility for Ba^+ in He," Gordon Research Conference in Atomic and Molecular Interactions, Plymouth State College, Plymouth, NH, August 1988.