**REPORT DOCUMENTATION PAGE**

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<th>1. REPORT NUMBER</th>
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**REPORT TITLE**

ATOMIC AND MOLECULAR PROCESSES IN ATMOSPHERIC ENVIRONMENTS.

**AUTHOR(s)**

Manfred A. Bondi

**PERFORMING ORGANIZATION NAME AND ADDRESS**

Depts. of Physics and Chemistry University of Pittsburgh Pittsburgh, Pa. 15260

**CONTRACT OR GRANT NUMBER(s)**

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**ABSTRACT**

The research topics carried out under this contract are stated and references are given to the publications of the scientific findings resulting from the research. The personnel supported by the contract are listed.

**KEYWORDS**

ion-molecule reaction rates, metal atoms, metal oxides, chemiexcitation, chemiluminescence, metastable species, excited states, electron-ion recombination, electron attachment, infrared emission, energy transfer processes, air chemistry, fuel-oxidizer reactions, optical discrimination, laser reactions, particulates, theoretical reaction rates, formal collision theory, airglow interferometry, ionospheric modification, atmospheric composition, auroral studies.
ATOMIC AND MOLECULAR PROCESSES IN
ATMOSPHERIC ENVIRONMENTS

ARPA Order No. 826
Project P-6563-P

Final Report
by
Manfred A. Biondi

September 11, 1975
For Period 26 April 1966 - 30 June 1975

The Advanced Research Projects Agency
DA-31-124-ARO-D-440

Physics & Chemistry Departments
University of Pittsburgh
Pittsburgh, Pa. 15260

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.
I. Summary of Research

During the period of this contract, April 26, 1966 to June 30, 1975, research was carried out in the following areas of atomic collisions and upper atmosphere studies:

A. Laboratory Studies

1. Radiative Properties of Simple Molecules for Optical Discrimination Studies
2. Clean Air Chemistry and Chemiluminescence
3. Sodium Ion and Other Reactions
4. Processes Involving Metastable Species
5. Ion Molecule Reactions and Excitation Processes in a Fast Flow System
6. Ion Molecule Reactions at Elevated Temperatures
7. Electron Attachment to Metal Oxides
8. Attachment of Electrons to Hot Oxygen
9. Crossed Beam Studies of Radiating State Excitation by Vibrational Energy Transfer
10. Reactions of Metal Atoms with Ions in Magnetically Confined NO⁺ Plasmas
11. Afterglow Studies of the Excitation of Radiating States by Vibrational Energy Transfer: Optical Pumping Experiments
12. Coincidence Scattering Experiments
13. Internal Energies of Photodissociation Products
14. Time of Flight Experiments
15. Laser Ion-Molecule Reaction Rates
16. Particulate Technology
17. Kinetic Energy of Excited Metal Atoms in Chemical Reactions
18. Neutral-Neutral Reactions in Crossed Beams
19. Energy Partitioning in Metal Atom Chemi-Excitation
20. Processes Involving Metastable Species
21. Dissociative Excitation of CO(\(A^1\Pi\)) by Electron Impact on CO\(_2\)

22. Infrared Emission From Recombination and Energy Transfer Process of Air Species

B. Theoretical Studies

2. Ionization and Excited State Populations in Barium Plasmas
3. Resonance Line Profiles in Alkali Vapors
4. Quantum Theory of Dissociative Recombination Rates
5. Pseudopotential Studies of Atoms and Molecules
6. Low Energy Atom-Atom Collision Cross Sections
7. Formal Collision Theory
8. Auger and X-ray Spectra
9. Energy Distribution in Ion Drift Tubes

C. Ground Based Observations, Rocket and Satellite Measurements

1. Airglow Interferometry
2. Optical Interferometric Studies of Barium Releases
3. Auroral Interferometry
4. Optical Photometer Studies of Nightglow Ionospheric Modifications
5. Measurements of the Ionized and Neutral Constituents of the Atmosphere

D. Model Calculations of Atmospheric Composition and Response

1. Composition of the Mesosphere and Lower Thermosphere
2. Distribution of Gases in the Mesosphere

E. Informal Workshop on Atmospheric Metastables and Infrared Emitters

II. Research Publications Produced Under the Contract

The following is a list of the scientific publications which set forth the results of research of interest to ARPA carried out during this period and in many cases supported under this contract.
"Negative Ions of N\textsubscript{2}0 and CO\textsubscript{2}", J. N. Bardsley, J. Chem. Phys. 51, 3348, 1969.


"Electron Temperature Dependence of Recombination of O\textsubscript{2}\textsuperscript{+} and N\textsubscript{2}\textsuperscript{+} Ions with Electrons", F. J. Mehr and M. A. Biondi, Phys. Rev. 181, 264, 1969.

"Ion-Molecule Reactions Involving N\textsubscript{2}\textsuperscript{+}, H\textsuperscript{+}, O\textsubscript{2}\textsuperscript{+} and O\textsuperscript{+} Ions from 300°K to ~1 eV", R. Johnsen, H. L. Brown and Manfred A. Biondi, J. Chem. Phys. 52, 5080, 1970.


"Recombination Processes (Charged Particles)", Revised 1969, M. A. Biondi,
DASA Reaction Rate Handbook.


"Measurements of Recombination of Electrons with H\textsubscript{2}O\textsuperscript{+}.(H\textsubscript{2}O)\textsubscript{n} Series Ions", M. T. Leu, M. A. Biondi, and R. Johnsen, Phys. Rev. 7, 292, 1973.


"Discussion of An Experiment to Measure the Polarization of Dayglow Lyman \alpha", T. M. Donahue, Planet. Space Sci. 15, 1535, 1967.


"Classical Approximation for Ionization by Heavy Particle Impact", J. D. Garcia, E. Gerjuoy and J. E. Welker, Leningrad Conference Abstracts, ibid, pp. 653-654


III. Personnel Supported by this Contract

The following personnel have received partial or total support under this contract.

Faculty Members:

J. N. Bardeley
M. A. Biondi
R. T. Brackmann
T. M. Donahue
W. L. Fite
E. Gerjuoy
F. Kaufman
E. C. Zipf

Post-Doctoral Personnel:

J. G. Anderson
W. Borst
J. W. Bozzelli
R. B. Cohen
E. Enemark
F. Faisal
A. Farragher
T. Finn
J. Fricke
R. Gann
J. D. Garcia
J. Geddes
M. F. Golde
B. Guenther
R. Gutchek
R. D. Hake, Jr.
W. R. Henderson
R. Johnsen
B. R. Junker
J. B. Kumer
H. H. Lo
J. Mehr
R. Myer
H. Nakamura
R. Nieman
G. Nitt
A. Roche
H. W. Rundel
V. B. Shecrey
D. P. Sipler
D. E. Shemansky
A. I. Stewart
E. Stone
S. Studniarz
P. J. Teubner
B. K. Thomas
R. Thomas
G. Unger
W. C. Wells
Visiting Faculty:
R. Bassel
W. Jackson
H. B. Palmer
P. Stone

Graduate Research Assistants:
R. A. Bain
V. M. Bierbaum
D. Brocklebank
H. L. Brown, Jr.
P. Buchwalter
B. Carnahan
R. Castell
Y. F. Chong
L. Clendenning
R. Cody
V. Donnelly
N. Dorn
P. Erdman
R. Fralick
R. J. Girmius
B. Guenther
R. Gutchek
R. D. Hake, Jr.
J. M. Heimerl
C. M. Howard
W. E. Kauppila
B. Kim
H. Krause
J. J. Kumer
L. Kurzweg
D. Lessie
S. Levine
S. C. Liu
H. H. Lo
J. L. McCrumb
R. McLaughlin
J. J. Margitan
M. Mumma
R. Myer
R. Nieman
W. R. Ott
J. Peden
J. Ross
S. Sinha
D. P. Sipler
C. V. Sukumar
H. Tai
B. K. Thomas
G. Unger
B. Wasser
C. S. Weiler
T. Zajdel
### IV. Degrees Awarded

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree</th>
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<tr>
<td>C. S. Weller</td>
<td>Ph.D.</td>
<td>1967</td>
</tr>
<tr>
<td>James Peden</td>
<td>M.S.</td>
<td>1967</td>
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<td>J. Casalese</td>
<td>M.S.</td>
<td>1968</td>
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<td>N. Dorn</td>
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<td>George A. Doschek</td>
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<td>J. M. Heimerl</td>
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<td>J. W. Philbrick</td>
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<td>1968</td>
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<td>B. Guenther</td>
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<td>J. B. Kumer</td>
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<td>1969</td>
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<td>Hsi-Hu Lo</td>
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<td>T. Parkinson</td>
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<td>R. Fralick</td>
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<td>R. D. Hake, Jr.</td>
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<td>H. F. Krause</td>
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<td>L. Kurzweg</td>
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<tr>
<td>M. Mumma</td>
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<td>1970</td>
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<td>H. Tai</td>
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<td>1970</td>
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<tr>
<td>Kwang Ok Yeo</td>
<td>M.S.</td>
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<td>L. M. Clendenning</td>
<td>Ph.D.</td>
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<td>R. Cody</td>
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<td>A. Poeth</td>
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<td>B. K. Thomas</td>
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<td>R. J. Girnius</td>
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<td>S. Z. Levine</td>
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<td>R. L. Myers</td>
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<td>1973</td>
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