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Technical Progress Letter 45

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AF Contract 29(601)-6729, Project 5710
Air Force Weapons Laboratory
Kirtland Air Force Base, New Mexico

'Study and Experimental Work on Atomic Collision Processes Occurring in Atmospheric Gases'

Atomic and Molecular Sciences Research and Development
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Unless otherwise noted, the results given in this memo should be considered as preliminary.

Approved
R. E. Fox, Director
Atomic and Molecular Sciences
Research and Development

This report covers the research conducted under the AFWL-supported portion of our program of studies of atomic collision processes occurring in atmospheric gases. The remainder of the program is reported under ARPA Order No. 125 (Amd. 11), Contract NONR-2584(00) with the Office of Naval Research.

I. Proposed Research Program and Schedules

Under Supplemental Agreement No. 1 (S.A. #1) the termination date for research conducted under the present contract has been extended to February 14, 1967. The increase in man-effort outlined in S.A. #1 will not utilize the full-time efforts of the scientific personnel for the entire contract extension period. For purposes of continuity we plan to utilize scientific effort on this contract at the normal full-time rate until the labor-effort requirements have been fulfilled. On this basis the active contract period will end in September or October 1966.

The names, classifications and time assignments of the scientific personnel working on this contract are as follows:

Dr. W. H. Kasner; Senior Physicist, full time

Dr. J. L. Moruzzi; Senior Physicist, full time

Dr. A. V. Phelps; Advisory Physicist, one-quarter time.

A. Electron-Positive Ion Recombination

The temperature dependent studies of electron-positive ion recombination in atmospheric gases will be continued during the contract extension. During the first phase of this contract the studies of the temperature dependent recombination of N_2^+ ions with electrons were completed. In order to make similar measurements in oxygen it is necessary to modify the experimental system so that it will operate in a single pulse mode. It is estimated that approximately 3 months of the contract extension period will be required for the completion of these modifications and the subsequent testing of the apparatus. Electron-positive ion recombination studies will then be conducted in gas mixtures where the predominant ion species are those found in the ionosphere, for example, O_2^+ and NO^+. These studies will be continued throughout the remainder of the active contract period. This work will be carried out by Dr. W. H. Kasner, Senior Physicist, with technician support as required.

B. Attachment and Detachment in O-O_2 Mixtures

The experimental studies directed toward the measurement of attachment and associative detachment rates in mixtures of atomic and molecular oxygen will continue during the contract extension period. Near the end of the first phase of this contract a reaction consistent with associative detachment in O-O_2 mixtures was observed. In this next period experiments will be performed to determine what neutral species, see section II. B, are involved in this reaction. If this is successful then it is hoped to be able to determine a rate for this reaction. The mass spectrometer will then be attached to the flow tube in order to identify the negative ion species involved. This work will be carried out by Drs. J. L. Moruzzi, Senior Physicist and A. V. Phelps, Advisory Physicist, with technician support as required.

C. Theoretical Studies

The theoretical studies conducted under the contract extension will be restricted to the analysis of the experimental data obtained in the studies outlined in sections I. A and I. B.

II. Report on Progress During Current Reporting Period

A. Electron-Positive Ion Recombination

The major portion of the present report period has been spent testing the operation of the system following the change over to the single pulse mode of operation. As indicated in the last report the single pulse observation technique is being used in the recombination studies in O_2-Ne mixtures in an effort to reduce the negative ion effects to a minimum. When first using the single pulse technique it was observed that the discharge did not "fire" consistently at the beginning of the microwave power pulse. This malfunction was overcome by creating a small dc discharge between two pointed tungsten wires located near the cavity wall. This discharge is of ~ 50μ sec duration and is coincident with the beginning of the microwave power pulse.

After the change-over had been completed, it seemed advisable to check out the system by conducting some further studies of N_2-Ne gas mixtures. The initial tests indicated good agreement, within 4%, between the room temperature recombination coefficients for N_2^+ ions and electrons obtained via the single pulse and recurrent modes of operation. Further tests conducted after the system had been idle for a few weeks seemed to show rather poor recombination control of the afterglow, i.e., the reciprocal of the electron density did not increase linearly with time, when the single pulse mode was used. Some preliminary afterglow studies in O_2-Ne gas mixtures have been made using both the single pulse and recurrent modes of operation. These studies also show poor recombination control of the afterglow. Various tests are now being conducted in an attempt to explain the apparent degradation of the system. No specific conclusions can be made at the present time.

B. Attachment and Detachment in O-O_2 Mixtures

Using the glass-aluminum flow tube, destruction of negative oxygen ions has been observed when the atomic oxygen discharge source is operating. Unfortunately, this source also produces excited molecular oxygen and possibly heats the neutral oxygen to temperatures sufficiently high to cause collisional detachment. Ground state atomic oxygen can be produced without the simultaneous production of excited molecular states by titrating atomic nitrogen with an equimolar amount of NO,

$$N + NO \longrightarrow N_2 + O.$$

This techniques has been used in our flow system. However, chemi-ionization, as a result of the following reactions,

$$N_2^* + N + O \longrightarrow N_2 + NO^+ + e$$

$$N + N + NO^* \longrightarrow N_2 + NO^+ + e$$

$$N_2^* + NO^* \longrightarrow N_2 + NO^+ + e$$

produces a high background signal level in the detachment region which masks the detached electron signal.

Attempts to reduce the chemi-ionization signal have been unsuccessful and it may be necessary to produce "pure" atomic oxygen by thermal decomposition of ozone. However before attempting to use this technique efforts will be made to measure a rate coefficient for the asociative detachment reaction using a buffer gas and the oxygen discharge as the source of atomic oxygen.

The mass spectrometer is ready to be coupled to the flow system at any convenient time. During some tests performed with the mass spectrometer in mixtures of CO-O_2 H_2-O_2 and NO-O_2 reactions consistent with associative detachment were observed, i.e.,

$$CO + O^- \longrightarrow CO_2 + e$$

$$H_2 + O^- \longrightarrow H_2O + e$$

$$NO + O^- \longrightarrow NO_2 + e,$$

the respective apparent rates being 7.2×10^{-10}, 7.5×10^{-10} and 2×10^{-10} in units of $cm^3 sec^{-1}$.

III. Meetings, Trips, etc.

None.

A. V. Phelps W. H. Kasner

Principal Investigators