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Photoabsorption and Photodissociation of Molecules Important in  
the Interstellar Medium

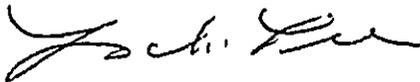
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## I. INTRODUCTION

This report describes the results obtained in the period from May 15, 1984 to May 14, 1985 for the research program supported by NASA under Grant No. NAGW-319. This research program is to measure the photoabsorption and photodissociation cross sections of molecules and radicals important in the interstellar medium. These data are currently needed for understanding the formation and destruction processes of these molecules and radicals in the interstellar medium.

## II. RESEARCH ACCOMPLISHED

In this research program, we have measured the photoabsorption and photodissociation cross sections of several interstellar molecules and radicals in the 105-210 nm region. The research results accomplished during this funding period are briefly described below.

### A. Photoabsorption Cross Section of OD

The OD radical is very similar to the most abundant interstellar radical OH in both physical and chemical nature. The photodissociation rate of OD by the interstellar radiation field is thus interested in understanding the isotope effect of the interstellar chemistry. We have measured the photoabsorption cross sections of OD in the 115-180 nm region in the current funding period. The results are summarized in a paper published in the Journal of Chemical Physics which is attached as Appendix A.

The photoabsorption cross sections are used to calculate the

photodissociation rate of OD by the interstellar radiation field. The results are summarized in a paper published in the Astrophysical Journal that is attached as Appendix B.

#### B. Photoabsorption Cross Section of CN

The CN radical is quite abundant in the interstellar medium, whose destruction is mainly through the photodissociation process. We have investigated the photoabsorption of CN in the 115-200 nm region in the current funding period. The absorption cross section is so small that only an upper limit is established. The upper limit for the photodissociation of CN by the interstellar radiation field in the 115-190 nm region is  $2 \times 10^{-10} \text{ s}^{-1}$ . This upper limit has been used by Dr. Steven Federman at the Jet Propulsion Laboratory to confirm his analysis of field observation (private communication 1984). Our results are summarized in a paper attached as Appendix B.

#### C. Photoabsorption and Photodissociation of HCl

The cross sections for the photoabsorption and fluorescence of HCl have been measured in the 105-200 nm region using synchrotron radiation as a light source. The results are summarized in a paper attached as Appendix C. In the present results, we find that the absorption cross sections at the peaks of some absorption bands are quite high so that the light source intensity may be totally attenuated at the gas pressures we used. This will make the measured photoabsorption cross sections appear low. We will confirm the measurement in the next synchrotron radiation experiment.

#### D. Photoabsorption and Photodissociation Cross Sections of CH<sub>3</sub>OH

The photoabsorption and fluorescence cross sections of methanol vapor were measured in the 106-198 nm region. Weak structures were observed in the 110-140 nm region and were classified into three Rydberg series. The fluorescence cross section was used to infer the photodissociation cross section of CH<sub>3</sub>OH that is useful for calculating the photodissociation rate of CH<sub>3</sub>OH by the interstellar radiation field. This work has been summarized in a paper attached as Appendix D, which is accepted for publication in Chemical Physics.

#### III. Publications and Presentations Resulting from this Research Program

The cumulative publications and presentations obtained from this research program are listed as follows.

PUBLICATIONS AND PRESENTATIONS RESULTING FROM THIS RESEARCH PROGRAM

1. L. C. Lee, "Emissions from Photofragments of HCN", presented at the 178th American Chemical Society Meeting, Washington, D. C., September 10-14, 1979.
2. L. C. Lee, " $\text{OH}(A^2\Sigma^+ \rightarrow X^2\Pi_1)$  Yield from  $\text{H}_2\text{O}$  Photodissociation in 1050-1370 Å", J. Chem. Phys. 72, 4334 (1980).
3. L. C. Lee, " $\text{CN}(A^2\Pi_1 \rightarrow X^2\Sigma^+)$  and  $\text{CN}(B^2\Sigma^+ \rightarrow X^2\Sigma^+)$  Yields from HCN Photodissociation", J. Chem. Phys. 72, 6414 (1980).
4. L. C. Lee, "Photodissociation of Interstellar Molecules,  $\text{H}_2\text{O}$  and HCN", presented at the 1979 Synchrotron Radiation Users Group Meeting, Madison, Wisconsin, October 25-26, 1979.
5. L. C. Lee, " $\text{CN}(A^2\Pi_1, B^2\Sigma^+ \rightarrow X^2\Sigma^+)$  Yields from HCN Photodissociation", presented at the 14th Informal Conference on Photochemistry, Newport Beach, California, March 30 - April 3, 1980.
6. L. C. Lee, " $\text{OH}(A^2\Sigma^+ \rightarrow X^2\Pi_1)$  Yield from  $\text{H}_2\text{O}$  Photodissociation", presented at the VI International Conference on Vacuum Ultraviolet Radiation Physics, Charlottesville, Virginia, June 2-6, 1980.
7. J. A. Guest and L. C. Lee, "Photoabsorption and Photodissociation of Interstellar Molecules, NO", presented at the 1980 Annual Synchrotron Radiation Users Group Meeting, Madison, Wisconsin, October 20-21, 1980.
8. J. A. Guest and L. C. Lee, "Quantitative Absorption and Fluorescence Studies of NO Between 1060-2000 Å", J. Phys. B: Atom. Molec. Phys. 14- 3401 (1981); Also presented at the Thirty-Sixth Symposium on Molecular Spectroscopy, Ohio State University, Columbus, Ohio, June 15-19, 1981.
9. L. C. Lee and J. A. Guest, "Quantitative Absorption and Fluorescence Studies of CO from 1060-1550 Å", J. Phys. B: Atom. Molec. Phys. 14, 415 (1981).
10. L. C. Lee and C. C. Chiang, "Fluorescence Yields from Photodissociation of  $\text{CH}_4$ ", presented at the 1981 Annual Synchrotron Radiation Users Group Meeting, Madison, Wisconsin, October 19-20, 1981.
11. L. C. Lee and C. C. Chiang, "Fluorescence Yields from Photodissociation of OCS at 1060-1240 Å", Chem. Phys. Lett. 92, 425 (1982).
12. M. Suto, R. L. Day, and L. C. Lee, "Fluorescence Yields from Photodissociation of  $\text{SO}_2$  at 1060-1330 Å", J. Phys. B: At. Mol. Phys. 15, 4165 (1982); also presented at the International Symposium on Chemical Kinetics Related to Atmospheric Chemistry, Tsukuba, Japan, June 6-10, 1982.
13. R. L. Day, M. Suto, and L. C. Lee, "Photodissociation Yields of  $\text{CS}_2$  at 1060-1520 Å", J. Phys. B: At. Mol. Phys. 15, 4403 (1982).
14. M. Suto, R. L. Day, and L. C. Lee, "Photodissociation Processes of  $\text{SO}_2$  at 1060-1330 Å", presented at the XV Informal Conference on Photochemistry, Stanford, California, June 26 - July 1, 1982.

15. R. L. Day, M. Suto, and L. C. Lee, "Photodissociation Processes of CS<sub>2</sub> at 1060-1520 Å", presented at the XV Informal Conference on Photochemistry, Stanford, California, June 26 - July 1, 1982.
16. R. L. Day and L. C. Lee, "Photoabsorption Spectrum of OH in the Vacuum Ultraviolet Region", presented at the XV Informal Conference on Photochemistry, Stanford, California, June 26 - July 1, 1982.
17. M. Suto and L. C. Lee, "Fluorescence Yields from Photodissociation of NH<sub>3</sub>", presented at the 15th Annual Synchrotron Radiation Users Group Meeting, Madison, Wisconsin, October 18-19, 1982.
18. L. C. Lee and M. Suto, "Photodissociation Processes of NH<sub>3</sub> at 106-220 nm", presented at the Fall Meeting of American Geophysical Union, San Francisco, California, December 7-15, 1982.
19. L. C. Lee and C. C. Chiang, "Fluorescence Yields from Photodissociation of CH<sub>4</sub> at 1060-1420 Å", J. Chem. Phys. 78, 688 (1983).
20. M. Suto and L. C. Lee, "Photodissociation of NH<sub>3</sub> at 106-200 nm", J. Chem. Phys. 78, 4515 (1983).
21. R. L. Day, and L. C. Lee, "Photoabsorption Spectrum of Radicals Produced by a Pulsed Discharge of Trace H<sub>2</sub>O in Ar", Chem. Phys. 75, 17 (1983).
22. M. Suto and L. C. Lee, "Photodissociation Processes of N<sub>2</sub>O, HNO<sub>3</sub>, and C<sub>2</sub>H<sub>2</sub>", presented at the 16th Annual Synchrotron Radiation Users Group Meeting, Madison, Wisconsin, October 24-25, 1983.
23. L. C. Lee and M. Suto, "Photodissociation of C<sub>2</sub>H<sub>2</sub>", presented at the 1983 Fall Meeting of the American Geophysical Union, San Francisco, California, December 4-9, 1983.
24. L. C. Lee, "Photodissociation Rates of Molecules by the Interstellar Radiation Field", Astrophys. J., 282, 172 (1984).
25. M. Suto and L. C. Lee, "Quantitative Photoexcitation and Fluorescence Studies of C<sub>2</sub>H<sub>2</sub> in Vacuum Ultraviolet", J. Chem. Phys., 80, 4824 (1984).
26. J. B. Nee and L. C. Lee, "Photoabsorption Cross Section of OH in Vacuum Ultraviolet", J. Chem. Phys. 81, 31 (1984).
27. J. B. Nee and L. C. Lee, "Photoabsorption Cross Section of OD at 115-180 nm", J. Chem. Phys. 81, 3811 (1984).
28. J. B. Nee, M. Suto and L. C. Lee, "Experimental Studies of the Photodissociation Processes of OH, OD, and CN" presented at the XVI Informal Conference on Photochemistry, Harvard University, Boston, August 20-24, 1984.
29. J. B. Nee, M. Suto and L. C. Lee, "Photoexcitation Processes of HCl and HBr in VUV", presented at the 1984 Synchrotron Radiation User's Meeting, Madison, Wis., Oct. 22-23, 1984.

30. J. B. Nee, M. Suto and L. C. Lee, "Photoabsorption and Photodissociation of HCl and HBr in the Vacuum Ultraviolet Wavelengths" presented at the 1984 Fall Meeting, American Geophysical Union, San Francisco, Calif., Dec. 3-7, 1984.
31. J. B. Nee and L. C. Lee, "Photodissociation Rates of OH, OD and CN by the Interstellar Radiation Field", *Astrophys. J.*, 291, 202 (1985)
32. J. B. Nee, M. Suto, and L. C. Lee, "Photodissociation Processes of Hydrogen Halides Studied with Synchrotron Radiation", to be presented at the XIV International Conference on the Physics of Electronic and Atomic Collisions, Palo Alto, CA., July 24-30, 1985.
33. J. B. Nee and L. C. Lee, "Photoabsorption Cross Sections of Interstellar Free Radicals in the Vacuum Ultraviolet Wavelengths", to be presented at the 17th International Symposium on Free Radicals, Granby, CO., Aug. 18-23, 1985
34. J. B. Nee, M. Suto and L. C. Lee, "Photoexcitation Processes of CH<sub>3</sub>OH; Rydberg States and Photofragment Fluorescence", *Chemical Physics*, in press.