LABORATORY MEASUREMENTS OF OSCILLATOR STRENGTHS OF ULTRAVIOLET MOLECULAR LINES OF HCl AND H_2O AND COLUMN DENSITIES OF THESE MOLECULES IN THE ZETA OPHIUCHI CLOUD

Peter L. Smith, K. Yoshino, and W.H. Parkinson
Harvard-Smithsonian Center for Astrophysics
Cambridge, Massachusetts, U.S.A.

The oscillator strengths of two ultraviolet molecular lines expected to be seen in diffuse interstellar clouds have been measured. For the 1290.257 Å line of HCl, f=0.16±0.06. For the 1114.225 Å line of H_2O, $f=(5.0\pm2.0)\times10^{-3}$. These results have been used in conjunction with observational data to compare measured and predicted column densities of these molecules in the ζ Ophiuchi cloud.

INTRODUCTION

The study of molecules in interstellar clouds can provide information about the physical conditions prevailing in the interstellar gas and can be used to test models of the chemical evolution of such clouds. Quantitative comparisons of observed molecular column densities with those predicted by the model calculations require oscillator strengths (f-values) for the lines studied. This paper presents the results of f-value measurements for the R(0) line of the $C(0)^1\Pi$-$X(0)^1\Sigma^+$ band of HCl and of the 1_{11}-0_{00} line of the $\tilde{F}$-$\tilde{X}$ band of H_2O. Rotational analyses of these bands have been given by Tilford et al. (1970) and by Johns (1978), respectively. The astrophysical implications of the f-value data are also discussed; the results of observations and model predictions for the column densities in the ζ Ophiuchi cloud are compared.

MEASUREMENT & DATA ANALYSIS

The apparatus and method were similar to those used for our measurements of the f-values for the $\tilde{C}(0)^1B_1$-$X(0)^1A_1$ band of H_2O (Smith and Parkinson, 1978); some differences in equipment and procedures are discussed in this section. For the measurements on HCl, an absorption cell 8.1 mm long and HCl pressures of 2.1, 2.7, and 3.2 N/m^2 were used. For the measurements on H_2O, the entire spectrograph (6.65 m focal length, 2400 line/mm grating) was filled with water vapor and the absorption by the $\tilde{F}$-$\tilde{X}$ band was compared to that by the $\tilde{C}$-$\tilde{X}$ band. Consequently our results for H_2O are relative to the absolute scale established by Smith

B. H. Andrew (ed.), Interstellar Molecules, 269–270.

and Parkinson (1978). Two plates with H_2O pressures in the ratio of approximately 1.5:1 were obtained.

The lines of the C(0)-X(0) band of HCl had a width (FWHM) of more than 70 mÅ whereas the instrumental line width was ≲15 mÅ. For the study of the $\tilde{C}(0)$-$\tilde{X}(0)$ and $\tilde{F}$-$\tilde{X}$ bands of H_2O, the second order of the spectrograph was used and the line widths were ≥30 mÅ and ≥15 mÅ respectively whereas the instrumental width was ≲6 mÅ. A computer program using Lorentz profiles was used to fit the absorption spectra.

RESULTS AND DISCUSSION

The oscillator strength of the 1290.257 Å line of HCl is 0.16±0.06. This is larger than the value, f=0.05, estimated by Morton (1975). When our value is used to revise the analysis of the observations of absorption by the ζ Oph cloud by Wright and Morton (1979), an upper limit to column density of 8.4×10^{11} cm^{-2} is obtained. That predicted by Black and Dalgarno (1977) is 2.6×10^{13} cm^{-2}. A discussion of this discrepancy and of chlorine chemistry in diffuse interstellar clouds is given by Black and Smith (1979).

The f-value of the 1114.225 Å line of H_2O is $(5.0 \pm 2.0) \times 10^{-3}$. This value has been used by Snow and Smith (1979) to estimate a probable column density of 1.7×10^{13} cm^{-2} for H_2O in the ζ Oph cloud based on a detection at the 1.8 σ level. The value predicted by Black and Dalgarno (1977) is 1.1×10^{12} cm^{-2}.

The oscillator strengths of other lines in the C(0)-X(0) band of HCl and the $\tilde{F}$-$\tilde{X}$ band of H_2O will be published (Smith et al. 1979).

The authors are indebted to J.R. Esmond and H.E. Griesinger for their indefatigable assistance. We also thank J.H. Black and T.P. Snow for their comments and advice and T.P. Snow and Wm. H. Smith for permission to quote their unpublished data. This work was supported in part by NASA Grants NSG-7034 and NSG-7156.

REFERENCES

Black, J.H., and Dalgarno, A.: 1977, Astrophys. J. Supp. Ser. 34, pp. 405-423.
Black, J.H., and Smith, P.L.: 1979, proceedings of this symposium.
Johns, J.W.C.: 1978, personnal communication.
Morton, D.C.: 1975, Astrophys. J. 197, pp. 85-115.
Smith, P.L., and Parkinson, W.H.: 1978, Astrophys. J. Lett. 223, pp. L127-L130.
Smith, P.L., Yoshino, K., and Parkinson, W.H.: 1979, in preparation.
Snow, T.P., and Smith, Wm. H.: 1979, in preparation; (cf. Snow, 1979).
Snow, T.P.: 1979, proceedings of this symposium.
Tilford, S.G., Ginter, M.L., and Vanderslice, J.T.: 1970, J. Mol. Spectrosc. 33, pp. 505-519.
Wright, E.L., and Morton, D.C.: 1979, Astrophys. J. 227, pp. 483-488.