CHLORINE CHEMISTRY IN DIFFUSE INTERSTELLAR CLOUDS

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The results of recent observations of the column densities of chlorine species in diffuse interstellar clouds are inconsistent with the column densities predicted by model calculations. The use of new atomic and molecular data fails to decrease the discrepancy. We speculate that the exothermic reaction $Cl^+ + H_2 \rightarrow HCl^+ + H$ may not be rapid at the low temperatures prevailing in diffuse interstellar clouds.

INTRODUCTION

The chemistry of chlorine in interstellar clouds has been discussed by Jura (1974) and Dalgarno *et al.* (1974). The abundances of chlorine-bearing species have been predicted for the ζ Oph and ζ Per diffuse clouds by Black and Dalgarno (1977) and Black *et al.* (1978), respectively. Observations of chlorine species have been made by Morton (1975), Jura and York (1978), and Wright and Morton (1979), who used the *Copernicus* satellite, and by one of us (JHB) who used IUE.

ABUNDANCES OF CHLORINE-BEARING SPECIES IN DIFFUSE INTERSTELLAR CLOUDS

Wright and Morton (1979) set an upper limit of W<1.9 mÅ for the equivalent width of the 1290.257 Å line of HCl in the ζ Oph cloud. Smith *et al.* (1979) have measured the oscillator strength of this line, f=0.16±0.05; thus the column density of HCl is $N(HCl) < 8.4 \times 10^{11}$ cm^{-2}. The observed column densities of Cl and Cl^+ in the ζ Oph cloud are $N(Cl) = 1.1 \times 10^{14}$ cm^{-2} and $N(Cl^+) = (1.2-4.3) \times 10^{13}$ cm^{-2} (Morton 1975). Black and Dalgarno (1977) predicted $N(HCl) = 2.6 \times 10^{13}$ cm^{-2} for this cloud. Even with an improved cross section for photoionization of Cl (Brown *et al.* 1978) in the model calculations, the predicted abundance, $N(HCl) \simeq 1.6 \times 10^{13}$ cm^{-2}, exceeds the observed limit by a factor of 18. The model also underestimates the abundance of Cl^+.

Jura and York (1978) predict a ratio of column densities $N(HCl)/N(Cl) = 0.01$ in typical diffuse clouds with high H_2 concentrations. A

B. H. Andrew (ed.), Interstellar Molecules, 271–272.

https://doi.org/10.1017/S0074180900072673 Published online by Cambridge University Press

recent survey of interstellar molecules with the IUE satellite (cf. Black 1979) establishes N(Cl) and limits to N(HCl) for the lines of sight to 13 highly-reddened stars. By neglecting the saturation of the strong 1347.24 Å line of Cl I, it is found that N(HCl)/N(Cl)<<0.1. Toward HD46223, N(HCl)/N(Cl)<0.003. Such a low limit to the HCl/Cl ratio and the relatively large Cl^+/Cl ratio in regions of high H_2 concentration like α Cam, ξ Per, and ζ Oph (cf. Jura and York (1978)) are difficult to explain merely by reducing the rate of photoionization of Cl as suggested by Jura and York (1978).

DISCUSSION

The reaction

$$Cl^+ + H_2 \rightarrow HCl^+ + H$$

both leads to the formation of HCl and reduces the abundance of Cl^+ relative to that of Cl (Jura 1974, Dalgarno *et al.* 1974). Although this reaction has a large rate coefficient, $k=7\times10^{-10}$ cm^3 s^{-1} at T=297 K (Fehsenfeld and Ferguson 1974), it is exothermic by a small amount, 0.22±0.02 eV, and the existence of a modest energy barrier can presumably not be excluded. The presence of an energy barrier would reduce the rate coefficient at interstellar temperatures, T=20-100 K, with the result that the predicted abundance of Cl^+ would increase while that of HCl would decrease. A temperature dependence in the rate of the Cl^++H_2 reaction could remove the discrepancies between the observed and predicted column densities. An experimental test of this conjecture would be useful.

We acknowledge discussions with M. Jura, T.P. Snow, and T.W. Hartquist. This work was supported in part by NASA Grants NSG-5380 and NSG-7034.

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