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SEARCH FOR H_2COH^+ AND $H_2{}^{13}CO$ IN DENSE INTERSTELLAR MOLECULAR CLOUDS

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ABSTRACT

We have searched for the 2 mm transitions of H_2COH^+ (2_{02} - 1_{01}) and $H_2{}^{13}CO$ (2_{02} - 1_{01}, 2_{12} - 1_{11}, and 2_{11} - 1_{10}) toward the dense interstellar molecular clouds Orion A, TMC-1 and L134N using the FCRAO 14 m telescope. None of the transitions have been detected except the $H_2{}^{13}CO$ transitions toward Orion-KL. We set upper limits for the abundances of the protonated formaldehyde ion (H_2COH^+), which are close to the abundances expected from ion-molecule chemistry.

Key Words : interstellar medium: abundance - molecules.

I. INTRODUCTION

Formaldehyde (H_2CO), a relatively simple organic molecule, has been found to be abundant in a variety of interstellar molecular clouds since the first detection in 1969 by Snyder et al. and Palmer et al. Even in the outer regions ($A_V \approx$ 1-4 mag) of interstellar clouds, significant amounts of H_2CO exist (cf. Federman & Allen 1991). Abundances of many molecules are thought to increase rapidly in the dense cores of molecular clouds because of the reduced number of dissociating photons. In the dense cores of molecular clouds H_2CO and the key ions of gas phase chemistry, such as H_3^+ and HCO^+, can form the protonated formaldehyde ion (H_2COH^+) easily by proton transfer reactions (Prasad & Huntress 1980). Consequently, H_2COH^+ plays a role mainly in the depletion of H_2CO and its abundance should depend critically on the abundance of H_2CO. We have searched for the 2_{02} - 1_{01} transition of H_2COH^+ using the frequency derived by Amano & Warner (1989). In this paper we report the non-detection of this transition in several interstellar molecular clouds and discuss its chemical implications.

In addition we observed the ^{13}C-containing formaldehyde ($H_2{}^{13}CO$) lines in dense molecular clouds to constraint the formaldehyde abundances better than previous results, which have been derived mostly from the optically thick main isotope lines with the aid of excitation models. The J=2-1 transitions of $H_2{}^{13}CO$ have been detected only toward Orion-KL. For the non-detected sources we set upper limits for the $H_2{}^{13}CO$ abundances and discuss our results by comparison with the main isotope H_2CO abundances in dense molecular clouds.

II. OBSERVATIONS AND RESULTS

Observations were carried out using the FCRAO 14 m telescope in 1990 January and 1992 February. Observed transitions and telescope parameters are included in Table 1. The FCRAO 2 mm receiver employs a cryogenic Schottky diode mixer, which gave total system temperatures of 600-900 K (SSB) corrected to outside the atmosphere (Ziurys, Erickson, & Grosslein 1988). Data were taken in single-sideband mode, with the image sideband terminated

Table 1. Observed Transitions and Telescope Parameters

Molecule	Transition	Rest Frequency (GHz)	FWHP (arcsec)	Beam Efficiency (%)
H_2COH^+	2_{02}-1_{01}	126.9267[a]	47	40
$H_2{}^{13}CO$	2_{02}-1_{01}	141.98375[b]	42	36
	2_{12}-1_{11}	137.44997[b]	42	36
	2_{11}-1_{10}	146.63569[b]	40	35

[a] from Amano & Warner (1989).

[b] from Johnson, Lovas, & Kirchhoff (1972).

Table 2. A Summary of the H_2COH^+ and $H_2{}^{13}CO$ Survey

	Observed Antenna Temperature (mK)				Column Density (cm^{-2})[b]	
Source[a]	H_2COH^+ (2_{02}-1_{01})	$H_2{}^{13}CO$ (2_{02}-1_{01})	(2_{12}-1_{11})	(2_{11}-1_{10})	H_2COH^+	$H_2{}^{13}CO$
Orion-KL	$\leq$ 96	570	640	430	$\leq$ 3.1(13)	5.1(13)[c]
Orion(3N)	$\leq$ 90	-	$\leq$ 210	$\leq$ 375	$\leq$ 6.1(12)	$\leq$ 4.5(12)
TMC1(HCO^+)	$\leq$ 108	$\leq$ 72	$\leq$ 126	$\leq$ 78	$\leq$ 1.5(12)	$\leq$ 8.5(11)
L134N(3N)	$\leq$ 192	$\leq$ 114	$\leq$ 96	$\leq$ 48	$\leq$ 2.7(12)	$\leq$ 1.3(12)

NOTES.- Upper limits are 3σ. Numbers in parenthese are powers of 10. Spectral resolutions are 250 kHz for Orion data and 100 kHz for TMC-1 and L134N data.

[a] Positions (R.A.[1950], Decl.[1950]): Orion-KL ($5^h32^m47^s$, -5°24'23"); Orion (3N) ($5^h32^m49^s$, -5°20'53"); TMC1(HCO^+) ($4^h38^m 16^s$, 25°42'46"); L134N(3N) ($15^h\ 51^m\ 34^s$, -2°40'31").

[b] In deriving the column densities, rotational temperatures were assumed to be 30, 15, 5, and 5 K, and line widths for the undetected transitions 3.0, 1.5, 0.6, and 0.6 km s^{-1} for Orion-KL, Orion(3N), TMC-1(HCO^+), and L134N(3N), respectively. A correction for the cosmic background radiation has been used in deriving the column densities of TMC-1 and L134N. $H_2{}^{13}CO$ column densities were derived using the 2_{02}-1_{01} transitions except for Orion(3N) for which the 2_{12}-1_{11} transition was used. The ortho/para ratio of 3:1 was assumed; this provides an upper limit, since the ratio may well be smaller.

[c] The observed line width of 2.3 km s^{-1} was used.

at 20K. Observations were made by position switching 30 arcmin in azimuth, and spectra were obtained using 256 channel filterbanks with 250 kHz and 1 MHz resolution. The temperature scale is given as T_A^*, the beam-chopper-corrected antenna temperature. For calculating column densities, we use the main beam brightness temperature $T_{MB} = T_A^*/\eta_B$, where η_B is the main beam efficiency.

None of the lines in Table 1 have been detected except the $H_2{}^{13}CO$ transitions toward Orion-KL. We summarize the observations in Table 2. We also list beam averaged column densities and upper limits for H_2COH^+ and $H_2{}^{13}CO$ in Table 2, which are derived using the standard equation assuming optically thin emission and Boltzmann population distributions (cf. Irvine, Goldsmith, & Hjalmarson 1987). The parameters used in deriving the column densities are included in the notes of Table 2.

III. DISCUSSION

The main formation route for the protonated formaldehyde ion is the reaction between H_2CO and ions (H_3^+ or HCO^+), and the destruction occurs by dissociative recombination with electrons (Herbst & Klemperer1973; Prasad

& Huntress 1980). These processes are typical reactions in gas-phase chemistry, and the models predict a relative abundance [H_2COH^+]/[H_2CO] of about one thousandth. The upper limits of the observed H_2COH^+ abundances (Table 2) are very close to one thousandth of the H_2CO abundances previously reported (Kahane et al. 1984; Irvine, Goldsmith, & Hjalmarson 1987). Although we need smaller rms values than those in Table 2 to clarify the abundance limits and the chemistry of H_2COH^+, it may be suggested that the reactions with ions are not as effective a production route in dense gas as expected.

The H_2CO abundances, however, have been derived using very optically thick lines in most cases with the aid of the excitation models associated with the statistical equilibrium and the radiative transfer approximations. Since the observations of the optically thin $H_2{}^{13}CO$ lines would certainly give better formaldehyde abundances, we have observed its J=2-1 transitions but they were not detected except toward Orion-KL (Table 2). We derive the $H_2{}^{13}CO$ abundance in Orion-KL to be 5.1x10^{13} cm^{-2}, which is similar to that of Kahane et al. (1984). They also suggested that the H_2CO lines were strongly self-absorbed in other sources such as L134N, which would indicate a large abundance of H_2CO. The $H_2{}^{13}CO$ transitions, however, have not been detected to rms levels (3σ) in Table 2. Comparing these upper limits to the H_2CO abundances of Kahane et al. (1984) suggests that with slightly greater sensitivity, $H_2{}^{13}CO$ could be detected in dark clouds. This would allow an accurate measurement of the ortho/para ratio for formaldehyde, which is important because it can provide information on chemical pathways (cf. Minh, Irvine, & Brewer 1991 on H_2CS); and it would also provide a better limit on the $H_2COH^+/H_2{}^{13}CO$ ratio. Thus, further observations should be undertaken.

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