

FORMATION OF SIMPLE MOLECULES BY C⁺ REACTIONS ON OXIDE GRAINS IN
DIFFUSE CLOUDS

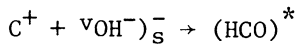
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ABSTRACT

The reaction between C⁺ ions and OH⁻ ions on the surface of oxide or silicate grains in diffuse clouds is shown to be a source of CH, OH, CO, HCO and H₂CO molecules.

The analysis of elemental depletions in the ISM by Duley and Millar (1978) has shown that selective depletion can arise through reactions of gas-phase ions with OH⁻ ions on the surface of oxide or silicate grains. The large ionization potential of C together with the fact that most C is present as C⁺ in diffuse clouds ensures that C is not selectively depleted by this mechanism. In the notation of Duley, Millar and Williams (1978) the reaction between C⁺ and surface OH⁻ can be written



where νOH^-_s is a surface OH⁻ ion adjacent to a cation vacancy. The complexes (HCO)* or (H₂CO)* are highly excited on formation and are assumed to leave the grain either as a whole or in part. Millar et al. (1979) have calculated the rate of H₂CO formation via this process and conclude that it can account for the observed H₂CO abundance in diffuse clouds (Davies and Matthews, 1972).

The formation rate of HCO or H₂CO on grains is

$$F = n_C v_C s_g n_g \quad \text{cm}^{-3} \text{sec}^{-1}$$

$$F = 1.9 \times 10^{-20} n_H^2 \quad \text{cm}^{-3} \text{sec}^{-1}$$

for oxide grains with $n_g = 4 \times 10^{-10} n_H$ and 10nm radius. n_H = the hydrogen space density, n_C = the carbon density, v_C = the thermal velocity of C⁺ ions (100 K assumed), s_g = the geometric cross-section of a grain, and

n_g = the space density of grains. For a typical diffuse cloud with $n_H = 100 \text{ cm}^{-3}$ and $A_V = 1$ the observed density of H_2CO can be shown to require a formation rate $F_{\text{H}_2\text{CO}} = 5 \times 10^{-17} \text{ cm}^{-3}\text{sec}^{-1}$ (Millar et al. 1979). The efficiency of H_2CO formation is then $\epsilon_{\text{H}_2\text{CO}} = 0.26$ assuming $n(\text{H}_2\text{CO})/n_H = 1.5 \times 10^{-9}$.

The complexes H_2CO^* and HCO^* may also dissociate. Products of the dissociation of HCO^* would be $\text{H}+\text{CO}$, $\text{O}+\text{CH}$, or $\text{C}+\text{OH}$. It is of interest to calculate ϵ for each of the diatomic molecules formed in this dissociation, as grain reactions may generate appreciable quantities of these species. Using relative molecular abundances for CH , CO and OH as given by Snow (1977) for ζ Per, one obtains, where L_X is the molecular loss or destruction rate,

X	n_X/n_H	$L_X(\text{sec}^{-1})$	$F_X(\text{cm}^{-3}\text{sec}^{-1})$	ϵ_X
H_2CO	1.5×10^{-9}	3.5×10^{-10}	5×10^{-17}	0.26
CH	10^{-8}	10^{-11}	10^{-17}	0.05
CO	5×10^{-7}	10^{-12}	5×10^{-17}	0.25
OH	5×10^{-8}	2×10^{-11}	10^{-16}	0.5

We conclude that since $\epsilon < 1$ for each of these molecules, C^+ -grain reactions occur at a sufficient rate to account for observed abundances. Since N is neutral in diffuse clouds, while C is almost wholly ionized, an analogous reaction scheme is not available for N. Thus NH should be reduced in abundance relative to CH and OH. The low abundance of NH in diffuse clouds has previously been ascribed to the dominance of gas-phase reactions (Crutcher and Watson, 1976).

REFERENCES

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