THE DETERMINATION OF ELECTRON ABUNDANCES IN INTERSTELLAR CLOUDS

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A new method for estimating electron fractions in shielded molecular clouds is proposed on the basis of gas phase ion-molecule reactions which involves measuring the quantity $\Xi = n(H_2)n(HCO^+)/n(CO)$. Applied to existing data, it yields upper limits to X_e in the range from 10^{-8} to 10^{-7} for a variety of clouds, warm as well as cool. An upper bound to the cosmic ray ionization rate is also obtained.

We propose a new method for the determination of electron abundances in dense clouds based upon the abundance ratio of two important interstellar molecules, HCO^+ and CO. In common with Watson's (1977) method, ours is derived from a simple application of gas phase, ion-molecule interstellar chemistry. Unlike the fractionation of deuterated molecules, it applies to warm as well as to cool clouds. Both procedures depend upon abundance determinations of interstellar molecules, which are still very uncertain. We shall illustrate this new method primarily with the results of the recent abundance survey of Wootten et al. (1978). In cases where deuterium enhancement is measured, we can also obtain an upper limit to the cosmic ray ionization rate.

Standard application of ion-molecule chemistry leads to the following relation for the HCO^+/CO ratio

$$\Xi \equiv n(H_2)\,\frac{X(HCO^+)}{X(CO)} = \frac{2\zeta K_1}{(\beta X_e+\delta)(\beta^1 X_e+\delta^1)} \qquad (1)$$

where K_1, β, and β^1 are measured rate constants; ζ is essentially the primary cosmic ray ionization rate; and δ and δ^1 are respectively neutral destruction rates for H_3^+ and HCO^+. Because δ and δ^1 are uncertain, the most useful form of (1) is the upper bound

$$X_e \leq \left(\frac{2\zeta K_1}{\beta\beta^1\Xi}\right)^{1/2} \qquad (2)$$

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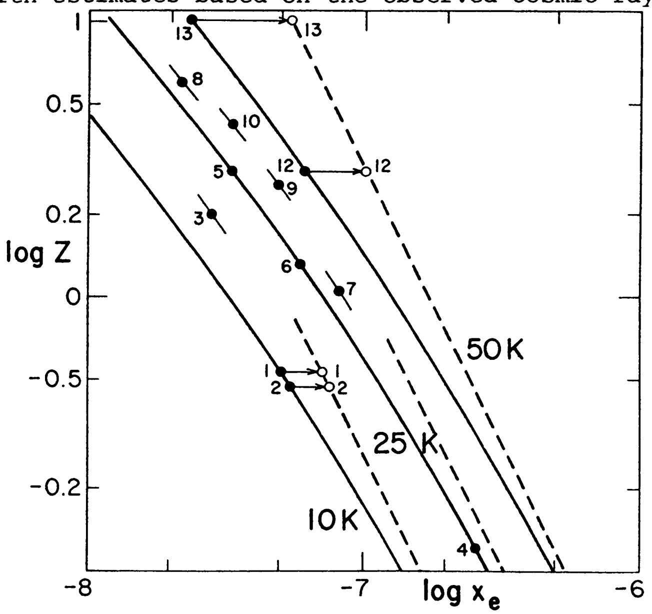
When an upper bound to X_e is already known from Watson's deuteration analysis, (1) can be converted into an upper bound on ζ:

$$\zeta \leq \frac{\beta\beta^1}{2K_1} \; [\mathrm{Max}\ (X_e)]^2 \mathcal{Z} \qquad (3)$$

Estimates of $\mathcal{Z}$ can be obtained from the analysis of molecular line emission. We illustrate the application of the above results with the data of Wootten et al. (1978) on the dense cores of molecular clouds. By placing the estimates of $\mathcal{Z}$ on the theoretical curve for the observed temperature, values for X_e can be determined. With a value for ζ of $5.10^{-18}s^{-1}$ upper limits for X_e from (2) lie in the range 10^{-8} - 10^{-7}. These limits agree with bounds already determined for L134 and L134N from analysis of DCO^+/HCO^+ ratios (Langer et al. 1978, Watson et al. 1978). For these two clouds, we deduce using (3) $\zeta \leq 5.10^{-18}s^{-1}$, in accord with estimates based on the observed cosmic ray spectrum above 1 GeV.



$\mathcal{Z}$ vs. X_e plot; filled circles are observed values numbered as in Wootten et al. (1978); solid curves are theoretical for several temperatures. Dashed curves are for $\delta=\delta^1=0$ for determining upper bounds.

References

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