RECENT OBSERVATIONS OF INTERSTELLAR MOLECULES: DETECTION OF CCO AND A LIMIT ON H$_2$C$_3$O

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Abstract. In order to test gas-phase reaction schemes for the production of small oxides of carbon in cold, dense interstellar clouds, we have searched for the radical CCO and for propadienone (H$_2$C$_3$O) in Taurus Molecular Cloud 1, a nearby cloud which exhibits a rich organic chemistry. The radical CCO has been detected with a fractional abundance some two orders of magnitude less than that of CCS, about one order of magnitude less than that of H$_2$CCO, and slightly less than that of C$_3$O. An upper limit has been obtained on the abundance of propadienone which is slightly less than that of its isomer propynal (HC$_2$CHO).

1. Introduction

There is a considerable body of evidence suggesting that some interstellar molecular material has survived incorporation into primitive solar system bodies such as carbonaceous chondrites, interplanetary dust particles (IDPs), and comets. In the case of the IDPs and meteorites, there are significant isotopic anomalies relative to solar abundances; for hydrogen, the deuterium enhancement of as much as two orders of magnitude has been attributed to ion-molecule reactions in cold interstellar clouds (e.g., Kerridge, 1991, and references therein). One would expect even clearer evidence once detailed chemical analyses are possible for cometary nuclei, which are significantly less thermally processed than the carbonaceous meteorites. Lacking such evidence at present, there is nonetheless the suggestive result that both ground-based spectroscopy and the spacecraft investigations of Comet Halley, including the results of mass spectroscopy, are consistent with a model in which comets are basically conglomerates of interstellar dust particles consisting of refractive cores and icy mantles (e.g., Whipple, 1987; Greenberg, this conference). It then follows that detailed chemical and mineralogical analyses of comets should provide evidence on the nature of the interstellar cloud where the solar system formed and the evolutionary processes leading to that formation. Conversely, the study of interstellar chemistry in star-forming regions will provide clues on the nature of the material accreted into comets and hence on models of cometary nuclei and their evolution.
At the present time it is unclear whether the solar system originated in a region where much more massive stars also were forming (a contemporary example is the Orion molecular cloud), or in one of the more quiescent, less massive dark clouds where some solar-type stars are known to be born. One may hope that a distinction can be made when more is learned of the chemical nature of cometary nuclei. The present paper is concerned with the chemistry of a cold, dark cloud, in particular of one of the most-studied core regions in such a cloud, that known as TMC-1 (e.g., Irvine, 1992). We shall deal specifically with the abundance of small oxides of carbon and their hydrogenated relatives, drawing upon observations of the rotational spectra observed at millimeter wavelengths.

It should also be borne in mind that strong arguments can be made in favor of comets and carbonaceous chondrites as the principal source of the Earth's volatiles, including the organic component (e.g., Delsemme, this conference; Chyba and Sagan, this conference; Oro, Mills and Lazzcano, this conference). Although the bulk of such material would have been pyrolyzed upon impacting the Earth's atmosphere and surface, it is certain that some complex biologically relevant molecules such as amino acids survived such impacts (Anders, 1989). It is then at least conceivable that some of these species played a triggering role in the events leading to the origin of life.

2. Testing Models of Interstellar Chemistry

The cold, dark interstellar clouds contain a number of organic molecules, including both species familiar to terrestrial biochemists and more exotic molecules which are stable in the near vacuum of interstellar clouds but highly reactive under laboratory conditions. There are, moreover, differences in abundance both among and within such clouds; for example, TMC-1 at the cyanopolyne peak is particularly rich in very unsaturated organic species, while the ammonia peak in this cloud and much of the cloud L134N are relatively richer in more hydrogenated molecules and in some oxygen-containing species (Irvine, 1992). The situation is complex, however, as some relatively large oxygen-containing organic molecules appear to be roughly equally abundant in both these clouds (for example, methanol and acetaldehyde).

Insofar as computations are possible, the abundances of the simpler species appear to be rather well matched by purely gas-phase chemical models of the ion-molecule type, which ultimately are powered by the ionization produced by cosmic rays (e.g., Bettens and Brown, 1992; Brown et al., 1990; Herbst, 1988). However, there remain a large number of free parameters in such models, in part because of the lack of laboratory data for many relevant reactions, as well as the incompleteness of laboratory data at the low temperatures characterizing these regions. Some of the modelling uncertainties can be eliminated by comparing the abundances of related molecular species. In the present paper we pursue our earlier investigations along these lines which resulted in the first astronomical identification of tricarbon