Reaction Rates and Branching Ratios of Molecules with Astrophysical Relevance

Nadine Wehres[1,2,*], Callie A. Cole[2], Nicholas J. Demarais[2], Zhibo Yang[2], Veronica M. Bierbaum[1,2] and Theodore P. Snow[1,3]

[1] Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, CO, USA
[2] Department of Chemistry and Biochemistry, University of Colorado, Boulder, CO, USA
[3] Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder, CO, USA
* Corresponding author: Nadine.Wehres@colorado.edu

Many organic molecules have been identified in the interstellar medium (ISM).[(1,2)] Studying molecules in the ISM is important, since they provide information on the local heating and cooling mechanisms and hence determine the physical conditions in their respective environments. The physical conditions can in turn trigger molecule formation, formation of stars and planets, and eventually drive the evolution of a whole galaxy; moreover they are key to our understanding of the formation and evolution of life.

Here, we will focus on methyl formate ($HCOOCH_3$), methanol (CH_3OH) and formic acid (HCOOH) which have been identified in the ISM.[(3-5)] The abundances of methyl formate in some interstellar environments are about 10^{-7} – 10^{-10} with respect to molecular hydrogen (H_2). Gas-phase reaction routes have been proposed in order to explain possible formation mechanisms, but most models significantly underestimate the abundance of methyl formate.[(6)] Inclusion of formation on interstellar grains increases the abundance of methyl formate, but does not disentangle the relative contributions of gas-phase and solid state processes. Thus, it remains unclear whether the current gas-phase models are complete, or instead further reaction pathways must be included to model interstellar gas-phase chemistry.

We will discuss possible gas-phase reaction routes to the formation of methyl formate in the gas-phase, which we have explored using a tandem FA-SIFT instrument (Flowing Afterglow-Selected Ion Flow Tube).[(1)] In general, the reagent ion (here, protonated methanol) is generated using electron ionization on a mixture of helium buffer gas and methanol. Mass-selection of the ions of interest is achieved by using a quadrupole mass filter, and helium buffer gas is used to thermalize the hot reactant ions. Upon injection into the flowtube, neutral species (here, formic acid) can be added and the ionic products are detected using a second quadrupole mass analyzer in combination with an electron multiplier. Preliminary results indicate the formation of protonated methyl formate from formic acid and protonated methanol as precursor gases. Reaction rates and branching ratios for different pressure and temperature regimes were obtained. We will discuss the results and their implications for astrophysical models.

References

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