Mechanisms of the formation of organic matter in protostellar objects

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The origin of life in the universe remains one of the most fundamental and interdisciplinary questions in modern science. In recent years, astrophysical studies aimed at studying the molecular composition of the interstellar medium have made a significant contribution in solving these questions. Next-generation ground-based instruments, as well as space missions, make it possible to discover an ever-widening variety of molecules in space.

Despite significant progress in observations, experiments and theoretical research, the picture of the evolution of organic matter in the Galaxy, as well as an understanding of the mechanisms and factors that influence the evolution of organic molecules in space, is still far from complete. Formation of complex organic molecules in several important astrophysical environments, including earliest stages of low-mass star formation and photodissociation regions (PDRs) is yet to be fully understood. Laboratory experiments on low-temperature reactivity on the analog of interstellar grains carried out recently challenge several long-standing concepts in astrochemistry, including important reaction schemes, e.g., formation of methanol, and even the entire diffusive chemistry paradigm.

Recent promising developments in astrochemical research include scenarios for the formation of cold complex molecules via gas-grain chemistry facilitated by reactive desorption, non-diffusive chemistry in the ice, understanding the role of cosmic rays in the processing of interstellar ice, observational constraints on the efficiency of reactive desorption and steps toward understanding the "top-down" chemistry in PDRs. It was shown that "top-down" chemistry can significantly affect abundances of species observed in PDRs, while gas-phase reactions between reactants formed on grains and ejected to the gas via reactive desorption, and non-diffusive chemical processes in interstellar ices may lead to the production of large amounts of complex organic molecules in prestellar cores. Research with recently launched James Webb Space Telescope (JWST) is expected to give a further boost to astrochemical research, especially to our understanding of the formation and evolution of complex organic molecules in the ices. New experimental facilities such as Monitor for Astrochemical Reactions on Surfaces (MARS) as well as microscopic and macroscopic models of the evolution of interstellar ices and astrophysical environments in general (e.g., MONACO) are already either under development or available for the community.

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