Formation of Complex Organic Molecules via Ice Mantle Reactions in Protoplanetary Disks

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We have contracted chemical reaction network with ice mantle reactions in addition to gas-phase reactions, gas-grain interaction, and grain-surface reactions in order to investigate their effect on formation of complex organic molecules in protoplanetary disks. As the reaction rate of the ice mantle reactions, we have developed a formula based on the recent laboratory experiments which suggest crystallization of water ice induces the mantle reactions. Periodic FU Ori-type outbursts, which sometimes observed in young protostellar objects, are considered as a heat source required for the ice mantle reaction. Our calculations show that the ice mantle reactions occur efficiently at the temperature of >120K, where the time scale of the ice mantle reaction is sufficiently shorter than the time scale of the outbursts, and produce sufficient amount of ammonium carbamate, which accounts for the broad absorption features observed in the reflected spectra of the comet 67P/Churyumov-Gerasimenko in the Rosetta mission. We simply estimate the temperature of possible comet forming regions in the protoplanetary disks, showing that the mass accretion rate of 10^{-5} solar mass per year is required in order to explain the heating source to produce the ammonium carbamate by FU Ori-type outbursts. The effect of the ice mantle reactions depends on the structure of ices, namely the thermal history of small bodies and has room for further improvement in future work.

Keywords: protoplanetary disks, astrochemistry, formation of organic molecules

