Formation of complex organic molecules through ice mantle reactions

C.-E. Wei[1], H. Nomura[2], P. Theulé[3], and C. Walsh[4]

[1]*EPS Department, Tokyo Institute of Technology, Japan*
[2]*Divison of Science, National Astronomical Observatory of Japan, Japan*
[3]*Laboratory of Astrophysics of Marseille, Aix-Marseille Université, France*
[2]*School of Physics and Astronomy, University of Leeds, UK*

Recent solar system exploration missions, such as Rosetta mission, have found various complex molecules in solar system objects. Some of these materials are thought to be pristine and produced before the solar system objects are formed. Meanwhile, recent development in astronomical observations, for example, by ALMA, as well as in chemical model calculations have brought us new knowledge on formation of complex organic molecules in protoplanetary disks, natal place of planet formation [1][2][3].

In interstellar clouds it is believed that complex organic molecules are mainly formed through grain surface reactions. Meanwhile, laboratory experiments suggest that ice mantle reactions can proceed in certain conditions, and produce more complex species [4]. In this work we have constructed a formula of mantle reaction rate based on the recent laboratory experiments which show ice chemistry proceeding through the thermal process inside the ice bulk. Also, we introduced the obtained reaction rates to chemical reaction network with three phase model including gas-phase, grain surface, and ice mantle reactions. We performed model calculations with different physical conditions, which show that the mantle reactions can proceed efficiently when the temperature is higher than ~120K.

In addition, we adopt some physical conditions of protoplanetary disks in early evolution phase, taking account of the temperature increase caused by FU Ori type outbursts, and investigate the effect on formation rate of COMs via mantle reactions. We especially focus on the formation rates of the materials detected on the comet 67P/Churyumov-Gerasimenko in the Rosetta mission, and found that the mass accretion rate of 10^{-5} solar mass per year is required in order to produce the ammonium carbamate found in the comet 67P/C-G efficiently at comet forming region in protoplanetary disks [5].

References

[1] C. Walsh, T.J. Millar, H. Nomura et al. 2014, A&A 563, A33.
[2] C. Walsh, R. Loomis, K. Oberg et al. 2016, ApJL 823, L10.
[3] C. Walsh 2015, EAS Publication Series 75-76, 315.
[4] P. Ghesquière, A. Ivlev, J. A. Noble, and P. Theulé, 2018, A&A 614, A107.
[5] C.-E.. Wei, 2019, PhD Thesis.