From Interstellar Ices to PAHs
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INVITED TALK

Grain Surface Chemistry: What Happens Without Photons and Ions

Naoki Watanabe[1]

[1] Institute of Low Temperature Science, Hokkaido University, Sapporo 060-0819, Japan

E-mail: watanabe@lowtem.hokudai.ac.jp

In molecular clouds where radiation fields are very weak, nonenergetic processes on grain surfaces play a key role in chemical evolution before molecules are suffered from significant photons and ions (as reviews, see Watanabe & Kouchi 2008; Hama & Watanabe 2013). In fact, some abundant molecules like H_2, water, and primordial organic molecules are considered to be formed by grain surface reactions. The formation processes of these molecules were first proposed theoretically. Following the theoretical works, many experiments have been performed to demonstrate the formation pathways on grains. First set of experiments, and some of recent experiments, have focused on hydrogenation to produce H_2, H_2CO, CH_3OH, H_2O, NH_3 and so on. Subsequently, surface diffusion of hydrogen atom prior to reactions was targeted because surface reactions would occur predominantly via Langmuir-Hinshelwood mechanism. The next step is going on the diffusion and reactions of heavier species like oxygen and radicals. Grain surface reactions were found to also contribute to deuterium enrichment of molecules with the assistance of gas phase chemistry. To reach the extreme deuterium enrichments, it is crucial whether hydrogen-deuterium substitution process of which first step is tunneling reactions occurs. We investigated experimentally deuterium surface reactions for water, formaldehyde, methanol, ethanol, ethylene, ethane, methylamine, glycine, and etc. These molecules can be categorized into three groups in the order of feasibility of deuterium enrichment by surface reactions. Recently, several experiments showed that ice surface acts as catalyst for nuclear spin conversion of molecules, of which H_2 is closely related to H_2D^+ formation and thus deuterium enrichment in the gas phase. It should be understood how grain surfaces affect the ortho-para ratios of molecules like H_2 and H_2O. In my talk, I will overview the experiments on nonenergetic surface processes and give prospects for future experiments.

REFERENCES

Watanabe, N. and Kouchi, A. (2008) Prog. Surf. Sci., 83, 439
Hama, T. and Watanabe, N. (2013) Chem. Rev., 113, 8783