ROLE OF TUNNELING IN THE FORMATION AND DEUTERIUM ENRICHMENT OF MOLECULES ON DUST GRAINS. N. Watanabe[1], Y. Oba[1], T. Hama[1], H. Hidaka[1] and A. Kouchi[1], [1]Istitute of Low Temperature Science, Hokkaido University (N19-W8, Sapporo, Hokkaido 060-0819, Japan; watanabe@lowtem.hokudai.ac.jp).

Among many kinds of interstellar molecules observed, the abundances of some major species such as H_2, H_2O, and organic molecules cannot be explained by gas-phase synthesis; therefore, surface reactions on dust grains are considered for the synthesis of such molecules. In an interstellar molecular cloud where the temperature is as low as 10 K and the radiation field is very weak, the energetic processes of ice dust grain such as photolysis and ion-bombardment of ice mantles is inefficient and thus tunneling surface reactions involving hydrogen atom become important for chemical evolution [1]. Theoretical approach to the surface tunneling reaction is not easy because the tunneling is very sensitive to temperature, tunneling mass, and reaction potential surface which strongly depends on the composition and structure of the surfaces. Therefore, the quantitative experiments are desirable to understand the surface tunneling reactions relevant to chemical evolution on dust grains.

To date, various deuterated species have been found in interstellar clouds, comets, and meteorite. Deuterium fractionation process in interstellar molecules has long been a topic of interest in not only interstellar chemistry but also earth and planetary sciences, because it may be a potential explanation for the high deuterium fractionations observed in our solar system. Recently, some interstellar molecules such as formaldehyde and methanol are found to be multiply deuterated and extremely deuterium enriched up to the abundances of several tens of percent relative to normal molecules. Pure gas phase chemistry cannot explain this extreme deuterium enrichment. Therefore, deuterium-enrichment process on dust grains need to be investigated.

From the above background, we have performed a series of experiments to clarify the role of tunneling reactions in the formation and deuterium enrichment of molecules on ice dust grains [2]. We have demonstrated the formatin pathways for water [3,4], ethane, ethylene, formaldehyde, and methanol [5] molecules via tunneling mainly on the surface of ice dust analogues, amorphous solid water, at low temperatures as low as 10 K. In addition, we examined the tunneling deuterium reactions whether those can contribute to deuterium enrichments of above listed molecules and also, the other organic molecules: ethanol which is homologue of methanol, benzene [6], methylamine [7], and glycine [8] which is the simplest amino acid. We found that hydrogen-deuterium (H-D) substitutin reaction is a key to produce high-deuterium enrichment as observed in methanol and formaldehyde, while deuterium addition reaction can only contribute to moderate enrichment up to several percents. For H-D substitution reaction, the dependence of reactivity on molecular structure and functional group was investigated. In my talk, the series of our experiments on the formation and deuterium enrichment by tunneling reactions on ice dust are reviewed.

References:

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