【Grant-in-Aid for Scientific Research(S)】

Science and Engineering (Mathematical and physical sciences)

Title of Project： Mechanisms of formation and isotope fractionation of interstellar molecules on cosmic dust

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Research Area：Earth and Planetary Science

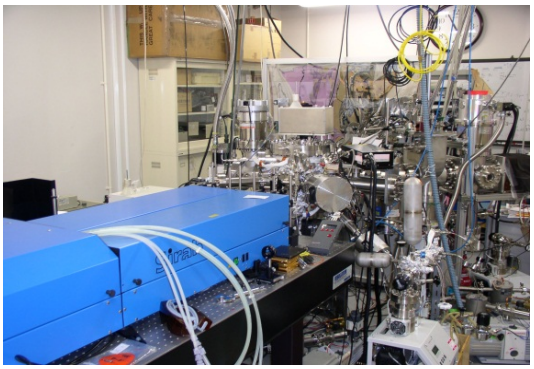
Keyword：Chemistry of the extraterrestrial material, Grain surface reaction

【Purpose and Background of the Research】

Formation and isotope fractionation of molecules in molecular clouds are very important as the initial stage of chemical evolution in space. Studies using gas-phase reaction network have been partly successful in explaining chemical evolution. However, it has been recognized that, among interstellar molecules observed, some dominant species such as H_2, H_2O, CO_2 and organic molecules are hardly produced in the pure gas phase and thus require the synthesis on cosmic dust grains. In spite of its importance, little is known about the details of grain surface reactions. Against this background, we have performed a series of experiments and found some important surface processes. The purpose of project is to considerably extend our research on grain surface reaction relevant to chemical evolution including the isotope fractionation.

【Research Methods】

A typical apparatus for our experiments consists of a He refrigerator, an atomic (radical) source, a Fourier-transform infrared spectrometer (FTIR), a tunable pulsed dye laser system, and a time of flight mass spectrometer in an ultra-high vacuum chamber as shown in Fig.1. The experiment will be performed typically with the following sequence: 1. preparation of dust grain analogues on a very low temperature substrate; 2. deposition of reactant molecules or atoms on the surface; 3. exposure of the sample surface to cold atoms (radicals); 4. measuring the number densities of parent and product molecules with FTIR and resonance-enhanced multiphoton ionization methods for solid (surface) and gas phases, respectively. With this procedure, we will obtain the surface reaction rates for specific channels and those dependences on surface material, temperature and structure, and also energy distribution and nuclear spin temperature of desorbed molecules. We will try to construct the grain surface reaction network including the isotope fractionation processes and to have a whole picture of chemical evolution on dust.



【Expected Research Achievements and Scientific Significance】

Our project would reveal experimentally for the first time how molecules such as H_2 and H_2O form on the surface of dust grains and how grains play a role in the isotope fractionation of molecules in molecular clouds. The determination of surface reaction rates and reaction channels will enable us to construct the reaction network for understanding chemical revolution. Our results would also provide the information of tunneling reaction on various kinds of surfaces, which would interest researchers in related fields of science.

【Publications Relevant to the Project】

- N. Watanabe, *et al.*, “Direct measurements of hydrogen atom diffusion and the spin temperature of nascent H_2 molecule on amorphous solid water”, Astrophys. J. Lett. 714, L233-236 (2010)
- N. Watanabe & A. Kouchi, “Ice surface reactions: a key to chemical evolution in space”, Prog. Surf. Sci. 83, 439-489 (2008)

【Term of Project】 FY2012-2016

【Budget Allocation】 99,800 Thousand Yen

【Homepage Address】

http://www.lowtem.hokudai.ac.jp/astro/index.html