The surface diffusion mechanism of hydrogen atom on interstellar ice

K. Kuwahata[1], T. Hama[1], N. Watanabe[1] A, Kouchi[1], Y, Kimura[1]

[1]*Institute of Low Temperature Science, Hokkaido University, Japan*

It has been recognized that the abundance of some important molecules, including H_2, H_2O and NH_3, cannot be explained by pure gas-phase formation, and that surface reactions on dust grains are crucial to explain the production of those molecules. Molecular formation on ASW proceeds via elementary processes of reactants: adsorption, diffusion, and reaction with another absorbed reactant. Since in cold and dense clouds dust grains are covered with amorphous solid water (ASW), the diffusion of H atoms on ASW is of significant importance for the surface reactions. For the diffusion mechanism of H atom on ASW, quantum tunneling and thermal hopping are often advocated [1]. However, there have been no experimental reports on the diffusion mechanism of H-atom on ASW. Recently, Watanabe et al. (2010) presented the results of a novel type of experiment to shed light on the longstanding dispute about the activation energy of H atom diffusion on ASW [2]. They performed direct detection of H atoms adsorbed on ASW using photostimulated desorption (PSD) and resonance-enhanced multiphoton ionization (REMPI). In the present study, we extended this method to measure the diffusion of deuterium atom on ASW. From the isotope effect of surface diffusion, we discuss the diffusion mechanism of H atom on ASW [3].

The figure shows the time variations of the signal intensities of H and D atoms (I_H and I_D) photodesorbed from ASW at 8 K as a function of the waiting time, *t*, after the deposition of atoms. Our another experiment found out that monoatomic desorption from ASW plays only a minor role, and the attenuations of I_H and I_D on the ASW surface after atomic deposition are thus caused mainly by recombination of the atoms following diffusion. Both I_H and I_D decrease at a similar rate. We derived the activation barriers for the diffusion of H and D atoms to be 22 and 23 meV, respectively. Since the tunneling effect strongly depends on the particle mass, thermal hopping better explains the diffusion mechanism rather than tunneling.

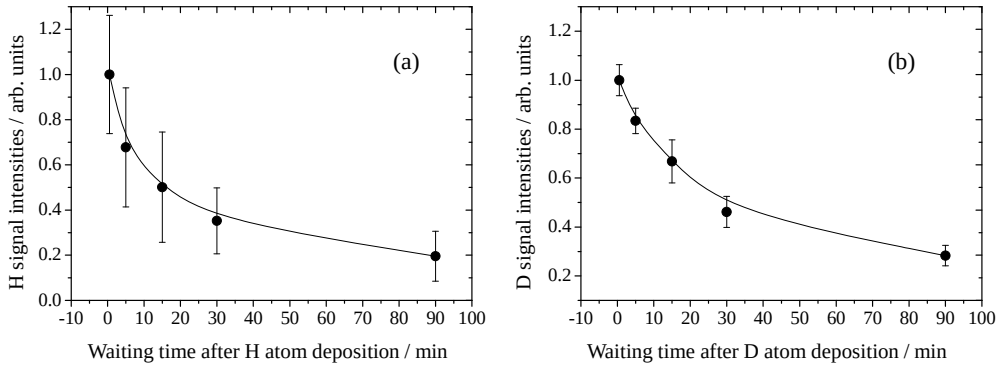

Figure: Attenuation of photodesorption intensities of (a) H atoms and (b) D atoms adsorbed on ASW at 8 K as a function of the waiting time after a deposition time.

References

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[2] N. Watanabe, Y. Kimura, A. Kouchi, et al. 2010, ApJ 714, L233

[3] T. Hama, K. Kuwahata, N. Watanabe, et al. 2012, ApJ 757, 185