Formation process of deuterated methanol from carbon monoxide on interstellar grains

Akihiro Nagaoka[1]; Naoki Watanabe[2]; Akira Kouchi[3]

[1] Inst. Low Temp. Sci., Hokkaido Univ.; [2] Inst. of Low Temp. Sci., Hokkaido Univ.; [3] Inst. Low Temp. Sci., Hokkaido Univ

1. Introduction

Recent observations have shown that deuterium enrichments in formaldehyde (H2CO) and methanol (CH3OH) in molecular clouds are four orders of magnitude lager than cosmic D/H ratio of 10^-5 [1, 2]. Some theoretical models including grain-surface reactions have been proposed to explain observed deuterium enrichments [3, 4]. In such models, the high atomic D/H ratio is produced by ion-molecule reactions in the gas phase and subsequently successive hydrogenation and deuteration of CO on grain surfaces leads to the D enrichment of formaldehyde and methanol. Our recent experiments, however, revealed that the rate of deuteration of CO is smaller than that of hydrogenation by a factor of 1/5 [5]. Therefore, successive hydrogenation/deuteration of CO on grains would not work efficiently as the D enrichment process. Recently, we proposed the H-D substitution reaction of D atoms with methanol as the D enrichment process on grains [6]. In the present work, to investigate the validity of our model, H-D substitution in methanol, directly, we expose pure solid CO to H and D atoms simultaneously at 10 K.

2. Experimental

The experimental apparatus and procedures are as follows. The aluminum substrate was placed in the centre of an ultra high vacuum chamber (10^-10 Torr) and cooled to 10 K by a helium refrigerator. CO gas was deposited to cold Al-substrate to produce an interstellar grain analogue. H and D atoms produced by microwave-induced discharge of H2-D2 mixed gas were irradiated to pure solid CO. During the irradiation of H and D atoms, the variations of chemical compositions in the sample were measured, in-situ, by FT-IR.

3. Results & Discussion

As a result of the irradiation of H and D atoms, H2CO, HDCO, D2CO, CH3OH, CH2DOH, CHD2OH, and CD3OH were produced, but no hydroxyl-deuterated methanol (e.g., CH3OD) were detected. The spectral change of CH3OH and CH3OH-d indicates that methyl-deuterated methanol (CH2DOH, CHD2OH, and CD3OH) do not form through successive hydrogenation/deuteration of CO, but H-D substitution reaction as we proposed [6].

The sum of observed abundances of deuterated methanol is reproduced in the present experiment with irradiation time of 100 min. This result demonstrates that the H-D substitution reaction of D atoms with methanol on grain surfaces plays an important roll in the D enrichment of methanol in molecular cloud. Deuteration of formaldehyde will be mentioned by Dr. Hidaka in the present session.

References

[1] van Dishoeck, E.F. et al. 1995, Astrophys. J., 447, 760
[2] Ceccarelli, C. et al. 2001, Astron. Astrophys., 372, 998
[3] Tielens, A.G.G.M. 1983, Astron. Astrophys., 119, 177
[4] Charnley, S. B. et al. 1997, Astrophys. J., 482, L203
[5] Hidaka, H. et al. 2004, Japan Earth & Planetary Science Joint Meeting, P058-007
[6] Nagaoka, A. et al. 2004, Japan Earth & Planetary Science Joint Meeting, P058-006