Formation process of deuterated methanol from carbon monoxide on interstellar grains

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1. Introduction

Recent observations have shown that deuterium enrichments in formaldehyde (H2CO) and methanol (CH3OH) in molecular clouds are four orders of magnitude larger 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 role in the D enrichment of methanol in molecular cloud. Deuteration of formaldehyde will be mentioned by Dr. Hidaka in the present session.

References