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Formation of deuterated methanol by surface reactions at 10 K

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Recent observations have revealed that the abundances of some deuterated interstellar molecules are extremely larger than the cosmic D/H ratio of 10^{-5}. In particular, the deuterium fractionation in methanol was found in not only molecular clouds [1, 2] but also comets [3] and the ratio of methanol-*d* to CH_3OH is up to approximately 0.4. Although several models have been proposed to reproduce the D-enrichments in the interstellar methanol, these are rather ambiguous due to the lack of information about the dust-surface reactions such as reaction channels and the rates of hydrogenation (deuteration). It is therefore highly desirable to clarify experimentally the role of the surface reactions in D fractionation. We report our experimental results demonstrating that the H-D substitution in solid CH_3OH proceeds more efficiently than successive H and D addition to solid CO to produce deuterated methanol at 10 K. These results indicate a key route for deuteration of methanol on ice dusts, which could explain the observed abundance of deuterated methanol isotopomers in molecular clouds.

The pure solid CO, prepared on an Al-substrate at 10 K, was exposed to cold (30 K) H and D atoms simultaneously at the atomic D/H ratio of 0.1. The variations of the column densities for the parent and products in ice were measured by FTIR. After the exposure, significant amounts of Me-d_n-OH molecules were obtained. The ratio of methanol-*d*/CH_3OH becomes approximately 0.3 at the exposure of 70 min, for which atomic fluence corresponds to that expected in a molecular cloud over 10^6 yr. These results are consistent with the observations very well. The features in the variations of Me-d_n-OH with the exposure clearly indicate H-D substitution in CH_3OH as a formation route rather than successive H and D addition to solid CO. The H-D substitution process must be the key route for D-enrichment in the interstellar methanol once the high atomic D/H ratio is achieved as suggested by the models.

References

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