Laboratory simulation of competition between hydrogenation and photolysis in the chemical evolution of H_2O-CO ice mixtures

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Photolysis and hydrogenation of ice dust are important processes of chemical evolution in molecular clouds. Phyotolysis has been studies experimentally by many researchers using astrophysically-relevant ice-mixture and found to yield various molecules [e.g. 1,2]. Hydrogenation has been first proposed theoretically since 1980s [3] as a main formation route of formaldehyde and methanol from a primordial CO molecule on ice dust. Recently, the series of our experiments [4] have confirmed that this process efficiently proceeds due to tunneling effect under the condition of quiescent molecular cloud where the temperature is as low as 10 K. Experiments of photolysis and hydrogenation were performed separately by different groups with their own experimental conditions. In addition, kinetic data such as rate constants obtained are still not enough. It is very difficult not only to measure those data for surface reactions but also to construct the models because reactions strongly depend on the surface composition and morphology. Therefore, the relative importance of photolysis and hydrogenation in molecular clouds was not examined. To do so, the simulation experiments for those processes under well controlled conditions were very desirable.

In the present study, photolysis and hydrogenation of H_2O-CO binary ice mixtures (as the analogues of the most primordial ice composition) at 10–50 K are investigated in order to quantitatively evaluate their relative importance in the chemical evolution of interstellar dust icy mantles [5]. The dominant product of photolysis was CO_2, with lower yields of formaldehyde, methanol, and formic acid, while only formaldehyde and methanol were obtained by hydrogenation reactions. Hydrogenation has higher formation efficiencies and yields of formaldehyde and methanol than photolysis. However, the contribution of photolysis should not be negligible for the formation of these molecules in molecular clouds, in contrast to the previously reported results [2]. The simultaneous irradiation of binary ice mixtures with hydrogen atoms and UV photons resulted in relative abundances of CO_2, formaldehyde, methanol, and formic acid that are consistent with the observed abundances. Our results show that the composition and structure of ice are crucial in the chemical evolution of ice mantles, as much as the temperature and the type of irradiation.

References

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