Chemical evolution of CO molecule on interstellar grain surfaces: Photolysis vs. Hydrogenation

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Chemical processes on dust grains play an important role in the formation of interstellar molecules such as H_2, H_2O, and organic molecules. The molecules formed on dust surfaces partly remain as icy mantle and thus become a dust-dust interface of aggregate. Therefore, chemical processes on the dust surfaces are relevant to not only chemical evolution in molecular clouds but also the growth of dust aggregate.

We are interested in the formation processes of the simple organic molecules, H_2CO, CH_3OH, and CO_2, observed in icy mantle on dust grains. These molecules are abundant in icy mantle and important as precursors of more complex organic molecules. To evaluate the roles of photolysis and reactions of hydrogen atoms (hydrogenation) in the formation of those molecules under the various conditions of molecular clouds, we performed the experiments on the UV and H atom irradiation of the analogues of primordial dust mantle (H_2O-CO ice). The measurements of atom- and photon-flux enable to investigate quantitatively these competing processes and determine reaction rates.

The major difference in the results between photolysis and hydrogenation is the number of products. Photolysis yields CO_2, HCOOH, H_2CO, CH_3OH, CH_3CHO, and possibly undetectable small amount of other products, while only H_2CO and CH_3OH are obtained in hydrogenation. The main channel of photolysis is the production of CO_2. The efficiency of H_2CO and CH_3OH formation (yields for 1 photon and 1 atom) and the total amount of those yields for the hydrogenation are higher than those for photolysis. Considering the condition of molecular clouds, we conclude that production of CO_2 is owing to photolysis, while hydrogenation is responsible for H_2CO and CH_3OH. The results for simultaneous exposure to hydrogen atoms and UV photons reproduced the observed abundances of CO_2, HCOOH, H_2CO, and CH_3OH fairly well.