

Molecular formation by transient diffusion of reaction products on cold ice surfaces

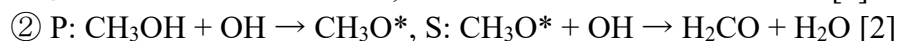
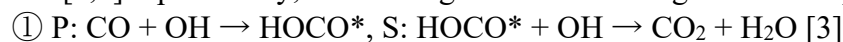
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In molecular clouds, molecular evolution proceeds efficiently through physicochemical processes such as adsorption, diffusion, association, and reactions of atoms and molecules on interstellar dust surfaces. In particular, thermal diffusion of hydrogen atoms is a crucial process for forming simple molecules, which has been widely studied [1]. On the other hand, the formation of complex organic molecules (e.g., HCOOCH_3) would require association reactions between “heavier radicals (e.g., HCO or CH_3O)” than hydrogen atoms. However, on the cold ice surfaces of 10 K, thermal diffusion of these heavier radicals is inefficient. In contrast, non-thermal diffusion processes of radicals may play a role in the formation of complex organic molecules under cold molecular cloud environments as low as 10 K. We experimentally observed that radicals generated by surface reactions transiently diffuse, even at 10 K, during the process of dissipating reaction heat to the surface [2, 3], which is referred to as “transient diffusion.”

In this work, we obtained information on transient diffusion by probing secondary reactions (S) of radicals (① HOCO , ② CH_3O) formed from primary reactions (P) between parent molecules (① CO , ② CH_3OH) and OH on 10 K ice surfaces, using a highly sensitive “ion pickup” apparatus [4,5]. Specifically, we investigated the following reaction sequence:



Here, “*” represents the transient state during the dissipation of reaction heat before thermalization at the surface temperature. The experimental procedure was as follows (Figure 1). First, trace amounts of OH (up to ~ 0.01 ML) radicals were produced by UV irradiation of the ice surface. After the irradiation, the parent molecules were deposited onto the OH -prepared ice surface at 10 K, which generated the radical products. Next, we detected products formed by secondary reactions between the generated radical products and another OH . Under the present experimental conditions, where the coverages of radicals were very low, the detection of secondary reaction products indicates the occurrence of transient diffusion, since the radical products and OH do not undergo thermal diffusion. By probing these secondary reactions, we obtained information on transient diffusion.

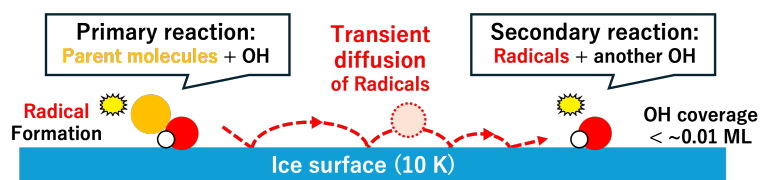


Figure 1: Schematic diagram of the present experimental procedure.

References

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