Fischer-Tropsch Catalysis and Clathrate Formation in Circum-Planetary Subnebula: Origin of Methane on Titan

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Titan has a thick atmosphere dominated by CH4. However, CO are thought to be the main reservoir of gas-phase carbon in the interstellar cloud and the solar nebula. Thus, methane-producing reaction from CO in circum-planetary subnebula is important for understanding the origin of CH4 on Titan. Fischer-Tropsch catalysis, which converts CO and H2 into CH4 on the surface of iron catalyst, has been suggested to proceed in the subnebula. However, the quantitative laboratory data under the condition of circum-planetary subnebula has not been available yet. It is, thus, difficult to assess accurately the role of Fischer-Tropsch catalysis in the subnebula and the origin of CH4 on Titan.

In this study, we investigate experimentally CH4 formation rate and conduct theoretical calculation of clathrate formation under the condition of circum-planetary subnebula. Our experimental data indicate that Fischer-Tropsch catalysis proceeds efficiently at T ~ 550 K in the subnebula.

As the subnebula cools with time, gas species are trapped into solids by clathration. Therefore, in the weakly mixing subnebula, CH4-rich satellitesimals are formed in the CH4-rich gas region, where Fischer-Tropsch catalysis proceeds efficiently. Outside this region, where the gas composition is estimated to be similar to that of the solar nebula, CO2-rich satellitesimals are formed.

Our result suggests that Fischer-Tropsch catalysis contributes for formation of the CH4-rich region in the subnebula, and CH4-rich satellitesimals formed in this region play an important role in the origin of CH4 on Titan.