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Polymerization of methane under the Earth mantle and Neptune conditions.

Hisako Hirai[1*], Ayako Shinozaki[1], Taro Kawamura[2], Yoshitaka Yamamoto[2], Takehiko Yagi[3]

[1]Geodynamics Research Center, Ehime Univ., [2]AIST, [3]ISSP, Tokyo University

Methane is the simplest hydrocarbon and exhibits a large distribution over the Earth, solar system and space as a gas, fluid and solid. In the Earth, C-H-O fluids, including methane, change critically melting temperature and properties of mantle minerals, which affects to magma formation, global material cycling, and mantle dynamics. According to a thermodynamic calculation, the speciation of C-H-O fluid is controlled by the oxidation states; at the crust and the upper part of the mantle, CO2-H2O fluid is major, while at the transition zone CH4-H2O fluid is major (Frost & MaCammon, 2008). A high-temperature-pressure experiment reported formation of methane molecules by a reaction of wustite, calcite and water under the upper mantle conditions (Scott et al 2004). Some theoretical calculations showed that methane and heavier hydrocarbons can exist stably in the mantle (kenny et al. 2002). Actually, methane fluid was found in diamond inclusions, and other hydrocarbons were also found in mantle-derived rocks. These experimental, theoretical, and field data showed that methane can exist stably in the mantle. However, study on state changes for methane coexisting with mantle minerals has been extremely limited, although comprehensive ones have been made on water-mantle mineral systems.

Outside of the Earth, methane is thought to be one of the most important constituents in the icy planets such as Uranus and Neptune. Based on many space craft probes and theoretical studies, a current model of the internal structure of the icy planets has been drawn, namely that these planets are composed of a hydrogen-helium atmosphere, a water-methane-ammonia ice mantle and a rocky or metallic core (e.g. Hubbard et al., 1991). Below the atmosphere there exists a vast, hot ocean of water-methane-ammonia at several thousand Kelvin (Hubbard, 1997), although that layer has been customarily denoted as ice. States of these constituents under such conditions have not fully been confirmed by experimental studies.

In this study, high-temperature-pressure experiments for methane together with olivine were performed by using laser-heated diamond anvil cells under mantle conditions. The X-ray diffractometry and Raman spectroscopy showed that polymerization of methane occurred to form heavier hydrocarbons. And, similar experiments were made for sole methane under the conditions comparable to those of the ice mantle of Neptune. The results revealed that methane melted above 1100K, and polymerization began in the melt. With increasing temperature, heavier hydrocarbons were formed, and finally diamond was produced.

Keywords: methane, polymerization, mantle condition, Neptune, diamond