

## Phase Equilibria and Crystallography of He + THF Clathrate Hydrate

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Clathrate compounds are crystalline materials formed by a physical interaction between host and relatively light guest molecules. Recently, we reported two peculiar phenomena, swapping and tuning, naturally occurring in the hydrate cages. Helium, one of the smallest light guest molecules, must be the challengeable material in the sense of physics and moreover possess the versatile applications in the field of superconductivity technology and thermonuclear industry. In this regard, we attempted for the first time to synthesize helium hydrates at moderate temperature and pressure conditions. According to inclusion phenomena, helium itself normally cannot form clathrate hydrates due to being too small molecularly without the help of hydrate former molecules. In this study, the hydrate equilibria of the binary clathrate hydrate containing tetrahydrofuran, helium, and water were determined at 2, 3, 5.56 THF mol%. The direct volumetric measurements were also carried out to confirm the exact amount of helium captured in the hydrate cages. Finally, the crystalline structure of the formed mixed hydrates was identified by the powder X-ray diffraction, resulting in structure II.