Spectroscopic identifications of binary (cyclobutanemethanol + methane) hydrate and its potential application for gas storage

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We introduced cyclobutanemethanol (CBM) as hydrate former for the first time and confirmed formation of structure II (sII) hydrate in the presence of methane(CH_4) gas using spectroscopic tools, such as ^{13}C solid-state nuclear magnetic resonance(NMR) and powder x-ray diffraction(PXRD). In NMR spectra, it was identified that CBM molecules were captured in the large cages of sII hydrate, and CH_4 molecules were captured in the large and small cages of sII hydrate, respectively. The crystal structure of a binary (CBM + CH_4) hydrate was refined with Rietveld analysis, indicating that the formation of sII hydrate with a lattice parameter of 17.23630 Å. In order to check potential application of gas storage using the binary (CBM + CH_4) hydrate, thermodynamic stability of the binary (CBM + CH_4) hydrate was measured. Phase equilibrium conditions of the binary (CBM + CH_4) hydrate was more stable than those of pure CH_4 hydrate. Finally, the gas storage capacity of the binary (CBM + CH_4) hydrate was investigated, and showed superiority compared to (tetrahydrofuran + CH_4) hydrate and (cyclopentane + CH_4) hydrate.