Formation, Decomposition and Swapping Dynamics of Clathrate Hydrates: Modeling and Validation

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Abstract

A large amount of energy, perhaps twice the total amount of all other hydrocarbon reserves combined, is trapped within the gas hydrate deposits. Despite emerging as a potential energy source for the world over the next several hundred years and one of the key factors in causing future climate change, gas hydrate is still poorly known in terms of its formation, decomposition and exchange mechanisms. To address this issue, a mathematical formulation is proposed to represent the physical insight into the processes of hydrate formation, growth and decomposition. This theoretical framework addresses several practically relevant aspects, including renewal of surface where hydrates form, uneven size and shape of internal pores in the porous material, hydrate formation in the interstitial and interior pore spaces of the unconsolidated porous particles, surface tension effect, and impeding nature of the salt ions present in seawater towards the hydrate formation, growth and decomposition. Besides, to safely extract the energy from the hydrate reservoirs, a theoretical formulation is proposed to understand the physical insight into the transient swapping between natural gas and CO_2 occurred under deep seabed and in permafrost. Addressing several practical concerns makes the model formulation novel and generalized enough in explaining the swapping phenomena at diverse geological conditions. In fact, the developed formulation has described the formation, growth, decomposition and swapping phenomena precisely and provided a promising performance with a close agreement with the extensive range of experimental data. Providing clearer insights into how hydrates are generated, deposited, decayed and swapped, this model can play a crucial role in gas storage and transportation, desalination, gas separation, CO_2 capture and sequestration, and outer solar system applications.

Keywords: Gas hydrates; formation and growth; decomposition; swapping; theoretical framework; seawater; porous media.