CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)
Juwon Lee

Project Number
S0619

Project Title

Toward a More Thermally Stable Halogen Gas Encapsulation Technique Using Heavy Water Clathrate Hydrates

Abstract

Objectives/Goals

Clathrate hydrates are solid crystalline inclusion compounds with host water cages that enclathrate (wrap around or encapsulate) small gas molecules such as halogens or small hydrocarbons such as methane. Methane gas hydrates, which solidify above the freezing point of water, can plug natural gas pipelines. This is a major energy transport problem but also an opportunity to store chemical potential energy in a safe form. Despite extensive study, both experimental and theoretical, the nature of the bonding in gas clathrate hydrates is still not fully understood. The objective was to change the nature of the host cage by replacing normal water with heavy water to increase thermal stability of the clathrate hydrates formed.

Methods/Materials

Different types of crystalline halogen clathrate hydrates were produced by condensing bromine and chlorine gases in normal water and heavy water in sealed optically transparent sample cells to allow UV-visible spectroscopic interrogation. The solid clathrates were grown on the cooled window of the sample cell. The clathrate hydrates were analyzed using both transmission and reflectance UV-visible spectrophotometers.

Results

Halogen clathrate hydrates made with heavy water cages showed markedly greater thermal stability (i.e., persisting significantly longer as temperature rose) compared to regular water clathrates. These clathrates could be distinguished by the eye via their distinctive coloration. Halogen clathrate hydrate spectroscopic results showed that the clathrate hydrate spectra were related to but different from both the water-free halogen vapor spectra and aqueous halogen solution spectra.

Conclusions/Discussion

The heavy water clathrates formed more quickly and disappeared more slowly compared to normal water clathrates as the temperature was lowered and raised. The deuterium oxide clathrate hydrates are therefore more amenable to spectroscopic interrogation than regular water counterparts. Elucidation of the structural properties of clathrate hydrates in different types of water cages helps to further understand and thus better address the challenge of methane clathrate hydrate plugs in natural gas pipelines while also pointing the way to improvements in gas storage and transportation techniques.

Summary Statement

I produced and spectroscopically analyzed halogen clathrate hydrates in normal water and heavy water cages to better understand the host-guest interactions.

Help Received

I thank my research advisor Dr. John W. Kenney III at Concordia University for his support and advice for my project. I also am pleased to acknowledge Dr. Ken Janda and his group at UC-Irvine for providing support, expertise, and materials.