All Caged Up

Gas hydrate or methane hydrate – what, exactly, is the structure pictured in the poster? Both names are correct. Methane hydrates, also known as gas hydrates, are frozen crystalline solids composed of rigid cages (clathrate structures) of water molecules enclosing methane and other low molecular weight gases. The maximum amount of methane trapped in the hydrate is fixed by the clathrate geometry: 1 m^3 of hydrate in situ (below the seafloor) yields 164 m^3 of methane at standard ambient temperature and pressure (STP) in a ratio of 1 mole CH_4: 5.75 moles H_2O.

Objectives

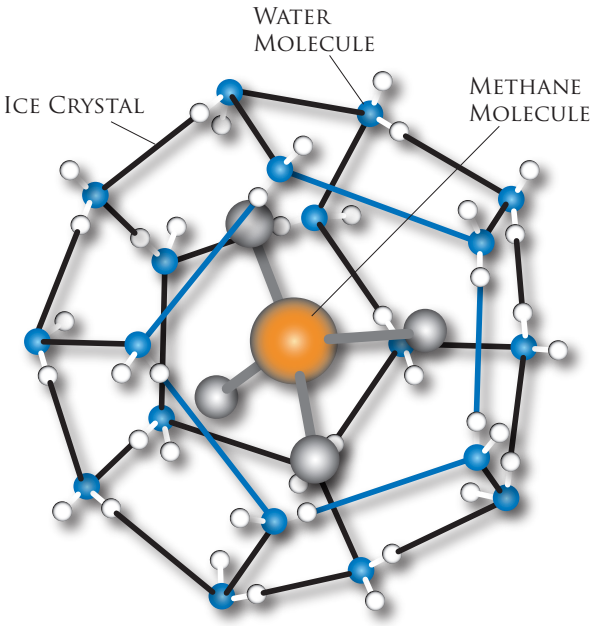
Students will be able to model, study, and compare clathrate structures commonly found in methane hydrates.

Vocabulary

clathrate structure
dodecahedron
gas hydrate
guest molecule
host molecule
hydrogen bond
methane

Materials

- Chemistry modeling kits or materials (at least 20 water molecules, methane molecule, and 30 bonding structures per student)
- Copies of the clathrate structures



What To Do

1. Examine the simplified clathrate structure pictured to the right. Hydrogen bonding causes the water molecules to arrange in pentagonal dodecahedral (12 five-sided "faces") host molecules around a single methane guest molecule. Count and record the number of hydrogen bonds and water and methane molecules needed to model one methane hydrate structure.
2. Construct the clathrate structure model.
3. Link your clathrate model (cage) to several others constructed by your classmates. Count and record the ratios of water molecules to methane molecules each time a cage is added.
4. Does the methane to water ratio change with the addition of new clathrates? If so, how?
5. Calculate the mass (in atomic mass units) of a single clathrate cage. Do the same for your multi-clathrate model.

Extensions

The simplified models you have constructed are small cages, but in reality, a structure I hydrate, the type most commonly found by researchers in gas hydrates, would contain both small and large cages. Large structure I cages are 14-sided, with 2 hexagons and 12 pentagons in a ratio of 2 small cages for every 6 large cages.

1. Construct a single large cage clathrate molecule.
2. For a real challenge, construct and link 2 small and 6 large clathrate cages to model a structure I methane hydrate.

Reference

Ripmeester, J.A., Ratcliffe, C.I., Klug, D.D., and Tse, J.S., 1994. Molecular perspectives on structure and dynamics in clathrate hydrates. *Annals of the New York Academy of Sciences*, 715: International Conference on Natural Gas Hydrates. The New York Academy of Sciences, New York, New York.