

# Empowering Sustainable Energy-Water-Environment Nexus: Green Promoters for Rapid Methane Hydrate Formation

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Synthetic gas hydrates is a **novel nanoporous material** for many energy transition applications but its applicability is hindered by the **slow formation kinetics**. Our group explored environmentally-friendly kinetic hydrate promoters (**KHPs**), like acidic/basic zeolites and amino acids, to improve methane hydrate formation kinetics.

**H-Y (FAU-type) acidic zeolites** were superior to Na-X (FAU-type) basic zeolites in enhancing methane hydrate formation kinetics, with the optimum performance observed at 0.5 wt % zeolite. H-SSZ-13 showed the best performance at 283 K, with an average induction time of 10.5 minutes, hydrate volumetric capacity of 115 v/v, and **recovery of 97%**. Of the amino acids tested, l-tryptophan outperformed others at 283 K and 288 K in terms of induction time and gas uptake. The effect of surface properties on hydrate formation kinetics using seawater was studied in a fixed bed reactor configuration. The results showed that more hydrophobic zeolites (USY-40) had superior performance compared to hydrophilic zeolites (USY-10), enhancing methane uptake and kinetics. Gas uptake could reach 40 mmol of gas/mol of water, which is the **highest reported under mild conditions using seawater**. The synthesized hydrates were stored for 4 months at 253.15 K and 1 atm, and **the methane weight loss outperformed liquefied natural gas (LNG)** for 4 months which is 5 times more than a typical LNG voyage.

These findings demonstrate the potential for using green promoters to develop sustainable economical gas hydrate technology with significant implications for biogas upgrade and storage, hydrogen storage, and carbon capture and sequestration.

