Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.22489

The Potential for Organic Synthesis in the Ocean of Enceladus

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The Cassini spacecraft detected a “soup” of organics in the plume of Enceladus. Those compounds could provide building blocks for the potential emergence or sustenance of microbial life in Enceladus’ subsurface ocean. However, the sources and stabilities of organics in Enceladus’ ocean are still poorly understood. Here, we perform non-equilibrium thermodynamic calculations to assess the energetics of abiotic synthesis for a broad spectrum of small organics under both cold oceanic and hydrothermal conditions on Enceladus. Most of the organics that we studied are thermodynamically favorable to synthesize at micromolar dissolved concentrations over wide ranges of pH (8.5 – 11) and redox conditions. This suggests that many of the organic compounds detected by Cassini may be derived from reactions of CO_2 and H_2. However, some widely assumed precursors of biomolecules, such as formaldehyde, hydrogen cyanide, and acetylene, are found to be unstable and therefore unfavorable to be synthesized. We also found that higher temperatures seem to favor the overall synthesis of organic species under Enceladus hydrothermal conditions. Detection of thermodynamically unstable species in the plume might reflect artifacts introduced during high-speed spacecraft flybys and/or active synthesis via degradation of primordial chondritic organics, radiation processes, or biological activities.