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Bioavailable energy distributions in the hydrothermal systems on Enceladus and early Earth

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A recent research by Cassini spacecraft suggests that there are silica nanoparticles in Saturn′ s E-ring derived from the Enceladus plume (Hsu et al., submitted). The findings of silica nanoparticles imply active water-rock reactions. Furthermore, an experimental study simulating the reactions between chondritic material and alkaline seawater revealed that the formation of silica nanoparticles requires hydrothermal reactions at temperatures higher than 100 deg. C (Sekine et al., submitted). Considering a short residence time of nanoparticles in the ocean, these studies imply geologically-recent or on-going hydrothermal activity in the Enceladus′ subsurface ocean. Therefore, we modeled possible hydrothermal fluid/rock reactions and bioavailable energy in the mixing zone between hydrothermal fluid and seawater on Enceladus. The thermodynamic calculations of reactions between CI chondrite and alkaline NaCl-NaHCO3 seawater at 100 deg.C indicate that the pH of fluid increases up to about 10 and hydrogen concentration in the fluid is elevated up to 20 mmolal through the water/rock reaction. Based on the estimated fluid compositions, we calculated chemical property of the mixing zone between seawater and hydrogen-rich alkaline hydrothermal fluid, which revealed that the a certain level of bioavailable energy is derived from redox reactions based on CO2 and H2 in the mixing zone whereas there are unlikely other electron accepters such as sulfate and nitrate that are abundant in the terrestrial seawater. Thus, the CO2-H2 pair can be used for possible metabolic reaction, namely hydrogenotrophic methanogenesis and acetogenesis. In the low-temperature zone, the available energy of the Enceladus methanogenesis is higher than that of methanogenesis in the Rainbow field (Mid-Atlantic Ridge) where methanogens are certainly separated. It is therefore highly possible that H2-based energy metabolisms have been generated in the Enceladus hydrothermal vent system. Considering that the most ancient metabolisms in the Hadean terrestrial hydrothermal vent system could be also H2-based redox reactions, there is an energetic similarity between hydrothermal vent systems on Enceladus and Hadean Earth. The future exploration of Enceladus′ plume would potentially provide clues to the origin of life on Earth.