Molecular hydrogen production during low-temperature serpentinization: A modeling study with implications for potential microbial life on Saturn’s moon Enceladus.

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Serpentinization of ultramafic rocks attracts great interest in research on the origin of life on Earth and the search for life on extraterrestrial bodies including icy moons like Enceladus. Serpentinization on Earth occurs in peridotite-hosted systems at slow-spreading mid-ocean ridges, and produces large amounts of molecular hydrogen (H_2) and methane. These reduced compounds can be utilized by diverse chemosynthetic microorganisms as a source of carbon and/or energy. A detailed understanding of water-rock interaction processes during low-temperature serpentinization is of crucial importance in assessing the life-sustaining potential of these environments. In the course of serpentinization, the metasomatic hydration of olivine and pyroxene produces various minerals including serpentine minerals, magnetite, brucite, and carbonates. Here, the PHREEQC code is used to model the pH- and temperature-dependent dissolution of olivine and pyroxene to form serpentine, magnetite, and H_2 under pressure and temperature conditions that may exist on Saturn’s moon Enceladus. Various model configurations from 25 to 100°C and 25 to 50 bar are run to assess the influence of environmental parameters on H_2 production. Three different mineral compositions composed of forsteritic olivine, fayalite, enstatite, and diopside are considered as primary minerals. The results reveal that H_2 production rates depend on the composition of the initial mineral assemblage, pressure, and temperature. Total gas production is constrained by the amount of iron metal within dissolving minerals, as well as the ambient pressure. The total H_2 and methane gas production potential of Enceladus is simulated. Moreover, calculated compositions of gases are approximated to the gas plume data by NASA’s Cassini INMS instrument in order to infer the possible rock composition reacting within Enceladus’ rocky core. The results offer new constraints on H_2 production rates over time, and may aid habitability assessments of extraterrestrial bodies where serpentinization could occur.