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Modeling low-temperature serpentinization reactions to estimate molecular hydrogen production with implications for potential microbial life on Saturn's moon Enceladus.

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Serpentinization of ultramafic rocks attracts much 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 and methane. These reduced compounds can be utilized by diverse chemosynthetic microbial consortia as a metabolic energy source. Although many hydrothermal vents emit hot and acidic fluids today, it is more likely that life originated in the Archean at sites producing much cooler and more alkaline fluids that allowed for the synthesis and stability of essential organic molecules necessary for life. Therefore, 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. Hydrogen production only occurs if ferrous iron within iron-bearing minerals is oxidized and incorporated as ferric iron into magnetite. The PHREEQC code was used to model the pH- and temperature-dependent dissolution of olivine and pyroxene to form serpentine, magnetite and hydrogen under pressure and temperature conditions that may exist on Saturn's icy moon Enceladus. Various model setups at 25 and 50°C were run to assess the influence of environmental parameters on hydrogen production. The results reveal that hydrogen production rates depend on the composition of the initial mineral assemblage and temperature. The current assumption is that there is a gaseous phase between Enceladus' ice sheet and subsurface ocean. To test various scenarios, model runs were conducted with and without the presence of a gas phase. The model results show that hydrogen production is further dependent on carbon dioxide partial pressure within the gas phase. Moreover, no other gases apart from hydrogen, such as methane, were produced in any of the model runs. The combined results offer a constraint on hydrogen production over time, and may aid habitability assessments of extraterrestrial bodies where serpentinization could occur.