

Enough sulfur and iron for potential life make Enceladus's ocean fully habitable

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The Cassini spacecraft revealed life-forming elements like CHNOP and diverse organic compounds from Enceladus's ocean. However, the availability of minor but bio-essential nutrients such as iron and sulfur remains unknown. Here, we perform geochemical modeling to explore their chemistry in Enceladus's ocean. We find that dissolved iron predominantly occurs as Fe(II) with a solubility ranging from 10^{-8} to 10^{-5} mole (kg H₂O)⁻¹ (decreasing with increasing pH). Dissolved sulfur, mainly present as HS⁻, is predicted to have a concentration of 10^{-6} to 10^{-4} mole (kg H₂O)⁻¹, and pH has only a minor effect on S solubility. Our predicted availabilities of Fe and S are close to measured concentrations in inhabited terrestrial serpentinization fluids, implying sufficient nutrients to support potential life. Our results also suggest that the reduction of ferric iron or sulfate might supply enough energy for chemotrophic metabolisms based on these reactions to complement previously proposed methanogenesis. The levels of bioproductivity supported by S availability are overall lower than those sustained by other nutrients, but still orders of magnitude higher than the maximum level of bioproductivity estimated from the supply of chemical energy.