H_2 production from radiolysis in a subsurface ocean on Titan

C. R. GLEIN[1*], C. RAY[1,2], J. H. WAITE[1,2]

[1]Space Science and Engineering Division, Southwest Research Institute, San Antonio, TX, USA
[2]Department of Physics and Astronomy, The University of Texas at San Antonio, San Antonio, TX, USA
[*]Correspondence: cglein@swri.edu

Saturn's largest moon, Titan, is one of the ocean worlds in the solar system, as revealed by data from the Cassini-Huygens mission. The likely presence of liquid water in the subsurface helps to make Titan habitable for life as we know it. However, the conventional model for the internal structure of Titan has an ocean sandwiched between a crust of hexagonal ice, and a layer of denser high-pressure phases of ice overlying a rocky core. This has led to the idea that Titan may be substantially less habitable than Europa or Enceladus, because there may be a lack of energy sources to support life in an ocean that is not in direct contact with rock. Here, we present the case for the generation of a continuous source of chemical energy in Titan's ocean based on the radiolytic decomposition of water molecules. This process produces molecular hydrogen, a key redox species for a diverse assortment of known microbial metabolisms.

Our geochemical model assumes that there is a significant amount of radioactive ^{40}K dissolved in Titan's subsurface ocean. This is supported by the presence of ^{40}Ar in Titan's atmosphere, and by the inference that some ^{40}K must be leached into the ocean to explain the predominance of hydrated silicates in the core. For a CI chondrite abundance of K in accreted rock, our model suggests that there could be $\sim 4\times10^{16}$ moles of ^{40}K in Titan's ocean at present.

Decaying ^{40}K atoms emit energetic electrons and gamma rays that can break apart surrounding H_2O molecules into H_2 and a ½ O_2 equivalent. Using the parameterized model of radiolysis presented by Ray et al. (2017, AGU), we calculate a present rate of H_2 production from radiolysis in Titan's ocean of $\sim 6\times10^{10}$ mol/yr. For comparison, the H_2 production rate attributed to water-rock reactions at Enceladus is $(1\text{-}5)\times10^9$ mol/yr. If we normalize these numbers to the surface area of the respective body, we obtain ~700 mol yr^{-1} km^{-2} (Titan) and 1000-6000 mol yr^{-1} km^{-2} (Enceladus). These comparisons demonstrate that radiolysis is likely to be an important source of redox species in Titan's ocean, which must now be considered in assessments of its habitability. Ongoing work is aimed at providing quantitative constraints for metabolic energy availability, based on redox disequilibria maintained by radiolysis in the ocean of Titan.