Reaction Rates and Products of Olivine Alteration in Ammonia Aqueous Solutions: Application to Icy Worlds

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Introduction: Geophysical and chemical data collected by the Cassini-Huygens mission at Enceladus supports the presence of a salty liquid ocean beneath an icy crust at the origin of plume activity [1][2]. The analysis of the ejected material from the plumes indicates an NH_3 concentration of ~1 wt% [3] and recent hydrothermal activity in the rocky core [4] powered by tidal heating [5]. Increasing experimental datasets on mineral dissolution and serpentinization in NH_3-fluids is of interest to conceptual and geochemical models of mineral weathering on Enceladus and other icy satellites.

Experimental: We conducted constant-flow and batch dissolution experiments of San Carlos olivine in a dilute seawater solution with varying NH_3 concentrations. Experimental temperatures range from -20 to 150 ^{0}C. Constant-flow experiments simulate reaction rates in high-flow systems. In contrast, the batch experiments simulate reaction rates and products in closed or low-flow systems.

Results: Fluid samples from the constant-flow experiments are used to calculate dissolution rates for comparison to existing rate laws in the basic pH range. Results from batch experiments characterize the fluid chemistry, gas phase and secondary mineral products as the olivine-water-ammonia system approaches chemical equilibrium. Gas samples from the batch reactors quantify H_2 generation and CH_4 synthesis over time in ammonia solutions. HRTEM is used to characterize alteration of the olivine and the formation of secondary reaction products. The kinetic results are being used to develop a model of hydrothermal alteration of olivine compatible with models of water flow in the tidally-heated porous core [5].

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