ROLE OF NON-WATER ICES IN DRIVING SALINITY AND ELECTRICAL CONDUCTIVITY IN OCEAN WORLDS.
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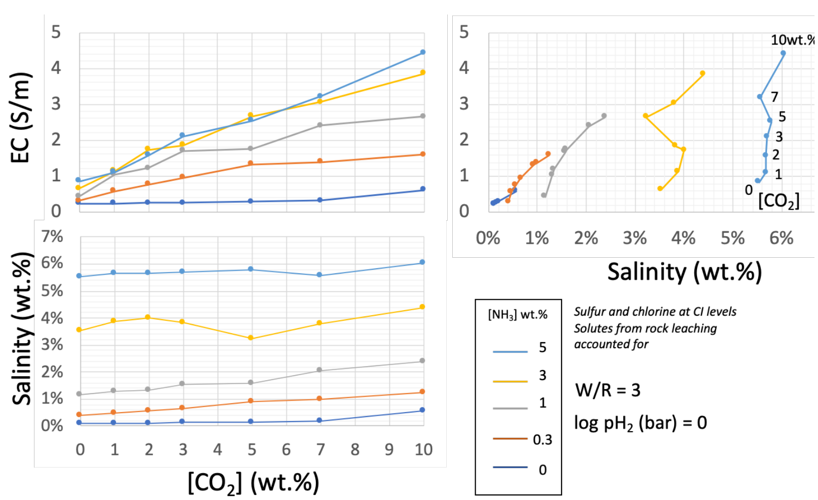
Introduction: Forward modeling of the electrical conductivity of icy moon oceans has assumed that chlorides, sulfates, and other ions released from rock leaching are the main solutes and generators of electrical conductivity (EC). We show that accreted volatiles, such as CO_2, and NH_3, can also contribute a significant fraction of solutes for bodies whose volatile content was in part supplied from cometary materials. These volatiles make a major contribution to the EC of aqueous solutions in icy bodies, which is an important consideration for future observations making use of electromagnetic sounding in searching for deep oceans.

Motivations: In recent formation models of giant planet systems, icy moons could acquire part of their materials from pebbles scattered from regions farther in the outer solar system. For the Galilean satellites, this implies a greater content in cometary volatiles than assumed in previous models. Recent evolution models also show that early oceans could be enriched in CO_2 and NH_3 following the breakdown of carbonates and organic compounds as a result of the thermal metamorphism of accreted carbonaceous chondritic materials. Carbonates have been found at Enceladus and Ceres; the latter also displays evidence for ammonium in multiple forms on its surface. Lastly, this study is responsive to the ongoing interest in future missions to the Galilean moons, Enceladus, Titan, Triton and the moons of Uranus, Pluto's system, and Ceres, many of which would include magnetometers.

Summary of Approach: We assess the fate of accreted volatiles using the Geochemist's Workbench (GWB) [1] at 1 atm. GWB computes EC using the approach of [2] which is suitable for ionic strengths up to 1 mol/kg over the range 0°C–95 °C, pH (1–10), and conductivity (30–70,000 10^{-6} S cm^{-1}). The EC estimates presented below assume that the hydrosphere is all liquid, i.e., not accounting for what occurs to solute concentrations in liquids upon freezing of an ice shell.

Key Results: If ocean salinity is a sole function of fluid-rock reaction under equilibrium conditions, then the salinity is on the order of 0.1–0.2wt. %, yielding an EC ~0.2 S/m. If CO_2 (and no NH_3) is added to the solution in small amount (<2 wt.%), it is consumed to form dolomite and magnesite with little contribution to salinity (less than [Na^+] and [Cl^-]). The fraction of bi/carbonate ions in solution increases with increasing [NH_3] (Figure 1). For [CO_2]=5 wt.% and [NH_3]~1% (as lower bounds on cometary abundances), the salinity is ~2wt.% and EC~2 S/m. Increasing temperature, pressure, and concentration following freezing of the ocean can increase the EC above 10 S/m.

Summary: Oceans expected in icy moons and dwarf planets, including Europa, some of the Uranian satellites, and Neptune's satellite Triton, could have high electrical conductivities due to abundant non-water ices, even if the extent of rock leaching during differentiation was limited and chlorine and sulfur abundances were at low, CI carbonaceous chondritic levels. The effects of non-H_2O ices require thorough quantification to aid the planning and future interpretation of magnetic induction experiments at candidate ocean worlds.



References: [1] Bethke, C.M. (2007) *Geochemical and Biogeochemical Reaction Modeling*, 2nd ed., CUP. [2] McCleskey, R. B., et al. (2012) GCA 77, 369-382.

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← Figure 1: Salinity and EC as a function of accreted CO_2 and NH_3 abundances (wt.% of volatile phase), calculated at 0 °C, 1 atm, W/R = 3, and log pH_2 (bar) = 0.