FY23 Strategic University Research Partnership (SURP)

Electrical Properties of Ocean World Solutions: Carbonate and Ammonia

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Objectives:

This work aims to provide missing information about the electrical conductivity of ocean world solutions. These data—including electrical conductivity and phase stability of single- and multi-component salt solutions at high pressures and temperatures above the liquidus—are critically needed for analyzing the magnetic responses of planetary oceans to infer their salinity. The starting focus for this project is Na2CO3 and NH3 because these solutions may have outsized contributions to the electrical conductivity in ocean worlds. Our strategic goals in working with UCLA are to develop a long-term partnership with Co-I Kavner, an expert in experimental mineral physics relevant to planetary interiors, and to train the graduate student in planetary science.

Background:

Determining the composition and concentration of materials in an ocean world is key to understanding its habitability. An ocean's salinity records the history of planetary heating, water–rock interaction, and loss of materials to space. Magnetic field data from the Galileo mission provided the most compelling evidence for salty subsurface oceans in Europa, Callisto, and Ganymede, but they did not provide information about the actual compositions of the oceans. Models predict the possible presence of dissolved SO_4^{-2} , Cl^-, and CO_3^- , as well as volatiles such as CH 4 and NH 3 . Magnetic induction can help to reveal the actual compositions because the electrical conductivity of a particular ocean composition which determines the inductive response—is also coupled to the temperature and density of the ocean. To fully characterize the ocean salinity within the capabilities of spacecraft magnetic investigations, it must be assured that the uncertainty in the measured conductivities of relevant solutions does not limit the interpretation of the magnetic field measurement. New measurements are needed of the electrical conductivity of salt solutions under conditions of high salinity, low temperature, and high pressure.

Approach and Results:

We developed the newly commissioned JPL Simulator for Icy World Interiors (SIWI) apparatus to measure electrical conductivity up to 700 MPa from -20 to 20 °C covering much of the solubility range for NH3-. In FY23, we have continued to refine the system, addressing the robustness of the wiring, adding wire guides and shielding to address inductive effects observed during testing. Meanwhile we have implemented the software and hardware needed for pressure and temperature readout and control. Through analyses based on our own simulations of Europa's magnetic induction, we identified the needed precision of measurements to be better than 1% for salinity in the range 0.1 wt%. Available measurements at 1 atmosphere have repeatability in this range, but do not extend to temperatures below 5°C. Measurements at high pressure and high salinity (1-10 wt%) have uncertainties in the range 10-15% at best; 10% uncertainty may be adequate in this range. Galileo magnetic constraints on Europa's ocean salinity are consistent with values in the broad range considered here. We conducted preliminary measurements in sodium chloride solutions and NIST-traceable standard KCl solutions at 1 atmosphere. The use of NIST standards and cross calibration will be essential to achieving the desired accuracy. Psarakis continued to work on molecular dynamics simulations of aqueous NaCl. Their first paper is nearing submission, and will be a key milestone toward obtaining the planned carbonate and ammonia measurements.

Significance/Benefits to JPL and NASA:

NASA funding, lab development, and modeling work supported by this SURP have positioned us to provide essential laboratory electrical conductivity data needed to support the Europa Clipper L1 of inferring the ocean's salinity. The NASA funded work supports an integrated team that will combine additional thermodynamic data and modeling expertise to provide for the joint inversion of magnetic sounding and gravity science data. This integrated approach constitutes the state of the art being pursued by other groups and is likely to be an essential part of future ocean worlds missions.

The only (minor) weakness in our NASA proposal evaluation was insufficient addressing of volatile carbon and nitrogen compounds, which we had omitted due to space constraints. This SURP project is thus recognized as an important component of our research program, and continued work in FY24 will position us strategically to win follow-on funding from an anticipated Ocean Worlds research program from NASA ROSES.

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