MODELING POSSIBLE OCEAN COMPOSITION FOR ENCELADUS. C. K. Nunn[1] and T. A. Kral[2], [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701 (cknunn@email.uark.edu), [2]Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

Introduction: Recent models of the interior of Enceladus agree that underneath the ice shell there exists a global ocean, with size estimates varying from 21-63 km thick [1,2]. While the details of the composition of this ocean are not immediately clear, the plumes of Enceladus can provide us with a glimpse of what is happening in the interior.

The latest analysis of Cassini data shows that H_2 makes up 0.4 to 1.4% of the total of Enceladus' plumes [3]. Analysis of the H_2/CH_4 ratio in the plume suggests that the H_2 must be actively generated [3]. The theorized major source of H_2 on Enceladus is the aqueous alteration of minerals [3]. Only as much as 40% of the core needs to have fully reacted to sustain the present level of hydrogen generation over the history of the Solar System [3]. This would seem to imply that not only have geochemical interactions happened in the past, but that they are ongoing and have the potential to continue for a significant amount of time.

While considerable attention has gone into understanding how geochemical reactions shape the rock and hydrogen production on Enceladus, seemingly less attention has been given to how these reactions impact the state of the ocean.

This work hopes to further quantify limits on a possible ocean composition for Enceladus through geochemical modeling of water-rock interactions between the core and ocean. Rather than focus on mineral composition and hydrogen production, modeling efforts will be focused on describing dissolved species in the ocean which have astrobiological significance.

Science Motivation: The prospect of active hydrogen generation is of great interest to those studying astrobiology, since hydrogen is a food source for microorganisms. The presence of not only liquid water but also a plentiful energy source makes Enceladus a great astrobiological target. In fact, Enceladus does seem to have all of the elements necessary for life [4]. To determine the likelihood of life surviving or thriving in Enceladus' ocean, however, we need to have a complete picture of the dissolved solids content, pH, temperature, and pressure of the ocean. This will allow us to understand the limitations placed on potential Enceladan life.

Modeling Approach: To investigate ocean composition through geochemical modeling, this project makes use of the freely available geochemical modeling software *PHREEQC 3.3.12* [5]. To focus only on species that are relevant to Enceladus, this modeling makes use of the *core10.dat* database, which was specifically designed by Neveu et al. [6] to model the geochemical interiors of icy worlds.

Initial core compositions were determined using a combination of the major rock types of Waite et. al. [3] and additional organics and trace elements as appropriate using the composition guidelines found in Neveu et al [6]. The initial fluid composition is taken to be that of cometary composition containing primarily C, N, S, and Cl, such as described by Neveu et al [6].

In order to place reasonable limits on biologically relevant species, this work looks at two different scenarios. In the first scenario, major rock types are allowed to react with cometary fluid without the addition of organics. This should set a lower limit on possible dissolved species concentrations. In the second scenario, the organics and trace elements are added in, which should set an upper limit for dissolved species concentrations.

For the purposes of this modeling, it is assumed that the ocean experiences complete mixing on reasonable timescales. It is also assumed that there is not significant melting of the overlaying ice sheet that would supply additional water to the ocean and thus change the concentrations. While this is a simplified model setup, it should still be possible to extract meaningful conclusions regarding the composition of Enceladus' ocean as it relates to the potential for life.

Implications: Results from this work can be used to make a solution that simulates Enceladan conditions. By studying microorganisms in this solution, it will be possible to investigate which microbes are capable of surviving such conditions and the extent to which they thrive in such an environment. From this, it will be possible to determine possible biosignature candidates and aid in the development of instrumentation for any future life-finding missions to Enceladus.

References: [1] Van Hoolst T. et al. (2016) *Icarus, 277,* 311-318. [2] Thomas P. C. et al. (2016) *Icarus, 264,* 37-47. [3] Waite J. H. (2017) *Science, 365,* 155–159 {Supplemental Materials}. [4] McKay, C. P. et al. (2014) *Astrobiology*, *14*(4), 352-355. [5] Parkhurst D. L. and Appelo, C. A. J. (2013) *Description of input and examples for PHREEQC version 3: a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations.* [6] Neveu, M. et al. (2017) *GCA*, *212*, 324-371.