

RPC 2020



Virtual Research Presentation Conference

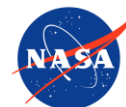
Organic Chemical Transformations on the Surface of Ceres and Enceladus

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Introduction

Abstract

Ocean worlds are of significant interest for finding life in the solar system, since some dwarf planets or icy moons show clear evidence of water-rock chemistry, a past or present liquid water ocean, and geochemical disequilibria that may be able to support life through hydrothermal processes. As well, there are many processes that produce organics abiotically in geological systems. In addition to variations in abiotic production of organics in subsurface geochemical systems, the surface conditions of oceans worlds can alter the abiotic (and biotic) organic signatures we seek to detect. Ocean world surfaces are subjected to a wide range of particle and ultraviolet radiation which primarily degrades, but can also produce organic signatures. However, the precise conditions under which production outpaces degradation are unknown. As well, the influence of minerals on these processes through heterogeneous chemistry is largely unexplored. Through the work proposed here, we began to experimentally investigate realistic chemical pathways that could occur at the surfaces of ocean worlds, focusing on surface conditions at Enceladus and Ceres.

Problem Description

Context

Ocean worlds are of significant interest for finding life in the solar system, since some dwarf planets or icy moons show clear evidence of water-rock chemistry, a past or present liquid water ocean, and geochemical disequilibria that may be able to support life through hydrothermal processes. Unfortunately, there are many processes that produce organics abiotically in geological systems. A clear understanding of these processes is needed to identify which organics and biomarkers are robust and reliable indicators of life (as opposed to those more likely to be abiotically driven) on these ocean worlds.

SOA

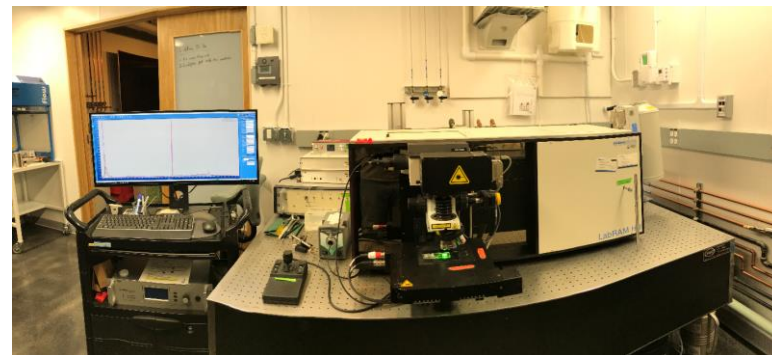
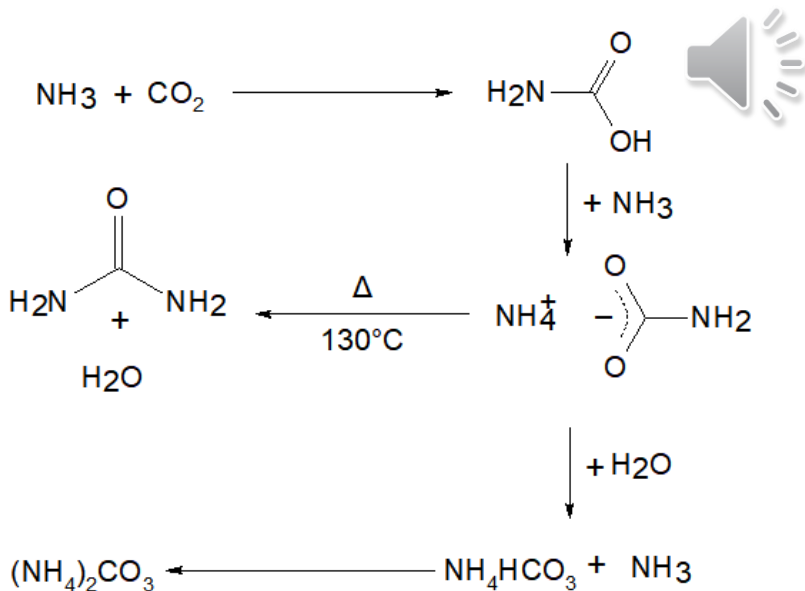
We use state of the art sample preparation and handling techniques to ensure that our samples are representative of the chemistry that may be found on the surfaces of Ocean Worlds. Our work with Raman-microspectroscopy to characterize chemical processes in low temperature condensed phases is at the forefront of the field.

Relevance to NASA and JPL

In order to understand whether future organic detections on the ocean worlds are convincingly suggestive of an extant biosphere, we must be able to distinguish from abiotic organic signatures. Thus we need to fully understand the range of abiotic / prebiotic organic chemistries that are plausible and favorable in these environments. In addition to variations in abiotic production of organics in subsurface geochemical systems, the surface conditions of oceans worlds can alter the abiotic (and biotic) organic signatures we seek to detect. Ocean world surfaces are subjected to a wide range of particle and ultraviolet radiation which primarily degrades, but can also produce organic signatures. However, the precise conditions under which production outpaces degradation are unknown. As well, the influence of minerals on these processes through heterogeneous chemistry is largely unexplored.

Methodology

Our overall objective is to experimentally determine the fate of organic molecules on the surfaces of Ceres and Enceladus, chosen as model ocean worlds and prime astrobiological targets. In the first year, our research focused on the potential for irradiated icy surfaces with entrained volatile organics to generate more complex organics. Specifically, we sought to determine the potential for abiotic synthesis of complex organics on the surface of Ceres, by studying the yields and product distributions for complex organics resulting from the vacuum ultraviolet irradiation of carbamic acid and ammonium carbamate under Ceres surface conditions.



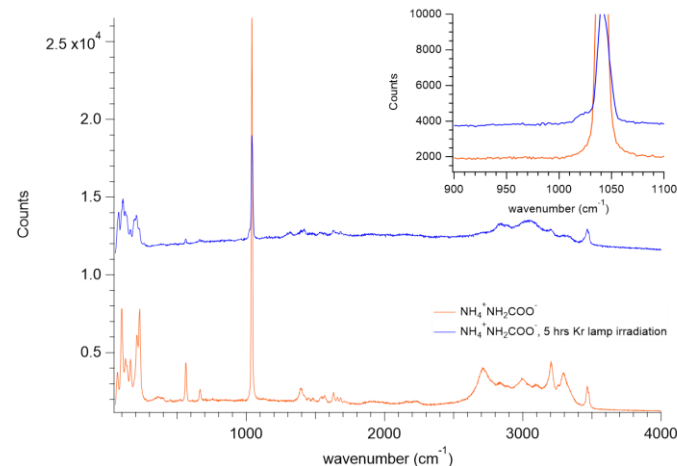
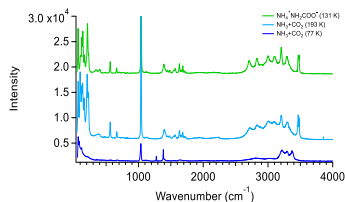
Samples are held in a Oxford MicroStatN2 cryostage which can replicate both the temperature and pressure conditions of Ceres surface.. This cryostage is used primarily for micro-Raman spectroscopy, using a Horiba Jobin Yvon LabRam HR. Raman spectra are obtained with resolutions as high as 0.4 cm⁻¹, with laser powers of 50 mW at 532 nm (frequency-doubled Nd:YAG). We deposit gaseous mixtures of ammonia and carbon dioxide onto the surface of the stage at 77 or 160 K (representative of Ceres surface temperature), and raise the temperature until we observe reaction to form carbamic acid.

Results

Due to the lab closure, progress on both objectives 1a and b has been halted since March. Limited access to our labs was resumed in August, and we hope to begin experiments again on a limited basis in October.

We have begun experiments, and confirmed the formation of ammonium carbamate from ammonia and carbon dioxide using Raman spectroscopy. The likelihood of both ammonia and carbon dioxide on Ceres indicates that the formation of ammonium carbamate on Ceres seems likely.

We have also begun experiments on the irradiation of ammonium carbamate. In these experiments, ammonium carbamate is placed under vacuum in an Oxford MicroStatN2 cryostage and irradiated at Ceres relevant temperatures. We have conducted experiments using Hg, D₂, and Kr resonance lamps. Preliminary results show possibility of photochemical conversion of ammonium carbamate to products using the Kr lamp.



Results

a) Significance

In addition to variations in abiotic production of organics in subsurface geochemical systems described in Section C, the surface conditions of ocean worlds can alter the abiotic (and biotic) organic signatures we seek to detect. Ocean world surfaces are subjected to a wide range of particle and ultraviolet radiation which primarily degrades, but can also produce organic signatures. Our results demonstrate the possibility of a complex chemical cycle based on the reaction of ammonia and carbon dioxide, as shown on Slide 4.

b) Next steps

Future work will be performed using higher levels of vacuum (to reduce VUV absorption), and the use of Fe oxide particles as a photocatalyst. Our initial work was performed at a pressure of approximately 1 Torr. Future experiments will use a turbomolecular pumping system to achieve vacuums of at least 10^{-5} Torr.

Publications and References