National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

Astrobiological Investigation of Amino Acids under Ceres Conditions for Future Missions

Principal Investigator: Jessica Weber (322)**; Co-Investigators:** Robert Hodyss (322), Bryana Henderson (322), Ellen Czaplinski (322)

Objectives: The objective of this RTD was to investigate amino acid stability and reactivity under Ceres-like conditions.

Background: Ceres is dwarf planet of that has garnered great interest since the Dawn investigation and the announcement that NF6 recommended Ceres sample return as per the 2023-2032 Planetary Science and Astrobiology Decadal Survey. Using VIR, Dawn has previously detected aliphatic organics on the surface of Ceres (De Sanctis et al 2017). Additionally, iron-bearing minerals are known to exhibit photocatalytic activity with organics. Experimental studies in this realm under relevant planetary conditions are extremely limited. **In order to be best prepared for future exploration of Ceres, we need to understand the reaction of organics on its surface, particularly those relevant for life.**

Approach: The mineral organic material that was synthesized using the procedure above was weighed and placed into and was introduced to a vacuum-sealed quartz cuvette. That was then connected to the vacuum system (Figure 1). The sample was held under low vacuum using an Edwards XDS 5 Dry Scroll Vacuum Pump for approximately one minute before switching to the high vacuum system (Varian turbo pump V 301) which is connected to a Residual Gas Analyzer (RGA) (SRS RGA 200, quadrupole, resolution better than 0.5 amu at 10% peak height) and stainless steel ionizer (open ion source, cylindrical symmetry) which was used to determine the volatile population of the reaction. An active vacuum (~10^{-6}) was maintained throughout the experiment. After an hour under the high vacuum system, the filament head was turned on, and scans were initiated using the Stanford Research Systems (SRS) RGA 3.0 software (0-100 amu). After 5 scans, the sample was irradiated using a Newport 50 W xenon arc lamp (60025 interface kit, 60076 Condensing Lens Assembly, and 69907 Universal Arc Lamp Power Supply) for one hour, after which the lamp remained off for ~3 scans before starting another hour-long irradiation. After irradiation, the sample was collected in Eppendorf™ Snap-Cap Microcentrifuge Safe-Lock™ tubes and stored in a -20 °C freezer before being prepared for LCMS and NMR Analysis.

Results: We achieved the experimental matrix we set out to explore and all reactions were run 3x. The irradiation had a clear impact on reactivity and stability (Figure 2). We observed increased reactivity with the silicate and mineral samples (Figure 3). Minimal reactivity was observed in the control samples with no mineral. Glycine oligomers were observed via LC-MS in the irradiated silicate reaction samples.

Significance/Benefits to JPL and NASA: Herein, we better understand the reactivity and stability of key amino acid compounds under ceres like conditions. This work expands our understanding on important prebiotic molecules and can inform us of where they exist within the solar system. With this knowledge, we could better understand observations from current and future missions, including the origin and stability of observed mineral assemblages; this work lays the groundwork for future experimental ROSES proposals as well as integration into mission proposals - specifically upcoming NF6 concepts for Ceres Sample Return.

Figure 4. Image of glycine control sample in cuvette pre-irradiation.

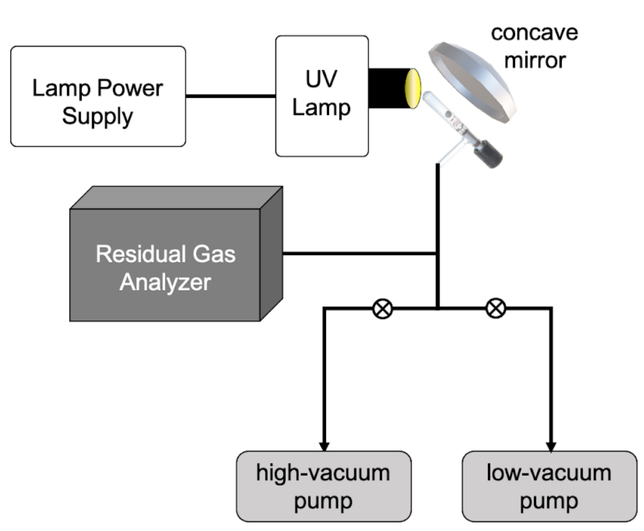

Figure 1. A schematic diagram of the RGA experimental setup. The UV lamp is directed onto the sample using a mirror. Products are analyzed within the RGA.

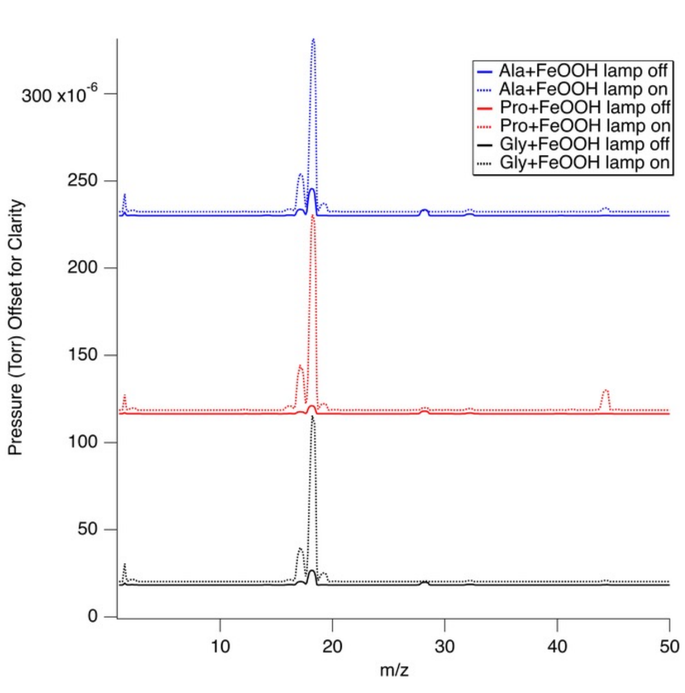

Figure 2. RGA spectra comparing alanine, proline, and glycine before and after irradiation

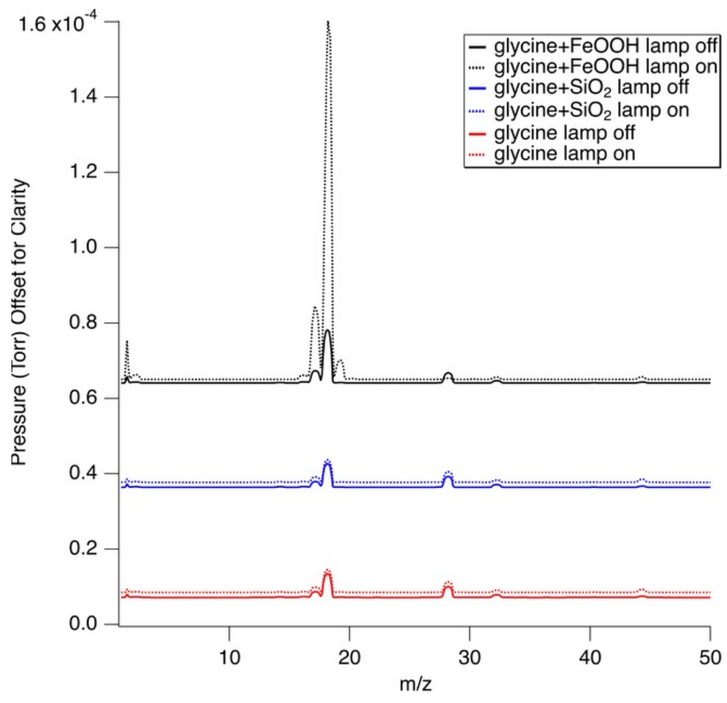

Figure 3. RGA spectra comparing the glycine control, glycine & SiO_2, and glycine & FeOOH mineral.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#00-0000
Poster Number: RPC#

Publications:

Ellen Czaplinski, Jessica Weber, Robert Hodyss, Bryana Henderson, Laura Barge, Julie Castillo-Rogez. "Photochemical Stability and Reactivity of Sodium Pyruvate: Implications for Organic Analysis on Ceres." *DPS-EPSC 55.* October, 2023, Oral presentation.

Jessica Weber*, Ellen Czaplinski*, Bryana L. Henderson, Laura M. Barge, Julie Castillo-Rogez "Photochemical Stability and Reactivity of Sodium pyruvate: Implications for Organic Analysis on Ceres." *Submitted to ACS Earth and Space Chemistry*. (*denotes equal contribution)

PI/Task Mgr. Contact Information:

Jessica M Weber jessica.weber@jpl.nasa.gov