National Aeronautics and Space Administration

Organic Chemical Transformations on the Surfaces of Ceres and Enceladus

Principal Investigator: Robert Hodyss (322); Co-Investigators: Tuan Vu (322), Laura Barge (322), Eduardo Martinez (322), Erika Flores (322)

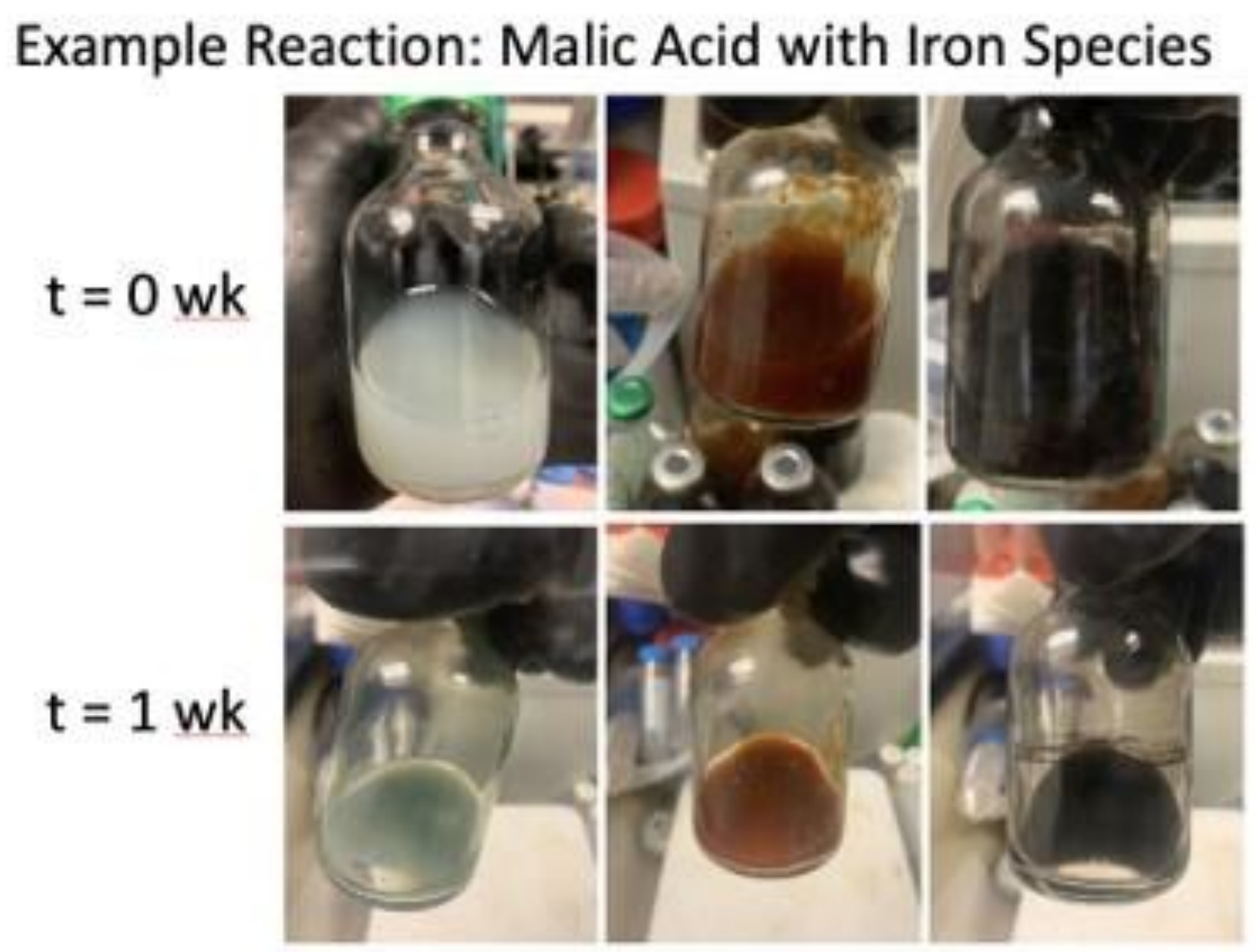
Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Fate of Organics in Ocean Worlds**

Objectives

Our overall objective is to experimentally determine the fate of organic molecules on the surface of Ceres, by examining the photocatalytic degradation of selected organics on iron minerals. Specifically, in past year our objective has been to measure the adsorption capacity of Ceres-type minerals for a set of relevant organics, such as amino acid and small carboxylic acids. Iron hydroxide and iron sulfide minerals were studied.

To our knowledge, these studies have not been previously performed under the conditions representative of planetary environments. The data we generated is unique and will enable a new understanding of organic chemical transformations on the surfaces of ocean worlds.

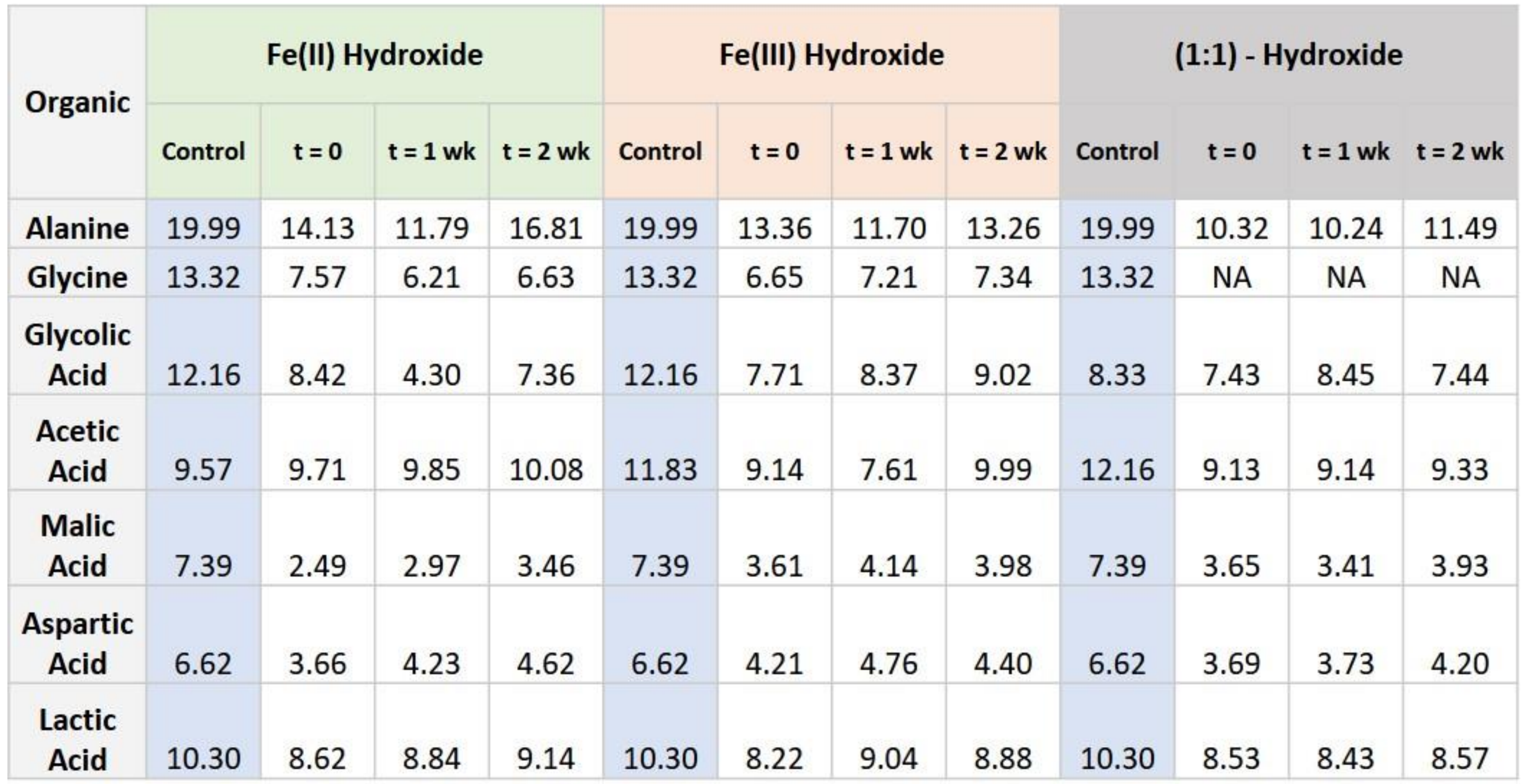
Approach and Results


Example Reaction: Malic Acid with Iron Species

Reaction bottles containing malic acid with iron oxyhydroxides. No apparent change in iron redox state is seen visually over 1 week.

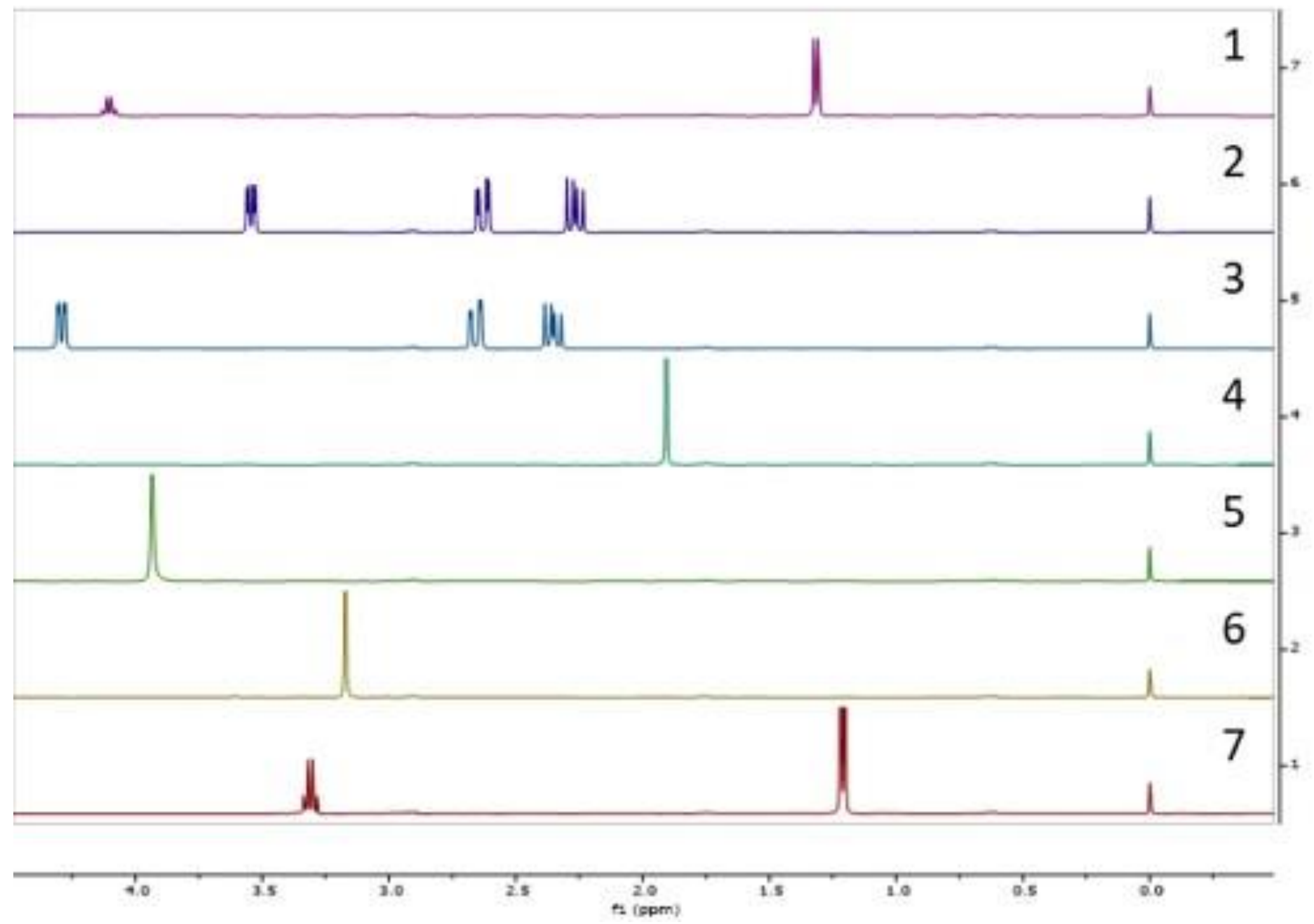
Background

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 tosupport life through hydrothermal processes. Developing methods for detection of organic molecules that are also found in terrestrial biology is one method for trying to identify whether or not life is present on these worlds, and organics have already been detected on the surface of Ceres and in the plumes of Enceladus. 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. On Ceres, photochemical mechanisms will be a major driver of surface chemistry, particularly through heterogeneous photochemistry. We have begun by examining the potential for clays and iron minerals to trap and adsorb organics, influencing transport and storage of organic molecules. This leads naturally to questions about the effect of Ceres surface conditions on mineral-organic bound states.



Organic	Fe(II) Hydroxide				Fe(III) Hydroxide				(1:1) - Hydroxide			
	Control	t = 0	t = 1 wk	t = 2 wk	Control	t = 0	t = 1 wk	t = 2 wk	Control	t = 0	t = 1 wk	t = 2 wk
Alanine	19.99	14.13	11.79	16.81	19.99	13.36	11.70	13.26	19.99	10.32	10.24	11.49
Glycine	13.32	7.57	6.21	6.63	13.32	6.65	7.21	7.34	13.32	NA	NA	NA
Glycolic Acid	12.16	8.42	4.30	7.36	12.16	7.71	8.37	9.02	8.33	7.43	8.45	7.44
Acetic Acid	9.57	9.71	9.85	10.08	11.83	9.14	7.61	9.99	12.16	9.13	9.14	9.33
Malic Acid	7.39	2.49	2.97	3.46	7.39	3.61	4.14	3.98	7.39	3.65	3.41	3.93
Aspartic Acid	6.62	3.66	4.23	4.62	6.62	4.21	4.76	4.40	6.62	3.69	3.73	4.20
Lactic Acid	10.30	8.62	8.84	9.14	10.30	8.22	9.04	8.88	10.30	8.53	8.43	8.57

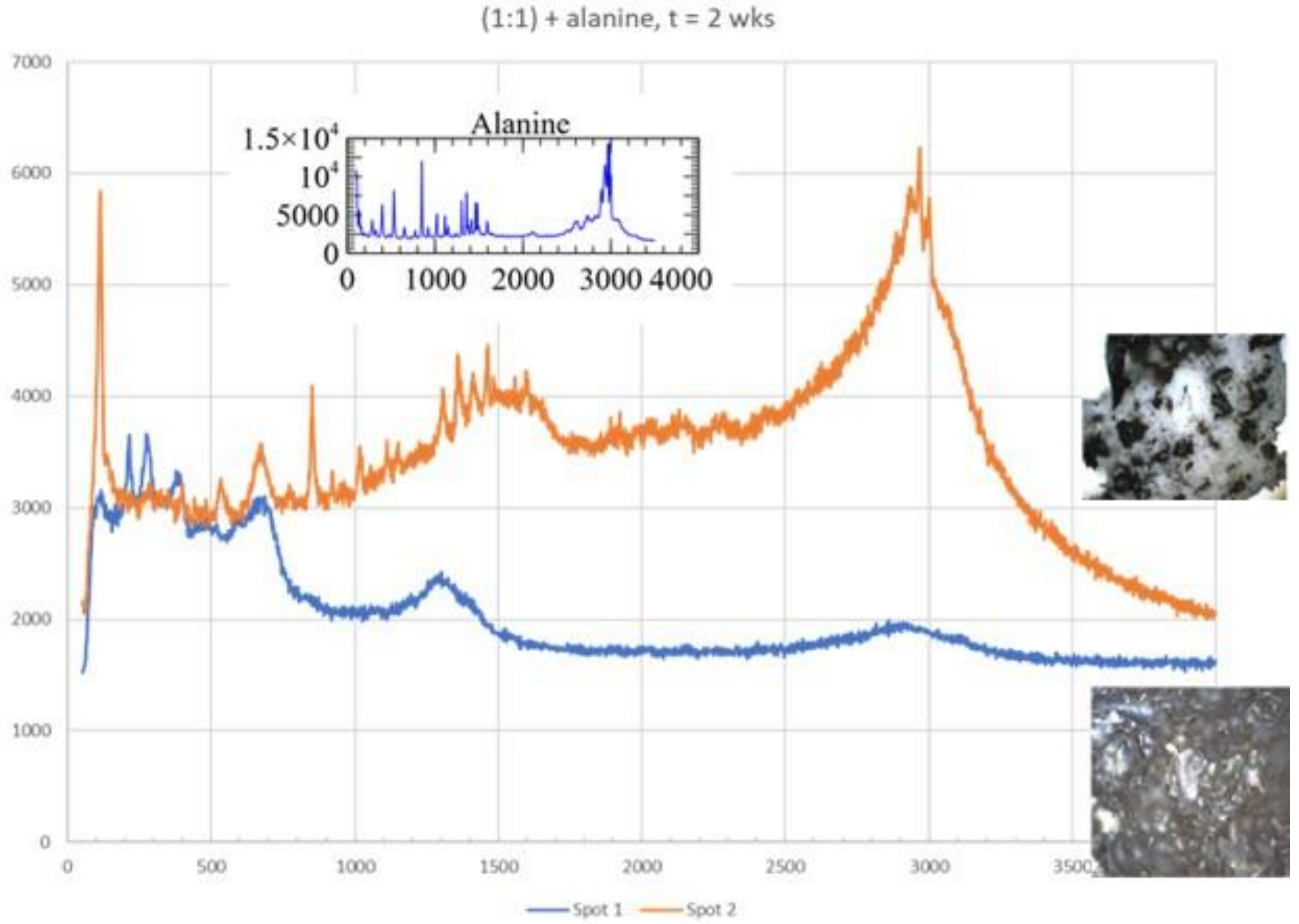
Organic absorption is seen in all organic/iron oxyhydroxide experiments, as shown by decreased NMR peak values compared to control experiments. Conversion of peak areas to concentration is ongoing.



Example NMR spectra of organic/Fe-sulfide adsorption experiments.

Significance/Benefits to JPL and NASA

This proposed task is closely linked to the other two tasks in this initiative: “Carbon Cycle in Small Ocean Worlds”, led by PI Castillo-Rogez, and “Understanding abiotic organic chemistry driven by minerals in Ceres’ and Enceladus’ oceans”, led by PI Barge. This initiative is the first to address the fate of organics in Ocean Worlds and is in direct response to SSED priorities. It will identify robust biomarkers, false positives to be avoided, and effective detection strategies (instrumentation, target locale, species) for in-situ (bio)signature analysis on Ocean Worlds. Our initiative will augment future opportunities for mission infusion for Ocean Worlds (e.g., Europa Clipper, Ceres, in situ / sample return). At the end of this work, we will identify high-fidelity biomarkers and conditions under which they may be preserved to identify science technologies for future investment. It will also enable new mission formulation for other high-priority Ocean Worlds, such as Neptune’s moon Triton and Uranus’ moon Ariel.



Raman spectra of Fe-hydroxide/alanine assemblage. Raman features due to organics are visible in some spots, indicating heterogeneous adsorption.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: Robert.P.Hodyss@jpl.nasa.gov

Clearance Number:
RPC/JPL Task Number: R20012