Survivability of Prebiotic Molecules on the Lunar Surface

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Introduction

One of the biggest curiosities from the Apollo era was the discovery of small amounts of prebiotic molecules like amino acids and hydrocarbons on lunar dust samples. This study aims to constrain the origin of these organic molecules by simulating the lunar environment and, making use of recent advances in organic molecule detection technology, measuring their survivability on lunar regolith.

Goals:
1. Reactivate Lunar Sample in Plasma Source Ion Implantation (PSII) Apparatus
2. Work-up method development for determination of reaction pathways

Fig. 1. Acceletron PSII reaction chamber is employed to desiccate and immerse samples in a reducing plasma environment prior to prebiotic molecule exposure.

Lunar Soil Samples

Table 1. Curated lunar regolith samples available for this investigation. This study compliments a recent study to determine the origin of amino acids in lunar samples by Elsila et al., Geochimica et Cosmochimica Acta 172 (2016)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Specific, parent</th>
<th>L/FeO ratio (maturity)</th>
<th>Mass analyzed (g)</th>
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<tbody>
<tr>
<td>73131</td>
<td>5, 0</td>
<td>16, immature</td>
<td>0.33d</td>
</tr>
<tr>
<td>73241</td>
<td>8, 0</td>
<td>18, immature</td>
<td>0.27d</td>
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<tr>
<td>78501</td>
<td>247, 234</td>
<td>36, submature</td>
<td>0.46</td>
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<tr>
<td>70011</td>
<td>211, 26</td>
<td>54, submature</td>
<td>0.27d</td>
</tr>
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<td>70011b</td>
<td>35, 0</td>
<td>54, submature</td>
<td>9.78</td>
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<td>72501</td>
<td>59, 0</td>
<td>81, mature</td>
<td>0.29d</td>
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<tr>
<td>78421</td>
<td>20, 5</td>
<td>92, mature</td>
<td>0.25d</td>
</tr>
<tr>
<td>69961</td>
<td>150, 44</td>
<td>92, mature</td>
<td>11.82</td>
</tr>
</tbody>
</table>

* From Morris (1978).
* Collected beneath lunar module as an exhaust-exposed sample.
* Collected 6.5 km from lunar module as lunar module exhaust control.
* Both hydrolyzed and non-hydrolyzed fractions analyzed.

Experimental Procedure

Starting with ~100 mg of loose-grain sample in a test tube, we begin with desiccating the samples via heating in high vacuum. In order to simulate the environmental conditions on the lunar surface, we reactivate the sample surface with PSII prior to exposure to various prebiotic molecules.

Our PSII technique employs a RF discharge H₂ plasma electrically coupled through the glass test tube to an electrode. Plasma ions are driven into the soil by an +/−8 keV in-house optocoupler circuit that we have nicknamed, Acceletron. The Acceletron is pulsed from ground potential to negative high voltage at ~1 kHz to replenish the plasma sheath above the sample surface with hydrogen ions, see Fig. 2.

Ultimately the soil sample tubes are removed from the vacuum to be chemically analyzed in collaboration with the Astrobiology Analytical Laboratory (AAL).

AAL Analysis of Amino Acids

Samples are analyzed via the commercial Waters AccQ-Tag protocol on the Xevo G2 XS. Separation of amino acids is accomplished by injecting 1 μL of the AccQ•Tag derivatized sample onto an Acquity AccQ•Tag Ultra C18, 150 x 2.1 mm column (1.7 μm particle size) and detecting the analytes with fluorescence detection and Xevo G2 XS high accuracy mass spectrometry.

Hot water exaction (1 mL) is performed on each test consisting of 3 tubes: a blank, control and experiment. The test tubes are flame sealed and extracted at 100°C for 24 hours. An aliquot of 100 μL is extracted and dried to evaporate any excess water and concentrate the sample before derivatization. Samples are also acid hydrolyzed at 150°C for three hours.

Fig. 3. Liquid Chromatogram Mass Spectrometer detection of derivatized amino acids.

Discussion

We are currently crafting the work-up methodology (derivatization) and quantifying the irradiation and organic exposure on 50 micron fused silica. Preliminary results indicate that amino acids are reacting with the fused silica i.e., not detected using just the hot water exaction technique. However, amino acids have been detected after hydrolysis implying that peptide bonds are forming on the fused silica surface and liberated only after hydrolysis breaks these peptide bonds. Future studies will be directed at quantifying peptide bond formation as a function of irradiation and lunar soil mineralogy.