The Stability of Amino Acids within Mars Regolith Simulant

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Abstract

This research project was to test the stability of proteinogenic and non-proteinogenic amino acids within the conditions found in Martian soil. The simulated Martian soil is called Mars regolith simulant MM2 (figure 9), and is over 90% identical to actual Martian soil. Recent Mars rover data show that there is up to 1% perchlorate salts in Martian soil, so 0.5% (m/m) sodium (Figure 5), magnesium (Figure 4), and calcium perchlorate (Figure 6) were spiked into the regolith simulant for this study. The aromatic amino acids studied were Tyrosine (Tyr) (figure 1), Tryptophan (Trp) (figure 2), and Phenylalanine (Phe) (figure 3). The objective of the study was to help answer if certain amino acids are more stable within the environmental conditions found on Mars.

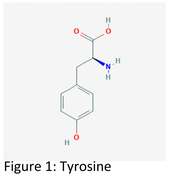


Figure 1: Tyrosine

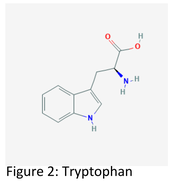


Figure 2: Tryptophan

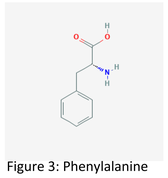


Figure 3: Phenylalanine

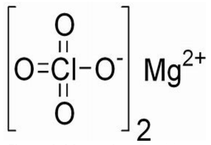


Figure 4: Magnesium Perchlorate

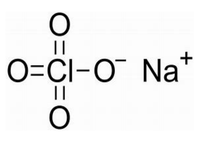


Figure 5: Sodium Perchlorate

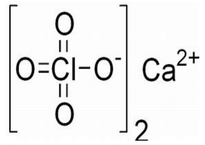


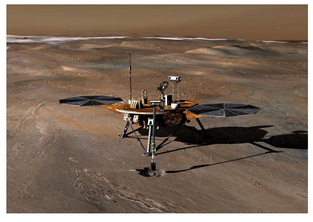
Figure 6: Calcium Perchlorate

Background

The discovery of perchlorates on Mars by NASA's Phoenix Lander (figure 7) has sparked many conversations about the possibility of life on Mars[1]. Mars Odyssey orbital spacecraft has shown that perchlorate is distributed across the surface of the planet[2]. Finding perchlorates on the surface of Mars is profound because of its water retention capabilities. The seasonal flow features spread across the globe suggest water may be accumulating below the surface. The strong attraction of water to the perchlorate salt would lower the freezing point, and during different times of the year, could allow water to flow on the surface, causing the erosion seen in the planetary photo[3]. Using a orthorectifier and a Digital Terrain Model of a detailed site on Mars, scientists at *NASA, JPL, and the University of Arizona* can obtain a clear picture of flowing seasonal water sites on Mars (figure 8). As seen on Earth, water holds a vast amount of microbial life. Some researchers are optimistic that a similar result could be found on Mars currently, or in the past.

Artist's conception of the Phoenix space Lander collecting samples near the north polar ice cap of Mars.

Photo credit: NASA/JPL



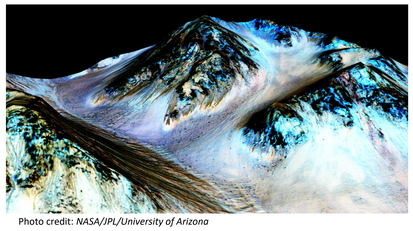


Photo credit: *NASA/JPL/University of Arizona*

Figure 8: The dark streaks called recurring slope lineae shows the salty water as it goes downhill during the warm seasons on Mars. The blue color seen upslope of the dark streaks is mineral pyroxene and not from flowing water

Methods

The Ultra High-Performance Liquid Chromatography Mass Spectrometer (UHPLC-MS) (figure 10) was used to determine the amount of amino acid remaining following subjection to Mars regolith simulant. Conditions created for each of the three amino acids were the following:

Controls: 1. neutral pH H_2O containing 500 µM of each amino acids (Tyr, Trp, Phe)
2. 8.3 pH H_2O containing 500 µM of each amino acid

Test Samples: 1. neutral pH H_2O containing 500 µM of each amino acid plus 0.5% of either magnesium, calcium, or sodium perchlorate.

2. neutral pH H_2O containing 500 µM of each amino acid plus 0.5% of either magnesium, calcium, or sodium perchlorate and 10% (m/m) Mars regolith simulant.

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Control and test samples were stored in sterile, sealed containers, and left at room temperature for 2 months (Figure 11) . Each sample was then placed into an auto-sampler vial and analyzed with liquid chromatography and mass spectrometry. Liquid chromatography peaks were integrated in order to determine the quantity of intact amino acid still present, and mass spectra were assessed to confirm the identity of the amino acid.

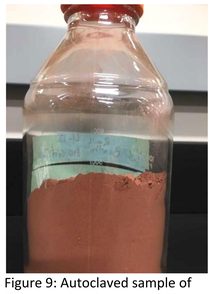

Figure 9: Autoclaved sample of Mars regolith simulant MM2

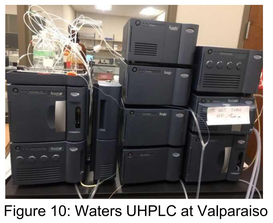

Figure 10: Waters UHPLC at Valparaiso University.

Figure 11: test samples were stored in sterile, sealed containers, and left at room temperature

Previous Work

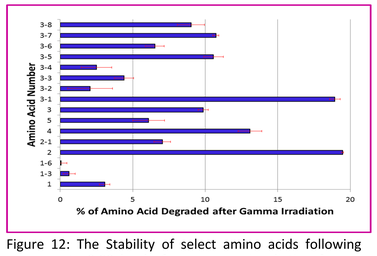

Figure 12: The Stability of select amino acids following exposure to 3.99 krad of gamma ray irradiation from a Cobalt-60 source. Error bars are shown in red.

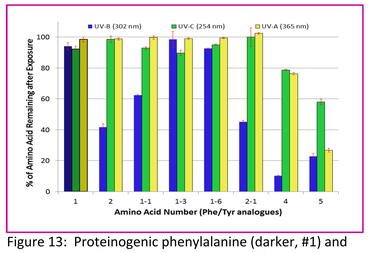

Figure 13: Proteinogenic phenylalanine (darker, #1) and other nonproteinogenic amino acids (see Tables 1 and stability following 24 h exposure to UV-C (blue bars), UV-B (green bars), and UV-A (yellow bars) rays. Error bars are shown in red.

Results and Discussion

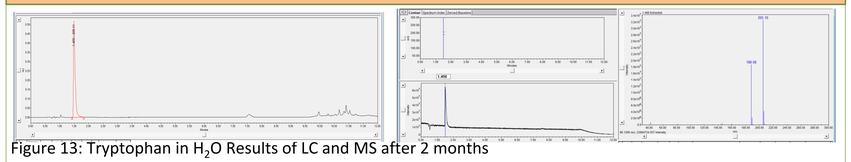

Figure 13: Tryptophan in H_2O Results of LC and MS after 2 months

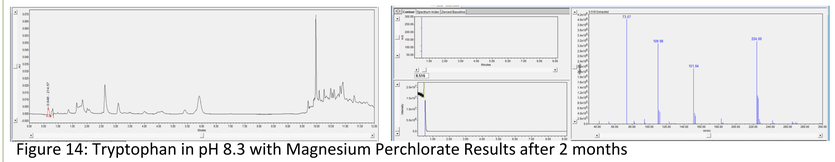

Figure 14: Tryptophan in pH 8.3 with Magnesium Perchlorate Results after 2 months

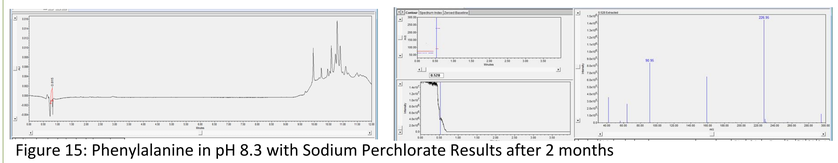

Figure 15: Phenylalanine in pH 8.3 with Sodium Perchlorate Results after 2 months

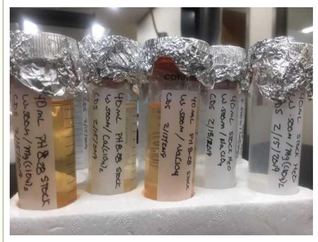

Figure 16: Possible oxidization of Solutions with pH 8.3 and perchlorates

All three amino acids held up in a neutral H_2O environment. After approximately three weeks, the tryptophan amino acid began to show signs of oxidation in all solutions of pH 8.3 with any of the perchlorate (Figure 16). After 2 months, all three Amino acids amino acid solutions were tested and showed that all amino acids in a simulated Mars environment degraded and could no longer be detected in the UHPLC.

Conclusions and Future Work

This work will be repeated with a shorter reaction time, 24 hours followed by 1 week, to ensure that not all of the amino acids are degraded due to regolith and perchlorate exposure. This is necessary so that the stability of different amino acids can be compared. Possible future work may also include simulating Mars atmospheric conditions, as well as soil conditions, using constructed "Mars Jars." Amino acid stability following exposure to 'extreme' Earth conditions, such as found in Yellowstone National Park hot springs, will also be completed in the future.

Acknowledgements

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References

1. Cull, S. C., Arvidson, R. E., Catalano, J. G., Ming, D. W., Morris, R. V., Mellon, M. T., and Lemmon, M. (2010), Concentrated perchlorate at the Mars Phoenix landing site: Evidence for thin film liquid water on Mars, *Geophys. Res. Lett.*, 37, L22203, doi:10.1029/2010GL045269.
2. Clark, B., & Kounaves, S. (2016). Evidence for the distribution of perchlorates on Mars. *International Journal of Astrobiology, 15*(4), 311-318. doi:10.1017/S1473550415000385
3. Mellon, M. T., & Phillips, R. J. (2001). Recent gullies on Mars and the source of liquid water. *Journal of Geophysical Research: Planets*, *106*(E10), 23165-2317₉.