

Photodegradation of selected organics on Mars

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Abstract

At least as much as 2.4×10^6 kg of unaltered organic material is estimated to be delivered to the Martian surface each year [1]. However, intense UV irradiation and the highly oxidizing and acidic nature of Martian soil cause degradation of organic compounds. Here we present first results obtained with the recently developed PALLAS facility at Utrecht University. This facility is specifically designed to simulate planetary and asteroid surface conditions to study the photocatalytic properties of relevant planetary minerals. Our results tentatively show degradation of several compounds and preservation of others.

1. Introduction

Even if life has never been able to flourish on the Martian surface, and thus no biogenic organic material is present, we should still be able to find organics delivered through interplanetary dust particles and meteorites. At least as much as 2.4×10^6 kg of unaltered organic material is estimated to be delivered to the Martian surface each year [1] and it has been estimated, based on Ni concentrations in Martian surface materials, that the Martian soil contains about 1 to 3 % of meteoritic material [2]. Furthermore, organic carbon has been confirmed to be present in meteorites and can survive meteorite impact [3] and should therefore be present at the Martian surface. A rough estimate of the concentration of organic carbon that should be present in the Martian soil is ~60 ppm [4]. This is a very rough estimate based on a constant meteorite influx, a lack of degradation of meteoritic organic carbon, efficient mixing of newly delivered material with the regolith, and a homogenous 100 m thick layer of regolith, with a density of 1200 kg m^{-3} .

The Sample Analysis at Mars (SAM) instrument on board MSL's Curiosity rover recently detected chlorinated hydrocarbons in drilled samples at Gale crater [5]. Additionally, sulfur-containing organics

were discovered [6]. Both types of compounds could have been released as such from the sample or, and most likely for the chlorinated compounds, have formed inside SAM by reactions of low temperature decomposed perchlorate or high temperature released SO_2 . This implies that some pristine organics can be found on the surface.

The Martian surface, however, is subject to intense radiation [7,8] and oxidation [9]. These processes significantly lower the likelihood of the presence of pristine organics on the Martian surface. In light of future organic detection missions to Mars it is therefore important to understand and characterize the reaction products of these processes and equally important the catalytic or protecting effect of minerals found on the Martian surface. Here, we present first results of laboratory simulations investigating the adsorption properties of organic compounds on minerals and the molecular degradation under Mars-like conditions.

2. Experiments in PALLAS

PALLAS, the Planetary Analogues Laboratory for Light, Atmosphere, and Surface Simulations, is a planetary surface simulation facility [10], is a $50 \times 50 \times 50$ cm stainless steel vacuum chamber, equipped with a turbo pump to create and maintain atmospheric pressure.



Figure 1: PALLAS

Samples were placed on a cooling table in the beam spot of a solar simulator equipped with a water filter to remove residual heat (LOT-Oriel, 450 W UV enhanced Xe, 180–900 nm). Experiments were carried out at $20 \text{ }^\circ\text{C}$ and $-55 \text{ }^\circ\text{C}$ in vacuum (10^{-7} mbar) and Mars-like atmospheric conditions (10 mbar CO_2) for 24–48 hours.

3. Sample preparation and analysis

Samples were prepared using two methods. In method 1 the organics were mixed with minerals and ground, then a small amount of water was added to promote binding of the organics to the mineral. The water was left to evaporate after which the dried sample was transferred to the sample holder. In method 2 the mineral powder was mixed with dilute aqueous solutions of organics, after which the suspension was homogenized by vortex and put on a test tube rotator for a time sufficient to reach steady state equilibrium. After equilibrium adsorption, the suspensions were centrifuged to pellet suspended mineral particles, which were dried at 50 °C to remove the residual water.

Before and after exposure the samples were analysed with Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS) and Raman Spectroscopy, enabling direct probing of the effects of the exposure to the Martian conditions, as the samples holders can be placed directly in the DRIFTS and the Raman.

4. Results

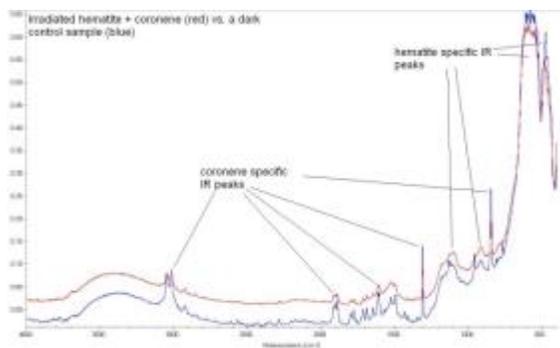


Figure 2: DRIFTS spectra of hematite spiked with coronene, before (blue) and after (red) irradiation

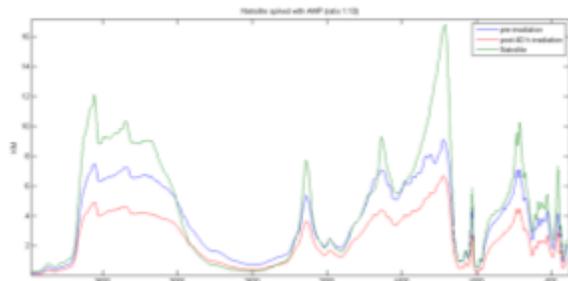


Figure 3: DRIFTS spectra of natronite (green), and natronite spiked with adenosine monophosphate before (blue) and after (red) irradiation.

5. Summary and Conclusions

Photocatalysis is a process known to effectively degrade organic compounds [11]. Previous work has shown that several organic species can be photo-oxidized on very common minerals, such as olivine [12]. Our results indicate that some minerals are more effective catalysts whereas others aid in the preservation of organic compounds. Furthermore, some of the compounds tested appear to be more stable than others. Further studies are underway to better understand the chemistry underlying these results.

Acknowledgements

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