EPSC Abstracts
Vol. 12, EPSC2018-997, 2018
European Planetary Science Congress 2018

Photocatalytic Properties of Minerals and their Role in Prebiotic Chemistry

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Introduction

A myriad of astrophysical environments, once thought to be barren of anything but hydrogen and helium, are now known to be rich in complex carbon chemistry. Not only are carbon molecules such as amino acids and polycyclic aromatic hydrocarbons (PAHs) present in interstellar space, but also on the rocky bodies of our Solar System, as confirmed by the species found in the Murchison and other meteorites. When these organic molecules are adsorbed to their mineral substrates, they undergo a different chemical evolution than they would in gas phase. The resulting reactions play a part in generating organic species important to the inventory of prebiotic chemistry on the early Earth, Mars, asteroids, and comets. In this PhD project, we specifically focus on photocatalysis: how iron and magnesium bearing minerals act as catalysts to accelerate the destruction of PAHs by radiation.

Experimental

The project aims to experimentally constrain photocatalysis products of selected extraterrestrially formed PAHs under a realistic range of UV-Vis radiation doses representative for early Earth, Mars, asteroids and cometary surfaces, and subsequently assess the reaction products of PAH-mineral aggregates. Our findings will be critical for interpretation of data from the Mars Organic Molecule Analyzer instrument (MOMA) onboard ESA's 2020 ExoMars rover and the Raman instruments onboard ExoMars and NASA's Mars2020 rover. They will further enable the development of a next generation of detectors of planetary organics.

To achieve this, irradiation experiments are preformed in PALLAS (the Planetary Analogs Laboratory for Light, Atmosphere, and Surface Simulations) [ten Kate & Reuver, 2015]. In these experiments two types of PAH-mineral aggregates are exposed to UV light, without and with water as a binding agent. The analytical techniques used include Fourier transform infrared (FTIR) spectroscopy, Raman spectroscopy, as well as gas chromatography mass spectrometry (GCMS). An example of the FTIR and Raman spectra is shown in Figure 1.

Background

In the presence of UV and Vis radiation certain mineral surfaces can display a photocatalytic effect, a well-known process in the semi-conductor field [Fox and Dulay, 1993]. This effect is characterised by the mineral surface acting as a catalyst that accelerates the photoreaction, generally resulting in the destruction of the attached organic molecules. The photocatalytic activity of a catalyst depends on its ability to create electron–hole pairs where reaction of the holes with adsorbed water molecules create OH free radicals that oxidize organic compounds [Fujishima et al., 2000]. Electron-hole pairs can also induce oxidizing reactions without creating free radicals by involving chemisorbed molecules that serve as hole traps [Shkrob et al., 2011a]. Here, we investigate the relevance of these effects in conditions of the early Earth, Mars, asteroids, and comets.

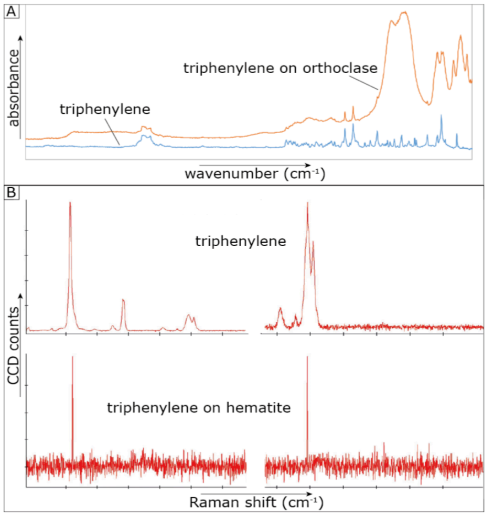

Figure 1. Preliminary (A) DRIFTS and (B) Raman spectra of both pure triphenylene and triphenylene adsobed onto orthoclase (A) and hematite (B).

References

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