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Looking for organics on Mars: using MTBSTFA derivatization to detect organic compounds in a SAM-like experiment

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Abstract

This work aims to analyze Martian analogue soils representing a variety of mineralogical and organic compositions in order to develop methodology for use on the Sample Analysis at Mars (SAM) experiment onboard the Mars Science Laboratory (MSL) rover. The organic molecules present in the soils must be extracted and derivatized before reaching the Gas Chromatograph – Mass Spectrometer (GC-MS) analytical device. Approaching the actual SAM experiment brings up numerous constraints. Even under these restrictions, detection of organic molecules is possible.

1. Introduction

Looking for extraterrestrial life, particularly on Mars, remains a challenging goal for future missions. Searching for organic molecules is an important objective that could lead to the first clues of extinct or extant Martian biota on this planet. Gas Chromatography Mass Spectrometry (GC-MS) is currently the most relevant space-compatible analytical tool for the detection of organics. Nevertheless, GC separation is intrinsically restricted to volatile molecules, and most of the molecules of exobiological interest are refractory or polar. To analyze these organics such as amino acids and nucleobases, an additional derivatization step is required to transform them into volatile derivatives that are amenable to GC analysis. A sample analysis system has been developed to process to the extraction and derivatization in a single step and single place, using N-methyl-N-(tert-butyldimethylsilyl)-trifluoroacetamide (MTBSTFA) as a derivatizating reagent [1].

2. Extraction-derivatization: SAM-like procedure

As part of the SAM instrument on the MSL Martian mission, a single-step protocol of extraction and chemical derivatization with the silylating agent MTBSTFA has been developed to reach a wide range of astrobiology-relevant refractory organic molecules.

To enable a more accurate interpretation of the in situ derivatization GC-MS results which will be obtained by SAM, the first lab experiment is performed in the restrictive conditions of the SAM flight instrument and under Mars conditions. In order to better simulate the actual experiment onboard MSL, a flight-like SAM derivatization test-bed which includes a similar hydrocarbon trap and derivatization oven is used to perform the extraction-derivatization-trapping of organic molecules. For this SAM-like investigation of the organics in the different samples, however, the analytical tool is a commercial GC-MS. First experiments display promising results, the system permitting an extraction and detection of several proteinic amino acids (Figure 1).

3. Martian analogue soils investigation

This procedure has been extended on a suite of terrestrial Mars analogue soils and spiked soils. These soils represent a wide range of potential mineralogical site on Mars regarding aridity, carbonate/sulfate/iron oxide contents, or supposed level of organics. The analogues and spiked soils have been investigated using MTBSTFA derivatization in a SAM-like experiment. Indeed, depending on the composition of the soil, the derivatization reaction can be inhibited, or

derivatization procedure could destroy the organic matter before the analysis. It is thus very important to know the exact behavior of the analytes and reagents regarding the mineralogical and physico-chemical environment.

Using the SAM one-pot one-step MTBSTFA procedure, organic molecules have been detected in various analogue soils. However, not all the analogues display a positive result, and further investigation must be done to better understand the role of the composition of the soil in the deactivation of the reaction. This analysis will able to better define the interferences caused by the soil itself, and adapt the extraction/derivatization steps in the SAM experiment, to reach any organics present at the actual MSL landing site.

4. Figures

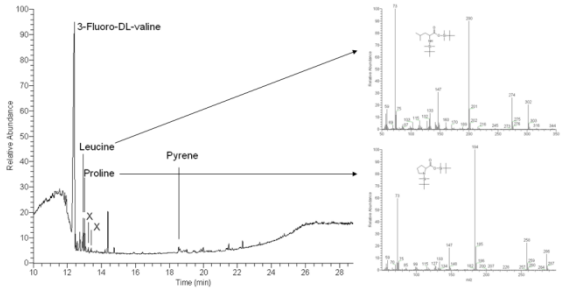

Figure 1: GC-MS analysis of a Mars analogue soil (carbonate-rich stromatolite sample AMASE05-JE01) after MTBSTFA extraction and derivatization. Right: mass fragmentation pattern of the corresponding MTBSTFA derivatives of leucine and proline.

References

[1] A. Buch, D.P. Glavin, R. Sternberg, C. Szopa, C. Rodier, R. Navarro-Gonzalez, F. Raulin, M. Cabane, P.R. Mahaffy. A new extraction technique for in situ analyses of amino and carboxylic acids on Mars by gas chromatography mass spectrometry. Planetary and Space Science 54 (2006) 1592–1599.