The derivatization procedure for the in situ analysis of organic compounds on Mars with the MOMA experiment onboard the Rosalind Franklin rover of the Exomars 2020 space mission

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Abstract

From decades of space exploration of Mars, we recently were able to conclude that regions at its surface should have been habitable in its past. However, information about organic matter present in the Mars soil and rocks remains very limited, although organic matter indigenous to Mars was recently discovered. For that reason, investigation of organic molecules at the Mars surface remains a primary objective for the Mars Science Laboratory and Exomars 2020 missions, as they are a required ingredient for habitability, and some of them can even be potential signatures of life (past and/or present). Onboard the Rosalind Franklin rover of the ESA Exomars 2020 mission, the Mars Organic Molecules Analyser (MOMA) instrument will be dedicated to the detection of organic molecules potentially present in the solid samples to be collected by the rover at *Oxia Planum* where it will land. The core of the MOMA instrument is a UV laser desorption / ionization ion trap mass spectrometer (LDI-ITMS) and a gas chromatograph-mass spectrometer (GC-ITMS). Sample preparation for GC-ITMS analyses includes pyrolysis and chemical derivatization which provide the unique capability to characterize a broad range of volatile and non-volatile organic compounds, and to achieve the chiral separation of enantiomers. To perform derivatization in space, the MOMA team

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developed a specific device associated with an appropriate automated procedure. It mainly consists of cylindrical cups filled with the chemical reactants selected for MOMA (i.e., N-tert-butyldimethylsilyl-N-methyltrifluoroacetamide (MTBSTFA), N, N-Dimethylformamide dimethyl acetal (DMF-DMA) and Tetramethylammonium hydroxide (TMAH)), and sealed with a specific eutectic. Each cup is placed in a separate oven of MOMA, and it releases its content into the oven when heated at the appropriate temperature (i.e. 145◦C for DMF-DMA, 200◦C for MTBSTFA and 309◦C for TMAH) to perform the chemical reaction with the organic molecules that could be present in the samples delivered by the rover sampling system. Although tests were performed during the development phase of the instrument to qualify this device for its use on Mars, they were limited. Therefore, to better constrain the efficiency and repeatability of the sample treatment using our derivatization capsules, we performed more systematic analyses using a homemade reactor reproducing the heating characteristics of the MOMA ovens, with a commercial gas chromatograph mass spectrometer. We used three sets of six capsules filled with MTBSTFA, DMF-DMA, and TMAH respectively. Then we tested the opening temperature of each capsule and submitted standard solutions of several chiral amino acids and non-chiral carboxylic acids to the MOMA derivatization procedure. The results obtained were compared to those obtained when using the standard derivatization procedure applied in the laboratory to the same set of standards. This comparison allows the conclusion that the derivatization procedure developed for the MOMA experiment is well suited to perform the analysis of polar organic molecules that could be present at the Mars surface, including molecules of high relevance for astrobiology such as amino acids.