

Studying processes impacting organic matter at Mars surface and subsurface

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Abstract

Understanding the evolution of organic matter on Mars is a major goal since no carbonaceous compound has been definitely detected so far on Mars. In this context, we developed the MOMIE project (for Mars Organic Molecules Irradiation and Evolution) dedicated to simulate the processes susceptible to impact organic matter in the environmental conditions of the Mars surface and subsurface. Earth-based testing of the degradation or preservation of organic molecules in a mineral matrix submitted to oxidation and/or irradiation will provide essential insights to guide and discuss *in situ* analyses at Mars.

1. Introduction

Several evidences suggest that the early Martian climate offered favorable conditions for long-term sustaining water [1]. As a consequence, we can assume that processes related to prebiotic chemistry, and even the emergence of life, may have occurred on early Mars. In those days, organic matter may have been widespread on Mars, due to exogenous delivery from small bodies, or endogenous chemical processes. Nowadays, in the harsh environmental conditions of the Mars surface, organic matter experienced UV radiations along with water ice and potential oxidants ([2], [3], and for a review [4]) which may have narrowed the inventory of organic compounds at the current surface or subsurface of Mars.

The search for organic relics from the early Mars is one of the major science objectives of the next space missions to Mars: NASA MSL 2011 and ESA ExoMars 2018. To fulfill these mission goals, we developed an experimental set-up enabling to simulate various interactions potentially encountered by organic matter on Mars. For instance, the relative

influence of hydrogen peroxide (H_2O_2) diffusion in the soil and of oxidants formed by UV-water ice or UV-minerals interactions can be studied by monitoring an organic sample with infrared spectroscopy. These processes can be studied separately or simultaneously. Here we present the experimental set-up, the preliminary results we obtained and the next experiments planned.

2. The experimental set-up

The studied sample is made of a thin deposit on a magnesium fluoride (MgF_2) window. In the frame of the first tests of our experimental set-up, organic molecules were deposited on the window in a vacuum chamber, giving a reproducible film of about 200 nm thickness. Then, a mineral phase can be sprinkled onto the organic deposit using a sieve.

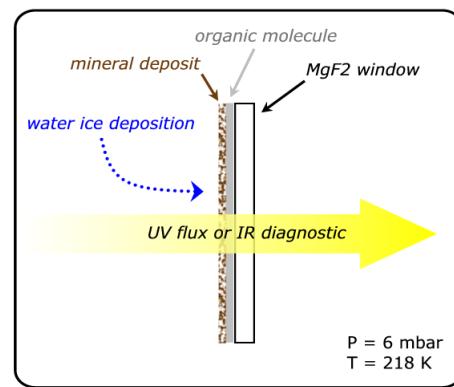


Figure 1: Example of an experimental set-up developed for the MOMIE project.

This thin deposit (with or without mineral) is placed in a reactor allowed to evolve at temperature and pressure representative of the surface of Mars (218 K, 6-10 mbar) (Figure 1). UV irradiation of the sample is performed using a Xenon arc lamp, delivering a flux close to the modeled Martian flux in the 190-250

nm range. Water or hydrogen peroxide can be introduced in the reactor through a gas inlet, forming an ice sheet on the sample. A mobile mirror allows switching from the irradiation mode to the infrared transmission diagnostic mode. Thus, sample evolution is qualitatively and quantitatively monitored in the 1000 to 7000 cm^{-1} infrared range (cutoff at 1000 cm^{-1} is due to the MgF_2 windows of both the sample and the reactor, but these are transparent to the light of the UV lamp).

A rich diversity of processes can be studied within this experimental setup, from the direct UV-irradiation experienced in the first millimeters of the Martian soil, to the likely interaction with H_2O_2 or others oxidants diffusing in the soil.

Table 1: Some results obtained with the experimental set-up of the MOMIE project.
* indicates duplication of the experiment.

Sample	Half-life time (hours)
Glycine + JSC Mars-1	no degradation
Glycine + H_2O	no degradation
Glycine + UV	$12,8 \pm 3,7$
Glycine + UV *	$23,1 \pm 15,4$
Glycine + JSC Mars-1 + UV	$19,3 \pm 4,8$
Glycine + JSC Mars-1 + UV *	$12,8 \pm 1,6$
Glycine + H_2O + UV	$7,7 \pm 1,2$
Glycine + JSC Mars-1+ H_2O +UV	$9,6 \pm 1,3$

3. Preliminary results

To qualify this experimental set-up, several experiments have been carried out with glycine deposits submitted to diverse conditions in the simulation reactor (Table 1). The thin film deposition allows us to make the assumption that the glycine layer is optically thin, so that the kinetic of UV-irradiation experiments is a first order decay. The half life time ($t_{1/2}$) presented in Table 1 are calculated assuming first order reaction kinetics: $t_{1/2} = \ln(2)/K$, with K being the destruction rate of glycine. This destruction rate (K) is the slope of the linear fit of the plot giving the natural logarithm of the normalised absorbance of glycine integrated from 1293.8 cm^{-1} to 1696.3 cm^{-1} against time. For experiments carried out with a mineral phase and/or water ice formation, first order reaction kinetics was found to best fit the data, allowing the same calculation of the half-life times.

The results presented in Table 1 indicate that the degradation of glycine under the UV flux is faster when it is covered with water ice. Dissociation of water molecules due to the UV radiation probably lead to the formation of reactive species, like hydroxyl radicals. The presence of a mineral phase simulating the oxidizing Martian soil (JSC Mars-1) does not seem to affect the glycine in our experimental conditions.

4. Further work

As clay minerals likely to have been host for organic compounds since early Mars -when prebiotic chemistry might have flourished- have been spotted from orbit [1], it seems essential to test the processes these organics may have undergone in these preferential mineral matrix. Consequently, we plan to improve the chemical interaction between the organic and the mineral phases in our experiment, by liquid phase adsorption of the organic molecules on the mineral surfaces prior to their evolution in the reactor. In particular, we plan to work with synthesized iron rich clays.

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