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Thermal evolution of organic residue and TOF-SIMS analysis in the framework of the COSIMA experiment

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Abstract

We have developed a new experimental setup allowing the study of thermal evolution of macromolecular organic compounds up to 800 K. We will present the first results concerning POM (polyoxymethylene – H_2CO polymer) and HMT (hexamethylenetetramine – $C_6H_{12}N_4$) heated at high temperature (300 – 800 K). The relevance of the results for cometary and meteoritic studies will be enlightened. Some organic residues have also been analyzed with a mass spectrometer similar to COSIMA allowing the preparation of the interpretation of the data of the time of flight mass spectrometer on board the Rosetta mission.

1. Introduction

Cometary grains with diameter smaller than 1 µm can reach temperature up to 600 K at 1 AU from the Sun [3] [4] and they are evidence that the insoluble organic matter (IOM) presents in chondritic meteorites could has been heated up to 1200 K [2]. To constrain the composition and the evolution of organic matter in small bodies, the study of the thermal-degradation and decomposition of macromolecular compounds synthesized in representative conditions is necessary.

We have developed a new experimental setup named OREGOC (French acronym for origin and evolution of ices and cometary organic compounds) in which the sample temperature can be controlled from 20 to 800 K. Macromolecular organic compounds are synthesized in conditions representative of giant molecular clouds by VUV photolysis and/or thermal processing of ice mixtures deposited at 20K. Once photolyzed for several hours, the ice mixtures are slowly heated forming organics residues after ices sublimation. The thermal-evolution of this carboneous solid phase is monitored by infrared spectroscopy (IRTF) and the gaseous species produced during the heating are analyzed by mass spectroscopy (MS).

Previous works have shown that the VUV photolysis of representative ice mixtures leads primarily to the synthesis of POM (polyoxymethylene – H_2CO polymer) [7] [8] and HMT (hexamethylenetetramine – $C_6H_{12}N_4$) [1] [6] [8]. So, we first focused our analysis on the thermal evolution of these both molecules.

Moreover, some of our organic residues have been analyzed at room temperature with a laboratory time of flight secondary ion mass spectrometer (TOF-SIMS) having similar instrumental characteristics than the COSIMA instrument on board the Rosetta mission. The goals of this study are to obtain reference spectra to facilitate molecules identification with COSIMA and to propose the best COSIMA operational strategy to detect POM and HMT in grains ejected by 67P/Churyumov-Gerasimenko during the European Space Agency (ESA) mission in 2014 and 2015.

2. POM

It has already been shown that POM is easily synthesized during thermal treatment or VUV photolysis of cometary ice analogs [7] [8]. Moreover, its presence and thermal decomposition into gaseous H_2CO is a convincing way to explain the presence of formaldehyde distributed source in cometary environment [3] [4]. Whereas its detection in cometary grains has been claimed several years ago [5], no unambiguous detection of POM in cometary environment has been obtained so far.

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With our apparatus, we have synthesized several polyoxymethylene samples by thermal processing of H_2CO: NH_3 ice mixture. We will present i.) thermal-degradation kinetic of polyoxymethylene at temperatures ranging from 320 to 350 K (Fig. 1) ii.) analysis of its mass spectrum allowing to prepare the interpretation of the COSIMA data (Fig. 2).

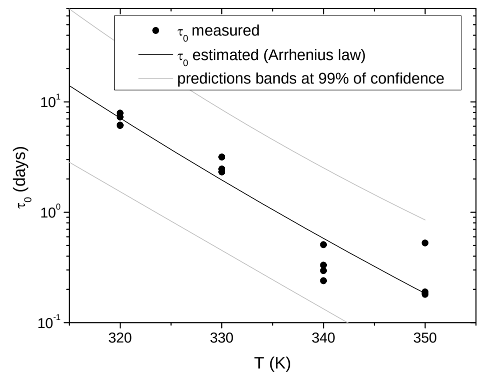

Figure 1: Characteristic decomposition time of POM as a function of the temperature.

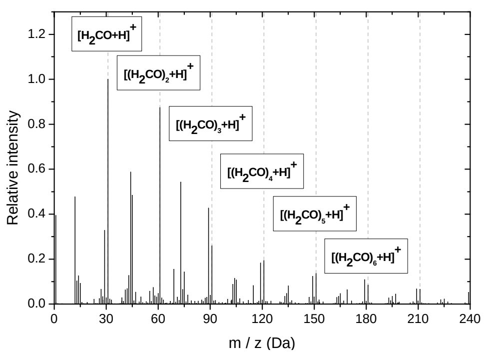

Figure 2: TOF-SIMS spectrum of a POM sample synthesized by thermal processing.

6. HMT

As for POM, it has already been shown that HMT is easily produced during thermal treatment or VUV photolysis of cometary ice analogs [1] [6] [8]. Its presence is thus expected in comets as well as in meteorites. Whereas, HMT has already been searched in meteorites, its presence has never been revealed.

We will present the results of a series of experiments focused on the thermal evolution of organic residues containing HMT to understand its absence in meteorites.

Acknowledgements

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