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The photostabililty of prebiotic organic compounds on cometary dusts.

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Abstract

A new methodology for measuring the photostability of organic compounds in extraterrestrial environments will be presented. It is based on Low Earth Orbit (LEO) and "classical" laboratory photolysis experiments, as well as on quantitative measurements of the VUV/UV (λ < 300 nm) absorption cross section spectra. We will discuss the complementarily and limits of each approach, and discuss the astrobiological relevance of such studies in the frame of the importation of organic matter to Earth via micrometeorites.

1. Introduction

Comets are considered as the most primitive objects of the solar system and may provide key information on its formation. However, so far, the knowledge of the chemical composition of cometary nuclei has been inferred from measuring gases and from analyzing dust in cometary comae. This dust may compose some micrometeorites and IDPs that are at the present day the dominant source of extraterrestrial material accreted by Earth. Cometary dust might then be relevant to the emergence of life [1], [2], [3]. It is crucial to know the chemical composition of these grains and to understand their chemical evolution from their ejection from the nucleus to their arrival on Earth. On a shorter time scale, in the frame of the ROSETTA mission, they might be processed before being analyzed by the instruments of the spacecraft. This evolution is notably linked to the photochemical stability of organic molecules in solar system conditions, i.e. submitted to energetic VUV/UV radiations (λ < 300 nm). Different approaches to measure this photostability will be presented in this work.

The focus of this presentation will be given on our newly developed methodology to measure VUV cross section absorption spectra of thin organic films. Measurements of the VUV spectra for two purines, adenine and guanine, and one pyrimidine, uracil, will be presented. Photodissociation rates derived from such measurements will be compared to direct measurements with laboratory UV lamps or measurements after direct exposure to the Sun in Low Earth Orbits. Advantages and limits of each method will be discussed.

2. Photostability studies

Photodissociation rates are controlled by UV and VUV solar radiations. To calculate them in these wavelengths range, we can use different approaches: (i) direct measurements in the laboratory or in LEO and (ii) calculation thanks to the knowledge of the solar spectral irradiance and the absorption cross section spectra in the VUV domain.

2.1 Direct measurements

A common approach to study the photostability of an organic compound is to photolyse samples in a vacuum reactor connected to a UV lamp such as a microwave-powered H_2/He-flow lamp which delivers an emission spectrum dominated by the Lyman α band in the VUV. This experimental device doesn't simulate accurately the actual solar emission [4]. This point is crucial for molecules such as adenine and guanine, which have an efficient absorption cross section in all VUV/UV domains.
In order to get proper photolysis conditions, relevant to the properties of the UV photons emitted by the Sun, photochemical experiments are also conducted

in Low Earth Orbit (LEO) on ESA facilities such as EXPOSE-E & -R outside the International Space Station. There, organic molecules are directly exposed to the real Sun emission spectrum [5], [6], [7].
In both cases, laboratory and LEO experiments, a first-order decay is assumed and the value of J (the photodissociation constant) is then measured experimentally.

2.1 Indirect measurements

Indirect measurements of the photostability of any organic compound can be done thanks to their cross section absorption spectra in the VUV domain. Such absorption spectra are very scarce for solid organic compounds in current literature.
Solid organic films are prepared by sublimation and recondensation on magnesium fluoride windows (MgF_2). Then they are analyzed using infrared and VUV spectroscopy. From VUV transmission data, the absorption cross section spectra is deduced. Calculation requires an accurate measurement of the thickness of the sample, calculated by two independent methods: one using interference fringes measured during the sample preparation and one using interferometric microcopy.
How VUV cross section spectrum can be used to derive actual photolysis rate will be discussed.

3. Applications

Such data can be used to model the chemical evolution of specific molecules on cometary dust grains between their ejection from a cometary nucleus and their arrival on Earth. This study is also relevant to assess the evolution of organic material from the nucleus of comet 67P/Churyumov–Gerasimenko to the Rosetta orbiter. For instance, it will be usefull for the interpretation of measurements by the COSIMA mass spectrometer, collecting grains in the coma, to link the composition measured in the cometary atmosphere to the actual composition of the nucleus.

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