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To cite this version:

HAL Id: insu-01348915
https://hal-insu.archives-ouvertes.fr/insu-01348915
Submitted on 26 Jul 2016

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The APSIS EXPERIMENT: Simulating the VUV Photochemistry of the Upper Atmosphere of Titan

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Titan, the largest moon of Saturn, has a dense atmosphere whose upper layers are mainly composed of methane (CH4) and molecular nitrogen (N2). The Cassini mission revealed that the interaction between those molecules and the solar VUV radiation, as well as the electrons from Saturn’s magnetosphere, leads to a complex chemistry above an altitude of 800 km [1].

This naturally ionized environment contains heavy organic molecules like benzene (C6H6) even at altitudes higher than 900 km [2]. This is consistent with an initiation of the aerosols in Titan’s upper atmosphere. Moreover, some N-bearing molecules of pre-biotic interest such as NH3 have been detected by the instruments; but in quantities that do not match the theoretical models [3].

The presence of those molecules makes Titan a natural laboratory to witness and understand prebiotic-like chemistry but despite all the data collected, all the possible chemical processes in such a hydrocarbon-nitrogen-rich environment are not precisely understood.

→ High interest of Titan’s ionospheric chemistry experiments with pure-photochemistry simulations

The APSIS Experiment

Atmospheric Photochemistry Simulated by Surfatron

In order to reproduce the efficient photochemistry occurring in this kind of upper atmospheres, we designed a gas reactor named APSIS. This reactor is to be coupled with a VUV photon source (figure 5) as N2 needs wavelengths shorter than 100 nm in order to be dissociated. The APSIS reactor is described in details in [4]. Briefly, it is a stainless steel chamber of dimensions 500 mm x 114 mm x 92 mm where the reactive 95:5 N2/CH4 mixture is introduced via a gas inlet (figure 4).

RESULTS

Psurf= 0.5 mbar
Pbase= 1 mbar
P=300 W

Diagnosis by mass spectrometry: HIDEN HPR-20 QIC mass spectrometer

Figure 7 shows analogue mass spectra prior (black curve) and after (red curve) irradiation of the reactive medium with the VUV surfatron-based source. It shows clear productions of C2 compounds, but also C3 and C4. This is confirmed by time-monitored spectra of the masses m/z=27 (figure 9) and 52 (figure 10) (possible molecules: HCN and C2N, respectively) which reveal a sharp rise of the signals when the VUV source is turned ON (red lines).

The consumption of methane is moreover followed versus time (figure 8), showing a decrease of nearly 5% in 25 minutes.

All the results are reproducible.

PERSPECTIVES

The high flexibility of our VUV source will allow us to change the rare gas and thus the wavelength used to irradiate the reactive mixture. For example, helium provides 58-nm radiations and argon 104-nm ones.

Inside APSIS, the pressures can also vary as well as the CH4 ratio.

Testing all those conditions will give us more information on the photochemical processes occurring in Titan’s upper atmosphere and shed some light on prebiotic-like chemistry.

References: