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# Laboratory simulation of the early Earth's upper atmospheric reactivity

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## Abstract

Studying the reactivity of the early Earth atmosphere is of the prime interest to understand the origin and the chemical evolution of the organic matter on Earth. We address the hypothesis of a possible organic growth in the upper atmosphere submitted to the harsh irradiation of the young Sun. Here we used a plasma experiment to simulate this specific reactivity. We will present recent results about the formation of organic products in gaseous phase.

## 1. Introduction

Recent geological studies gives more constrains about the composition of the primitive atmosphere of the Earth, before the rise of the oxygen, during the Hadean and Archean eons [1]. The origin of organic materials is crucial for this period where life is suspected to appear.

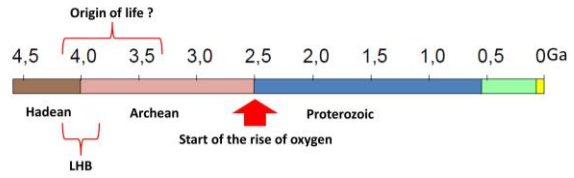


**Figure 1:** Geologic time-scale

The actual theory proposed an oxide atmosphere mainly composed by $N_2$, $CO_2$ and $H_2O$. The presence of reduced gas trace is also evocated principally to explain the faint young Sun paradox [2]. If a possible reduced organic chemistry in the early Earth atmosphere is evocated by Oparin and Haldane, then investigated experimentally by Miller [3], the reactivity of an oxide atmosphere is however relatively unknown. More recently, the irradiation at Lyman-α of $N_2/CO_2/CH_4$ has shown a potential $CH_4$-based organic growth [4]. However, this wavelength prevents the coupling with nitrogen chemistry. Based on these previous experiments, we proposed to study a possible organic chemistry involving nitrogen representative of the upper atmosphere of the early Earth.

## 2. The PAMPRE experiment

To reproduce the organic chemistry which could be initiated by solar VUV photons in the upper atmosphere of the early Earth, we used an experimental device named PAMPRE. This is a Radio-Frequency Capacitively Coupled Plasma (RF CCP) at low pressure [5][6]. The modeling of the plasma energy distribution showed a maximum at 600 nm and a tail with wavelengths down to 70 nm [7]. This similarity with the young Sun spectrum enables to simulate in the laboratory the energy deposition on the top of the early Earth atmosphere. We used different gaseous mixtures, in agreement with the known composition of the early Earth atmosphere.

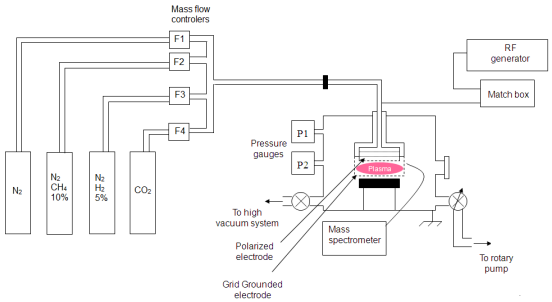


**Figure 2:** Schema of the PAMPRE experimental setup.

The gaseous products of these experiments are accumulated during few hours with a cryogenic trapping. Then, the composition of the gaseous phase

is analyzed *in-situ* by mass spectrometry and infrared spectroscopy.

## 3. Results

Products trapped during these experiments are analyzed by mass spectrometry. Figure 2 shows peak of species with mass up to 60 u reflecting a complex organic chemistry. This organic growth agrees with the previous experiment at Lyman-α by Trainer et al.

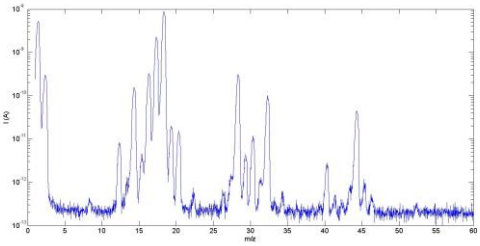

**Figure 3:** Mass spectrum of the gas products trapped during the experiment

The main species were identified by infrared spectroscopy: $NH_3$, $H_2O$ and HCN. This important result confirms the coupling with nitrogen chemistry in upper atmosphere conditions. HCN and $NH_3$ are involved in amino acids and nucleotide bases synthesis.

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