Soft X-rays photostability of amino acids and nucleobases in extraterrestrial environment analogs. S. Pilling¹, D. P. P. Andrade¹, R. T. Marinho², E. M. do Nascimento², H. M. Boechat-Roberty³, R. B. de Castilho³, G. G. B. de Souza³, L. H. Coutinho³, R. L. Cavasso-Filho⁵, A. F. Lago⁵, and A. N. de Brito⁶. ¹Universidade do Vale do Paraíba (UNIVAP/IP&D), SP, Brazil (sergiopilling@yahoo.com.br), ²Universidade Federal do Rio de Janeiro (UFRJ), RJ, Brazil, ³Universidade Federal da Bahia (UFBA), BA, Brazil, ⁴Universidade Federal do ABC (UFABC), SP, Brazil, and ⁵Laboratório Nacional de Luz Síncrotron (LNLS), SP, Brazil.

Introduction

The search for amino acids, nucleobases and related compounds in the interstellar medium/comets has been performed at least in the last 30 years[1,2]. Despite no conclusive detection of these compounds interstellar medium [3-6], the simplest amino acid (glicine) has been claimed to be present among the chemical inventory of comet Wild 2 [7]. The search for these biomolecules in meteorites, on the contrary, has been revealed an amazing number, up to several parts per million [8-11]. This chemical dichotomy between the molecular inventories found in meteorites and interstellar medium and comets remains a big puzzle in astrochemistry field and in the investigation about the origin of life.

To verify if these biomolecules on gas- or solid-phase, supposed to be formed in molecular clouds (MC) or protoplanetary disks (PPD), can survive long enough to soft X-ray exposition to be observed or even to be found in meteorites, we perform experimental photochemical studies employing the Brazilian Synchrotron Light Laboratory (LNLS) facility, located at Campinas, Brazil.

Experimental methodology and results

Briefly, the measurements have been undertaken employing 150 eV photons (~ 4 × 10¹¹ photons cm⁻² s⁻¹) from the toroidal grating monochromator (TGM) beamline under high vacuum conditions. The sample were analyzed using two different techniques: FTIR (infrared spectrometry) for solid samples and TOF-MS (mass spectrometry) for gaseous samples.

For the gas-phase experiments (glycine, adenine and uracil) the soft X-ray beam had intercepted perpendicularly the molecular beam. The produced ions were mass/charge analyzed by Time-of-Flight mass spectrometry (TOF-MS) employed in a photoelectron-photoion coincidence mode (Fig. 1a).

TOF mass spectra were obtained using the correlation between one photoelectron and a photoion [12] The ionized recoil fragments, produced from the perpendicular interaction of the light with the gas sample, are accelerated by a two-stage electric field and detected by two microchannel plate detectors in chevron configuration, after mass-to-charge (m/q) analysis by a TOF mass spectrometer. Due to the low vapor pressure of these compound, it was necessary to use a heated source for sublimation [13]. The experiments were at about 25 °C above Figure 1: a) Mass spectra of the ionic species produced by the interaction of 150 eV photons on two gaseous samples. b) Infrared spectra of two solid-phase samples before and after irradiation by 150 eV photons.
the temperature at which a sublimate was first noted. The base pressure in the vacuum chamber was in the \(10^{-8}\) mbar range. The relative species yield (branching ratio) were determined and ionization and dissociation cross section were determined adopting absolute values of absorption cross section from literature and described elsewhere [14].

In the case of solid phase samples (glycine, DL-proline, DL-valine, adenine and uracil), in-situ analysis were performed by a Fourier transform Infrared spectrometry (FTIR) coupled to the experimental chamber. The solid samples have been diluted and deposited onto a CaF\(_2\) substrate by drop casting following solvent evaporation. The sample thicknesses were measured with a Dektak perfilometer and were of the order of 1-3 \(\mu\)m. The samples were placed into a vacuum chamber (10–5 mbar) and exposed to different radiation doses up to 20 hrs (Fig. 1b). The experiments are performed at room temperature and takes about several weeks.

The results show that the gaseous amino acids are largely destroyed by soft X-rays while the nucleobases have a survivability of a few percents. As expected a similar behavior was also observed in the case of solid samples. The dissociation cross section of glycine in the gas phase is about 10 times lower than in the solid-phase. In the case of nucleobases both solid and gas-phase present similar dissociation cross section. The nucleobases photostability is up to two orders of magnitude higher than for the amino acids. The condensed amino acids can survive at least \(7 \times 10^5\) years and \(7 \times 10^8\) years into dense MC and PPD, respectively. For nucleobases this values is determined lifetime is of the order or even grater than MC and PPD lifetime.

This result corroborates the scenario in which during planetary formation (and after) these molecules, trapped into and onto dust grains, meteoroids and comets, could be delivered into the planets/moons possibly allowing pre-biotic chemistry in such environments where water was also found in liquid state.

**Sumary**

We present experimental studies on the interaction of soft X-rays on gas-phase and solid-phase amino acids and nucleobases in an attempt to verify if these molecules can survive long enough to be observed or even to be found in meteorites. Measurements have been undertaken employing 150 eV photons under high vacuum conditions at the Brazilian Synchrotron Light Laboratory (LNLS).

The produced ions from the gas-phase experiments (glycine, adenine and uracil) have been mass/charge analyzed by time-of-flight spectrometer. The analysis of solid phase samples (glycine, DL-proline, DL-valine, adenine and uracil) were performed by a Fourier transform infrared spectrometer coupled to the experimental chamber. Photodissociation cross sections and halflives were determined and extrapolated to astrophysical environments. The nucleobases photostability was up to two orders of magnitude higher than for the amino acids.

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**References**