"ORGANICS" EXPERIMENT ON THE INTERNATIONAL SPACE STATION

Richard Ruiterkamp¹, Pascale Ehrenfreund¹, Bernard Foing², and Farid Salama³

¹Sackler Laboratory for Astrophysics, Leiden Observatory, 2300 RA Leiden, The Netherlands
²Space Science Department, ESTEC, 2200 AG Noordwijk, The Netherlands
³Astrophysics Branch, NASA Ames Research Center, CA 94035-1000, Moffett Field, USA

ABSTRACT

In this experiment, large organics will be exposed on a long duration radiation facility on the International Space Station. The results of this experiment will help us to identify specific carbonaceous molecules in the interstellar medium (ISM) and to monitor their evolution and possible incorporation into Solar System material. The results also allow us to make predictions concerning the survival probabilities of specific organic species in space.

Key words: ISS; Astrochemistry; photochemistry.

1. INTRODUCTION

A large number of organic (carbonaceous) molecules have been detected in space (Tielens et al. 1999). We will investigate the chemical evolution of abundant organic interstellar molecules by long duration space exposure on-board the International Space Station. Three types of molecules will be exposed to the near earth orbit environment on the EXPOSE facility as part of the "ORGANICS" investigation (Ehrenfreund et al. 1995).

Polycyclic Aromatic Hydrocarbons (PAHs) have been identified in the ISM, meteorites and interplanetary dust particles (IDPs) (Ehrenfreund & Charnley 2000). In the ISM mixed, neutral and ionized PAHs are thought to be responsible for some of the infrared emission bands and the UV and visible Diffuse Interstellar Bands (DIBs) (Allamandola et al. 1999, Salama et al. 1996, 1999). As most abundant free organic molecules, PAHs are observed in reflection and planetary nebulae, H II regions and external galaxies. In UV dominated regions, a significant fraction of PAH molecules can be partly dehydrogenated or even fragmented (Vuong & Foing 2000). The physical conditions in the ISM could provide a selection mechanism that favors individual species of PAH.

Kerogen is that fraction of sedimentary organic matter that is insoluble in organic solvents. It serves as meteoritic and interstellar analog material and can be considered as a mixture of complex organic macromolecules (Tissot et al. 1974). Up to 90 % of the aromatic and 18 % of the aliphatic molecules in the Orgueil and Murchinson meteorites are included in the kerogen residue.

The famous polyhedral molecules first discussed by Kroto et al. (1985) could be an important carrier of carbon in our Galaxy. The C₆₀ cation has been tentatively detected spectroscopically and up to 0.9 % of the cosmic carbon could be in the form of fullerenes (Foing & Ehrenfreund 1994, 1997). In the Allende meteorite C₆₀ and higher fullerenes up to C₂₄₀ have been detected (Becker et al. 1999). The photochemical evolution of fullerenes is of great interest to astrochemistry.

2. EXPERIMENTAL SETUP

Selected samples will be exposed on the EXPOSE facility mounted on the outside of the International Space Station. The samples will remain approximately one year on-board the ISS before they are returned to Earth. The radiation dose that is collected by the samples during flight far exceeds the radiation dose which can be achieved in the laboratory. The results will greatly enhance our knowledge on the evolution of large organic molecules in space environment.

2.1. Sample Carriers

Samples are deposited by solvent evaporation on thin MgF₂ windows inside the sample cells. Dark samples on the lower sample carrier are shielded from the UV photons and enable us to discriminate between the effects of exposure to photons and cosmic rays. Figure 1 shows a schematic drawing of the sample cell layout. Additional filters will enable us to select spectral regions for sample exposure.
2.2. Sample Tray

The sample carriers containing the different experiments of the EXPOSE facility are integrated in the sample tray. This tray is sealed by MgF₂ windows and is equipped with shutters. Passive and active heating keep the temperature in the 0-25 °C range. Radiation is monitored by the R3D dosimetry experiment.

The "ORGANICS" experiment will be situated in two compartments of the tray as depicted in Figure 2. One compartment will be isolated from the external environment and one compartment will be vented to space.

3. EXPERIMENTAL GOALS

In the "ORGANICS" Experiment we will investigate the UV photochemistry of complex organic materials and study the survival of these molecules in space. By studying the chemical evolution of these substances under space conditions, we will be able to better constrain the composition of carbon in the ISM and may deduce survival rates of carbonaceous compounds.

The results of this experiment will also be of relevance to planetary sciences and could help to constrain the cosmic delivery of organics to early planets. Since PAHs are known pollutants, information on their stability in the upper atmosphere and on Earth could help solve environmental issues.

4. EXPECTED RESULTS

PAHs can be dehydrogenated and even dissociated by the energetic processes in the ISM (Tielens et al. 1999). The formation of radicals and ions adds an additional dimension to the chemistry of carbon based molecules. Moreover the physical conditions of the ISM could imply a selection mechanism that favors specific PAH species.

Fullerenes are expected to eject C₂ radicals under radiation exposure and thereby slowly degrade to smaller fullerene molecules. Since we aim at using fullerenes with more that 70 carbon atoms we expect degradation of larger molecules towards the stable molecule C₆₀.

Macromolecules such as kerogens, progressively aromatize, leading to a more stable configuration.

5. MATERIAL AND METHODS

From a set of 20 large PAH molecules, synthesised by the German PAH Forschungs Institut, flight samples will be selected. In our sample selection we will focus on large stable PAHs; azo- oxo- thio-PAHs; PAH isomers; potentially reactive PAH species and others.

The selection of large fullerene samples will depend on the availability of these exotic substances but will include C₆₀, C₇₀ and C₈₄.

The kerogen samples will be of type III since this type most closely resembles the infrared spectrum.
of carbonaceous extracts of the Orgueil meteorite (Ehrenfreund et al. 1991).

6. CHEMICAL AND PHYSICAL ANALYSIS

Pre-flight analysis of the PAHs, fullerenes and kerogen samples will consist of:

- Matrix Isolation spectroscopy (MIS)
- Infrared spectroscopy
- Fluorescence spectroscopy
- UV/Visible spectroscopy
- Time-Of-Flight Secondary Ion Mass Spectroscopy
- Gas Chromatography-Mass Spectroscopy
- Isotopic analysis and Magic angle spinning NMR

The change in the chemical composition due to the space environment will be evaluated after retrieval with the same methods. The EXPOSE platform is equipped with a dosimetry experiment that monitors the flux of radiation that hits the sample tray. This enables us to carefully monitor the total energy input on the samples as well as the spectral information.

7. RECENT RESULTS AND STATUS

In preparation for sample selection we have performed Matrix Isolation Spectroscopy (MIS) on selected large PAH samples (> 30 carbon atoms). This technique uses a cold (4K) substrate on which a highly diluted gas mixture of Neon and a PAH sample are frozen. The inert Neon is UV transparent
and these experiments are known gas-phase simulation techniques. Irradiation with UV photons from a hydrogen discharge lamp forms PAH ions that can be detected spectroscopically. These spectra can be used to search DIB spectra for matching profiles. It is clear that even for this small subset of PAH species, it is hard to identify DIBs with the laboratory MIS data (Ruiterkamp et al. 2001). Until gas-phase experiments become routine, MIS experiments provide easy screening of interesting species, and aid the selection of candidates for gas-phase spectroscopy. Laboratory spectra of large PAH in the UV-IR range allow to constrain the size distribution, stability and structure of PAHs in space.

Since the launch date of the EXPOSE experiment has been postponed until after 2005 we will continue to perform laboratory simulation studies. In addition we have will test a sample selection on the short duration exposure experiment BIOPAX. Samples will be launched end 2002 to return to Earth after a two week flight. First results are expected a few weeks after sample retrieval.

ACKNOWLEDGMENTS

The authors further want to acknowledge the support by the additional members of the "Organics" team: E. Jessberger, W. Schmidt, F. Behar, F. Robert and M. Breitfellner.

REFERENCES

Becker L. et al., 1999, Nature 400, 228
Ehrenfreund P. et al. 1995, "Evolution of organic matter in space" proposal for the EXPOSE facility on the ISS
Foing B. H., Ehrenfreund P., 1994, Nature 369, 26