ICEE: Next Generation Exobiology and Astrobiology Studies.

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Introduction: The presence of organic molecules, from simple to complex form are found in the ISM (interstellar medium) [1],[2]. Perhaps the largest of these molecules are the PAHs, or polycyclic aromatic hydrocarbons [3],[4], while smaller versions of PAHs have been identified in meteorites [5], IDPs (interplanetary dust particles) [6] and comets [7] within the Solar System. Life is comprised of organic molecules and, in one sense; the search for life is the search for and identification of organic molecules. This yields an interesting question. Can the organics in the ISM serve as the chemical feedstock to the prebiotic molecules identified in meteorites, comets and IDPs in a "Top-Down" synthesis mechanism? Most studies regarding the formation of prebiotic molecules focus on a "Bottoms-Up" mechanism, whereby simple organic compounds in ice form larger, more biologically relevant molecules when exposed to UV irradiation [8]. Here we present a next generation experimental setup which focuses on if larger, interstellar organics, such as PAHs (polycyclic aromatic hydrocarbons) can serve as the chemical feedstock for the organic inventory found in the Solar System.

This presentation introduces ICEE, the In-situ Carbon Evolution Experiment facility whose objective is to understand the modification of organic compounds under a wide variety of planetary, Solar System and ISM conditions. The presentation will detail the latest ICEE results regarding the formation of "Top-Down" synthesis of molecules from PAHs.

Methodology: ICEE is a state of the art facility, consisting of a ultra-high vacuum (UHV) chamber (10^{-8} torr), on which are mounted two radiation sources, a high energy electron gun and a flowing H_2 discharge lamp. The high energy electron gun is capable of producing electrons from 1 to 100 keV. The flowing H_2 microwave discharge lamp is capable of producing Lyman α photons (121.6 nm, 10.2 eV) as well as a broad continuum emission. An IR transparent window is mounted onto the tip of a rotatable Helium cryo-cooler, which is capable of temperatures between 15 and 300 K. A gas inlet and organic deposition port are located adjacent to each other in the vacuum chamber setup. Thus the sample window can be rotated to face both the gas inlet and organic deposition ports permitting deposition of a mixed sample onto a cold sample window. The sample window can then be rotated to face either, or both, radiation sources (see Figure 1).

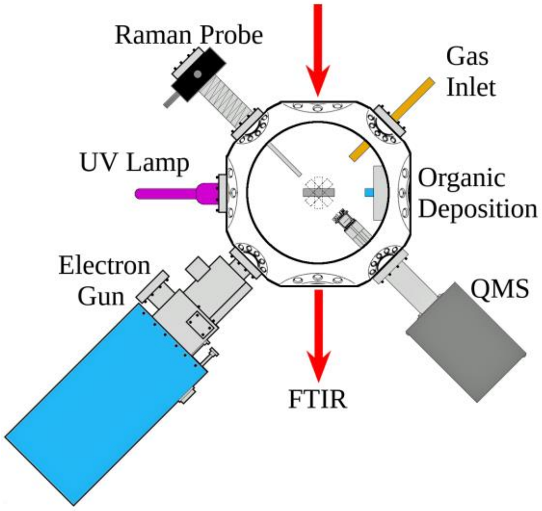

Figure 1. Overview of the ICEE chamber, showing the radiation sources as well as the in-situ characterization techniques.

In-situ analysis of samples is accomplished via three techniques (See Figure 1). A Hiden Analytical HAL 3F 301 mass spectrometry system consisting of both a Faraday and single channel electron multiplier detector, a triple mass filter, for added mass resolution, and is capable of mass analysis up to 300 amu (u) for volatile molecules in the gas phase. Raman probes (785 nm and 405 nm excitation wavelengths) are attached to the vacuum chamber permitting the collection of in-situ Raman spectra on pre and post-irradiated samples. Raman spectra are collected via a JASCO NRS-5500. The UHV chamber is interfaced to a Nicolet iS50 FTIR spectrometer. The iS50 FTIR spectrometer consists of an automated beamspittler changer and three internal detectors. An Axiot Analytical light pipe connects the FTIR spectrometer to the UHV chamber via diamond windows. This setup permits collection of IR spectra from 50 to 17,000 cm^{-1} (200 to 0.58 μm).

The PAH, pyrene ($C_{16}H_{10}$) was utilized in the initial experiments. Using the procedure described above, pyrene was co-deposited with the matrix being investigated (argon and H_2O). Following the initial collection of FTIR and Raman spectra, the sample was photolyzed using the flowing H_2 microware discharge lamp.

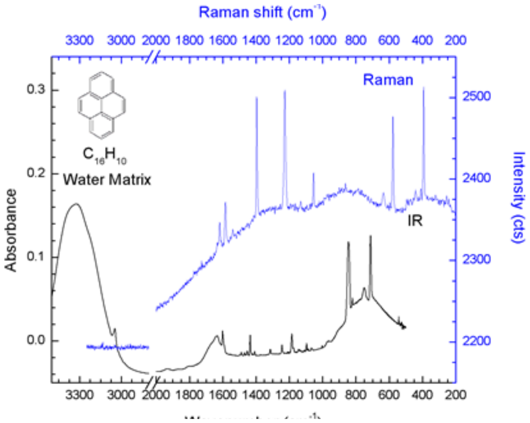

Figure 2. Comparison of the FTIR and Raman spectra of neutral pyrene encased in H_2O ice.

Results: Results on neutral and UV irradiated PAHs (polycyclic aromatic hydrocarbon) in both an argon and H_2O matrix, will be presented. Irradiation of PAHs in ices typically results in the decarboxylation of the molecule as well as the production of refractory materials containing C=O and –OH groups. These photoproducts make the use of Raman spectroscopy beneficial in conjunction with FTIR spectroscopy, as they are complementary techniques. While a molecular vibrational mode occurs at the same frequency or wavenumber in both the IR and Raman spectra the activity or intensity of the vibrational mode depends on the chemical bond. If a bond is between atoms with a large electronegativity difference or dipole moment (e.g., O-H) it exhibits a strong IR activity or intensity. In contrast, homonuclear bonds (e.g., C=C) or bonds with small electronegativity differences exhibit strong Raman activity or intensity. This is demonstrated in Figure 2, which shows the FTIR and Raman spectra of pyrene in water ice. As one can see the H_2O vibrational modes, with large dipole moments, are very evident in the IR spectra but not the Raman spectra. Similarly, for PAHs, the C-H out-of-plane modes are strong in the IR spectrum, while the C-C and C-H in-plane modes are strong in the Raman spectrum. This enables a greater understanding of the PAH chemistry occurring upon irradiation.

Conclusions/Future Work: The ICEE chamber represents the next generation experimental facility for investigating the radiation chemistry of PAHs in a variety of matrices. This presentation will present the latest results from ICEE and discuss future work using various radiation sources. Results from this research will be made available via searchable online databases for the FTIR (astrochem.org/pahdb) and Raman (astrochem.org/ramdb) spectroscopic data.

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