On the genesis and detectability of organic chemistry in hypervelocity impact ice spectra.

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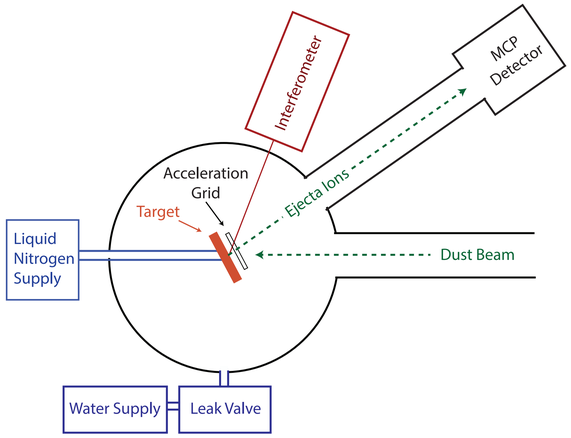
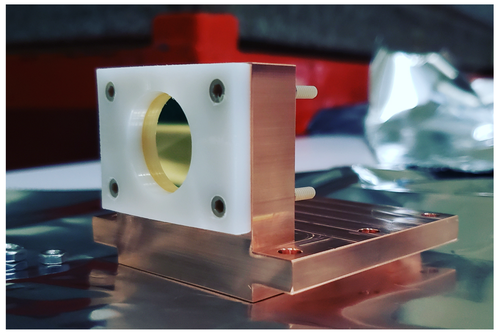
Project Overview

Although ice is prevalent in the solar system and the long-term evolution of many airless bodies is affected by hypervelocity micrometeoroid bombardment, there has been little experimental investigation into these impact phenomena. There similarly have been few experiments studying what types of chemistry can be measured by impact ionization Time of Flight (TOF) instruments on fly-by spacecraft, especially at the relevant speeds for these spacecraft. The cryogenic target at the NASA SSERVI Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT) dust accelerator makes possible the study of the effects of micrometeoroid impacts in a tightly controlled environment. This has allowed for a series of experiments detailing the long term chemical evolution of icy surfaces under dust bombardment and what types of chemsitry can be detected by TOF instruments on fly-by spacecraft.



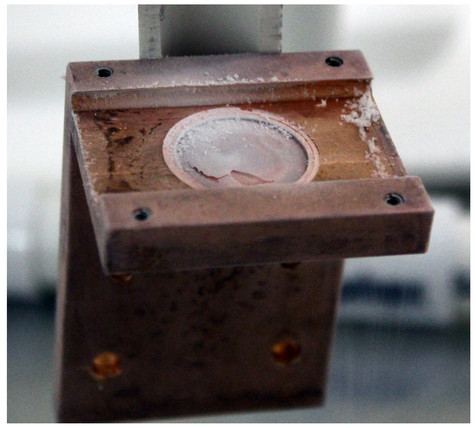
Ice surfaces are prepared either by vapor deposition or by flash-freezing an aquatic solution of desired composition. Iron or carbonaceous dust is accelerated to 3-50 km/s and impacted onto the surface. TOF mass spectra of the dust impact ejecta show that amino acids and even the more fragile di-peptide amino acid chains frozen into water ice can survive impact and be detected directly. Other spectra show evidence of fragmentation patterns that are similar to electron impact ionization TOF spectra of the same amino acids, indicating that even fragmented amino acids may be detectable by these instruments. Other experiments using trace amounts of CO2 in water ice show that the CO2 can be detected and that dust impacts covert some of this CO2 to the volatile CO, and may possibly increase the complexity of the chemistry by creating methanol. Most recently, the deuterium-hydrogen ratio of an ice sample was correctly measured. This means that TOF instruments on flyby spacecraft should be able to measure this ratio to constrain formation models for icy moons.

Ice Production



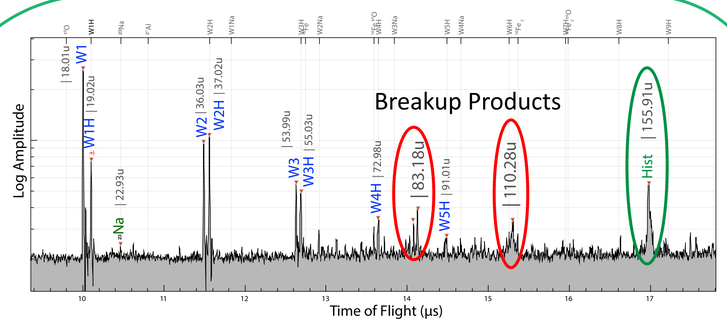
Simple mixtures such as pure water or methanol can be vapor deposited onto a gold-coated sapphire substrate. This allows for highly controlled growth at user-specified temperatures. Known isotopic ratios can be created by controlling the relative pressures of each isotope during growth. Thickness is measured during growth by Fabry-Perot Interferometry.

To preserve homogeneity in salty ice mixtures, a flash-freezing setup has been created. Liquid mixtures are placed on the target plate, and a Vespel cover is slid into place. The assembly is then dropped into liquid nitrogen, freezing the salts in place and preventing clumps from forming. The Vespel cover is removed after pumping down to high vacuum to prevent contamination from atmospheric moisture.



Alternative methods of creating homogeneous ice surfaces are also being pursued.

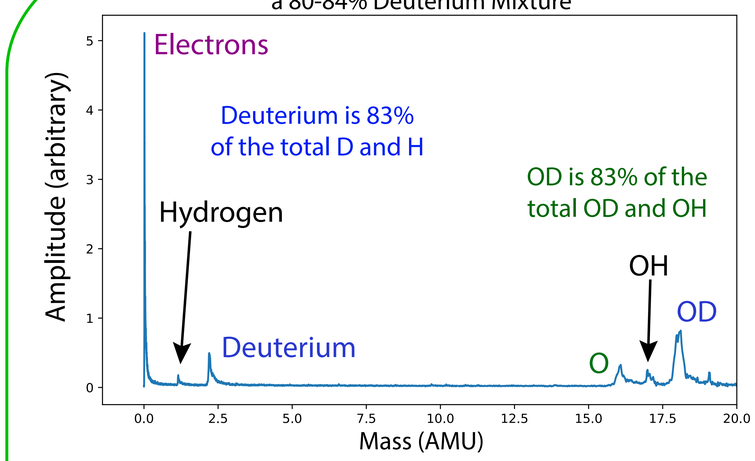
Detectability of Organic Chemistry



A spectrum produced by a **3.2 km/s iron dust** impact into water ice doped with **histidine**, a simple amino acid. The amino acid is easily identified directly, but breakup products are also detected. The fragmentation pattern is related but not identical to the observed pattern in NIST electron impact ionization spectra of histidine. This suggests that fragmentation itself may possibly be used as a "fingerprint" to identify amino acids even after breakup. Future experiments will further explore fragmentation patterns of amino acids.

Detection of D-H Ratio

Coadded Negative Ion Spectra from a 80-84% Deuterium Mixture



Coadded negative ion spectra from aluminum dust impacts into water ice containing 80% deuterium ions (relative to hydrogen ions). The D-H ratio is important in formation models for icy moons throughout the solar system. Our TOF was able to correctly identify the ratio of deuterium to hydrogen in a water ice sample by coadding spectra. This means that impact ionization TOF instruments on fly-by spacecraft should be able to measure the D-H ratio of icy moons and help constrain their formation models.

Upcoming Experiments

Ongoing experiments will further study the ability of impact ionization TOF instruments to **measure the D-H ratio** of ice surfaces. **Lower concentrations of D** will be used in future experiments.

In a separate set of experiments (not shown), **water ice doped with CO_2** was found to produce a **strong mass line at 32 AMU**, which may be methanol. While this may merely be O_2, these strong lines at 32 AMU are not observed in simple water spectra, where O_2 should ostensibly be created as well. Ongoing experiments will use **isotopic carbon-13 CO_2** to break this ambiguity. If methanol is created, this would indicate that inorganice chemistry can be converted to simple organic chemistry through dust impact.

Carbonaceous dust, such as graphite, will then be impacted into water ice and iron particles will be impacted into carbon bearing ice, such as methanol. The potential creation of CO_2 through these experiments may help explain Cassini observations of CO_2 and CO.

The breakup products of various amino acids will be further studied to **determine if fragmentation patterns can be used to identify amino acids in TOF mass spectrometers**. This will significantly increase the robustness of impact ionization TOFs as spacecraft instruments.