Laboratory Studies of Interstellar/Cometary Ice Analogs

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Interstellar molecules condense on cold grains in dense clouds and spend most of their time in icy mantles. New species form when reactive species combine on the grain surfaces or within ices subjected to radiative and thermal processing. Ices are also a significant part of comets, possibly some asteroids, and the surface materials of many outer Solar System bodies. Spectral analysis of lab ice analogs, especially in the IR, has proven to be necessary to identify these materials and understand their formation and evolution. Several examples of recent progress made at the Astrochemistry Laboratory at NASA-Ames will be presented.

Interstellar ices undergo both UV and cosmic ray processing. This breaks bonds and generates new ions, radicals, and molecules. For example, photolysis and warm up of ices containing H_2O, CH_3OH, CO, and NH_3, all known to exist in ices in space, produces organic residues with new molecules of interest to interstellar astrochemistry. Since the ISM contains polycyclic aromatic hydrocarbons (PAHs) and related materials, they too should be in interstellar ices. We have found that PAHs in ices are somewhat susceptible to attack by H, O, and OH liberated from photolyzed H_2O. The result is loss of some aromaticity and production of PAHs with peripheral ketone (C=O) groups and excess H atoms (H_n-PAHs). The IR signatures of these variants explain some enigmatic spectral features seen towards low excitation objects, and having dipole moments, allow for submillimeter search and detection.

The organic residues have other important properties relevant to extraterrestrial samples. Some of the complex organics in meteorites and IDPs are highly D-enriched. We have demonstrated that D in interstellar/cometary ice analogs concentrate into certain complex photoproducts. The C-rich fractions of meteorites also contain large concentrations of noble gases trapped by an unknown mechanism. However, using isotopically-spiked noble gases, we have shown that ice photolysis produces residues that trap noble gases at concentrations up to 100+ times above anything previously attained (Xe $= 10^{-6}$ CC-STP per gram, values comparable to those seen in meteorites). These noble gas trapping and D results suggest that a significant fraction of the organics in meteorites have an interstellar connection.

Another use of spectral data from our ice analogs is to identify the molecular components of interstellar ices, determine their column densities, grain sizes, etc. Most recently, we have shown that the strength of the N=N fundamental at 2328 cm^{-1} produced by N_2-rich ices can vary by up to *three orders of magnitude* depending on what other molecules are in the ice. This effect can profoundly alter current estimates of the abundance of N_2 in interstellar ices and certain outer Solar System bodies.

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