

Formation of Complex Molecules in Planetary Ice Analogs. M. H. Moore¹ and R. L. Hudson², ¹NASA's Goddard Space Flight Center, Astrochemistry Laboratory, Greenbelt, MD 20771, marla.h.moore@nasa.gov, ²Eckerd College, Department of Chemistry, St Petersburg, FL 33711, hudsonrl@eckerd.edu.

Introduction: Molecular ices are known to be part of the composition of many solar system objects, such as planets, satellites, rings, and comets. These ices exist in different radiation environments within the solar system, and are subjected to processing by keV-MeV ions and UV photons. Radiation processing results in changes in the chemical and physical properties of such ices with time. The observed inventory of planetary and satellite ice molecules includes H₂O, CH₄, NH₃, CO, CO₂, SO₂, SO₃, H₂O₂, O₂, O₃, the SO₄²⁻ ion in the form of hydrated sulfuric acid and/or mineral sulfates, hints of complex hydrocarbons, C≡N containing species, and possibly H₂S. Of these, it is generally accepted that H₂O₂, O₂, O₃, and features associated with hydrated sulfuric acid are signatures of energetic processing by the magnetospheric radiation environments of Jupiter and Saturn.

In the Cosmic Ice Laboratory at NASA's Goddard Space Flight Center, we study the photo- and radiation-induced chemistries of ices at 8 – 300 K. We find that radiolysis and photolysis destroy reactant molecules, synthesize new species, cause changes of phase in pure materials, and eject molecules from ices. These observed processes depend on radiation dose, ice temperature, and ice composition. We have examined photo- and radiation chemical changes in H₂O-rich ice mixtures as well as N₂-rich ices more relevant to Triton and Pluto.

Our laboratory radiation results call attention to possible species awaiting future detection. (1) Irradiated H₂O + SO₂ or H₂S ices. Our more-recent work has documented the overall principal chemical trend for sulfur-containing molecular ices as they become oxidized during radiation processing. New radiation products include both anions and cations all with spectral features that make them candidates for possible observation in the Jovian system. (2) Irradiated and thermally processed H₂O + NH₃ ices. Related to surfaces in the outer solar system, we measured changes in the near-IR NH₃ band with composition, formation temperature, and thermal- and radiation processing. These results reveal the difficulty in distinguishing amorphous NH₃ ice mixtures from NH₃ hydrates using a single absorption feature. (3) Irradiated H₂O + CO₂ ices. Irradiated terrains rich in H₂O and CO₂ form carbonic acid, H₂CO₃, which has a unique spectral signature and a volatility less than that of H₂O. Carbonic acid has been tentatively assigned to the weak 3.8- μ m band of Europa and Callisto. Irradiated terrains rich in CO₂ lead to a significant production of O₃. New results on the stability of H₂CO₃ and O₃ will be applied to possible future observations. (4) Irradiated N₂ + CO + CH₄ ices. The radiation products expected to form and survive on surfaces such as Triton, Pluto, and KBO's with N₂-rich terrains include anions (OCN⁻, CN⁻, and possibly N₃⁻), and these would be associated with the NH₄⁺ cation. The distinctive 4.6- μ m band of OCN⁻ has been detected in interstellar and even extragalactic ices and is considered a radiation marker. To date neither OCN⁻ nor its counterion, NH₄⁺ has been detected in planetary ices and so they remain important

species for future searches. (5) Irradiated H₂O + CH₃OH ices. Once present in ices, CH₃OH can undergo reactions to form complex organic species such as ethylene glycol, (CH₂OH)₂. Ethylene glycol is a good marker of radiation-induced chemistry, is less volatile than H₂O, and has known IR features in both the near- and mid-IR