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Evolution of Organic Molecules in Pre-Solar Ice

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Abstract

Comets and asteroids are the careers of complex organics, some of which are the building blocks of life. However, we do not have a clear understanding where and how these complex organics produced, preserved, and transported – finally forming the interior of comets and asteroids. We have explored laboratory studies on analogs of interstellar and cometary ice and followed the reaction pathways of radiation-induced chemistry.

1. Introduction

Interstellar ice grains and cometary outgassing have so much in common that it is hard to understand how such compositional similarity is preserved without the interstellar ice grains themselves preserved throughout the evolution of our solar system – from dense molecular clouds through protoplanetary disk to evolved solar system that has the cometary precursors – Kuiper Belt Objects and Oort Cloud.

While the link seems to be obvious, chemical evolution of ice grains in the protoplanetary phase is far from well understood. Particularly, if the ice particles were to cross the ice-line towards the protostar and sublimate leaving the refractory grains behind. It is hard to determine how similar composition is put together in the formation of cometary precursors. We have been following reaction pathways that could be used as tracers for the history of ice grain chemistry and transport.

2. Results

We have carried out UV- and electron irradiation studies on water-rich ices containing other impurities such as CO_2. We have used polycyclic aromatic hydrocarbons (PAHs) as probes to understand how chemical modifications have been triggered through UV or electron irradiation. We have used conventional UV and FTIR spectroscopic methods as well as in-house-developed two-step two-color laser ablation and laser ionization time-of-flight mass spectrometry (2S-LAI-TOFMS).

We found that (a) PAH molecules are ionized efficiently, (b) even at 10 K these ionized PAHs react with reactive intermediates of water ice matrix (such as OH or O) forming oxygenated PAHs, (c) a wide range of complex organics are formed from simple ice mixtures such as water/methanol/ammonia, (d) most (if not all) molecules we detected in the laboratory study are found in Rosetta outgassing.

We have also studied the effect of significant amount of CO_2 co-condensed with H_2O and found that PAHs are ionized even in CO_2 ice. These findings will be discussed in the context of how complex organics could have evolved, preserved, and transported across our solar system formation process.

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