

**THE GAS PHASE AS A PROBE OF THE CHEMISTRY OF ASTROPHYSICAL ICE ANALOGS**N. Abou Mrad<sup>1</sup>, F. Duvernay<sup>1</sup>, R. Isnard<sup>1</sup>, T. Chiavassa<sup>1</sup> and G. Danger<sup>1</sup><sup>1</sup>Aix-Marseille Université, PIIM UMR-CNRS 7345, F-13397 Marseille, France

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**Introduction:** Among the objects of the Solar System, comets have preserved a large part of the primitive organic matter. The cometary nucleus composition and the chemistry occurring within are of a crucial importance for the characterization of the least processed exogenous organic matter. In support to space missions and remote spectroscopic observations aiming to determine the composition of such objects, laboratory experiments on ice analogs reproducing the processing of ices in astrophysical environments have been widely conducted. Ice processing (thermal and photolytic sources) provides a rich chemistry. Some of the newly formed complex organic compounds are released into the gaseous phase with the heating of the ice, while others react in the ice matrix and constitute refractory organic residues, which present similarities with the soluble organic fraction of meteorites<sup>[1]</sup>. Considering that volatile organics are precursors of complex compounds found in the cometary nuclei and their abundance is mostly the “consequence” of the grain-surface chemistry occurring in the solid, their monitoring in the gaseous phase may be an indicator of the solid ice composition and the chemical reactivity occurring within.

**Materials and Methods:** To establish the relationship between compounds relative abundances in the gaseous phase and the solid ice composition and chemistry, different ice mixtures are photoprocessed in a high vacuum chamber ( $\sim 10^{-8}$  mbar) using a broadband hydrogen microwave-discharge lamp emitting  $2.5 \cdot 10^{13}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  in the VUV range. Pure methanol ices are taken as a reference, methanol being one of the major sources of reduced carbon in comets thus highly contributes to the organic chemical complexity observed in such objects<sup>[2]</sup>. The gaseous phase of simple ( $\text{CH}_3\text{OH}$ ), binary ( $\text{H}_2\text{O}:\text{CH}_3\text{OH}$ ,  $\text{CH}_3\text{OH}:\text{NH}_3$ ) and complex ice analogs ( $\text{H}_2\text{O}:\text{CH}_3\text{OH}:\text{NH}_3$ ) with various compositions after photolytic and thermal processes was monitored using gas chromatography coupled to mass spectrometry<sup>[3]</sup>.

**Results:** The quantitative survey of the gaseous phase of processed ice analogs highlighted chemical mechanisms and dominant reaction pathways occurring in the solid ice during processing. Ammonia addition to methanol ices enables competitive radical-radical reactions between methanol radicals and ammonia radicals, leading to a decrease in the abundance of compounds

such as alcohols and ethers in the solid ice, and the further destruction of compounds such as aldehydes due to thermal reactions<sup>[4]</sup>. The decreasing trend of all target compounds was perfectly translated in the gaseous phase. Water addition to methanol ices favors the production of aldehydes and the decrease of other compound classes, and both trends were observed in the gaseous phase.

The quantitative monitoring of volatile organic compounds seems a promising tool to understand and evaluate the contribution of each ice constituent to solid chemistry. Our data highlight a link between ice chemistry and ice composition and volatile abundances in the gaseous phase, which is ultimately important to decipher inaccessible astrophysical objects compositions such as comets based on the monitoring of the surrounding gaseous phase.

**References:**

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