Microfluidic sample preparation for collection, desalination / purification, derivatization, and delivery of biomolecules at ocean worlds.

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Relevant science mission abstracts: Mars Life Explorer, Mars Icebreaker, Enceladus Orbilander, Enceladus multiple flyby (EMF), Halley 2061

Abstract: This technology is a TRL3/4 *in situ*, automated sample ingress technology for icy samples (Figure 1), previously funded by a NASA ICEE2 grant. It is suitable to collect ice from a lander or ingress collected ice from a plume fly-by. The ice is melted, and desalinated via microfluidic ionic exchange column. The eluted materials, which are amino acids, proteins, and possibly other life molecules, are then sent to a cup in which the sample can be derivatized with MTBSTFA or other equivalent agent before sending to downstream chemical analysis that is determined by the mission needs.

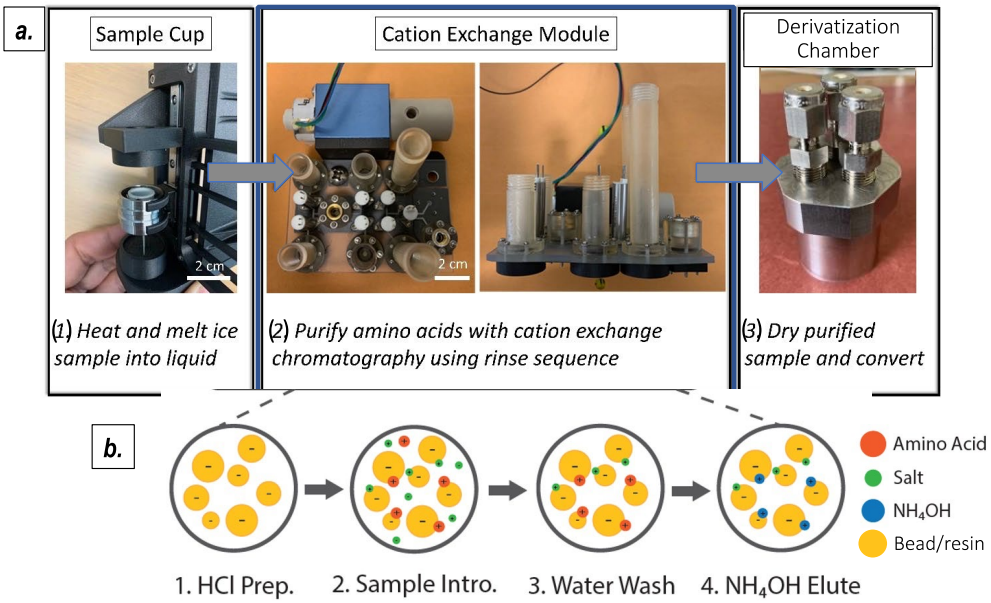

Figure 1. a. Standalone component prototypes and processing steps for the sample handling and preparation device for amino acids. (1) a sample cup, where an ice sample is received and then melts the ice through controlled heating and delivers the sample to (2) a cation exchange module where any amino acids present are purified and concentrated. (3b) shows the steps in the cation exchange process. They proceed to (3) the derivatization chamber where they are dried and derivatized, and available for analysis by a GC-GC-MS, GC-MS, (or similar) system.

The performance of the microfluidic ion exchange was recently published in Van Volkenberg et. al., Astrobiology, 22 (9), pp. 1116-1128; 2022 (https://doi.org/10.1089/ast.2021.0182). Experiments explored operational limits of binding capacity with phenylalanine and three model cations, Na+, Mg2+, and Ca2+. Phenylalanine recovery (94–17%) with reduced conductivity (30–200 times) was seen at high salt-to-amino-acid ratios between 25:1 and 500:1. Testing of competition between mixtures of 17 amino acids in a terrestrial ocean sample showed recoveries ranging from 11% to 85% depending on side chain chemistry and cation competition, with concentration shown for select high affinity amino acids. This technology outlines a nondestructive amino acid purification device capable of coupling to multiple downstream analytical techniques for improved characterization of icy samples at remote ocean worlds.