Microchip Electrophoresis Instrumentation for Determination of Chemical Distributions on Future Spaceflight Missions

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Introduction:

The search for evidence of life beyond Earth is among the highest level goals in planetary exploration and is potentially one of the greatest research opportunities for the future of chemistry. However, despite multiple orbiter and landed missions to extraterrestrial bodies in the solar system, we still haven't found evidence of life. A powerful and highly unambiguous approach in the search for life involves seeking biochemical signatures of life at the molecular level, as expressed in distributions of geometric and stereochemical properties of organic molecules. Microchip electrophoresis (ME) has tremendous promise for aiding in this search. [1-4] Depending on the detection method used, ME allows for the detection of organics as well as inorganic ions. ME also has minimal mass/power/volume requirements, which is essential for instrument payloads on spaceflight missions. However, in terms of spaceflight implementation, this technique is relatively new, and there are still many challenges to be addressed for future implementation on spaceflight missions. Here we will describe the status of ME instruments at JPL and the steps we are taking to someday enable the implementation of this technology on other worlds.[5]

Approach:

We focus here on two detection methods: laser-induced fluorescence (LIF) and capacitively coupled contactless conductivity detection (C^4D). We describe a ME-LIF system we dub The Chemical Laptop [6] (Figure 1), which would provide the sample processing capabilities required for *in situ* analysis on extraterrestrial destinations with parts-per-billion sensitivity in a compact, low-mass, and low-power package. This instrument concept could be adapted to the environmental requirements of a variety of astrobiologically interesting targets lie Europa, Enceladus, or Titan.

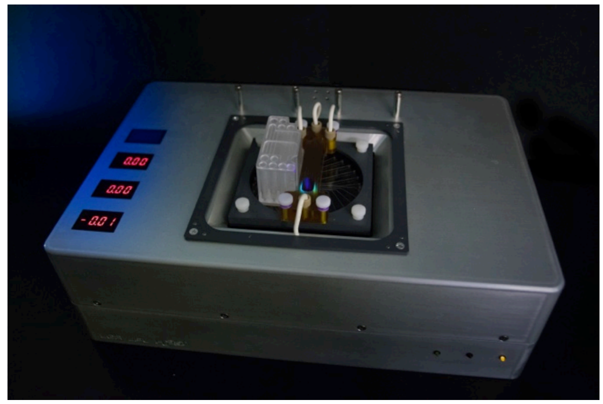

Figure 1. The Chemical Laptop *is a battery-powered, portable, automated, and reprogrammable microchip electrophoresis instrument capable of detection of organic molecules at the ppb and ppt levels.*

This instrument is the first battery-powered and truly portable "end-to-end" ME-LIF astrobiology instrument capable of receiving an unlabeled liquid sample and performing all operations required for analysis. We recently validated The Chemical Laptop by analyzing amino acids in the field.

The search for signatures of life on alien worlds like Mars or Europa imposes a low sensitivity requirement on in situ instrumentation seeking signs of life. Toward this end, we have optimized the optical system on the Chemical Laptop to achieve extremely low instrument detection limits. We demonstrated detection of a 200 pM mixture of amino acid (Figure 2).

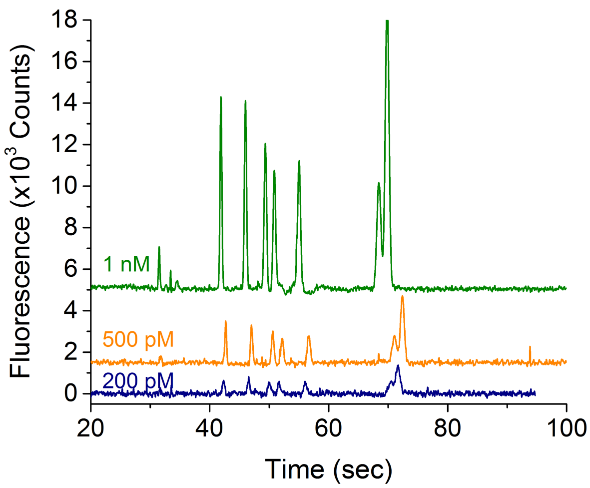

Figure 2. *Analysis of amino acid mixtures at low concentrations obtained with The Chemical Laptop. The lowest concentration analyzed was 200 pM.*

When analyzing "known terrestrial samples" we can select the appropriate methods for analysis and sample processing in such a way that the rest of the sample doesn't interfere with the detection of the compound of interest. On the other hand, analyzing unknown samples like the ones expected on alien worlds is a little more challenging. *Ideally, we need a method of analysis that can detect all of the compounds of interest with a single experiment.* Of course, in most cases this is not possible. **However, we can narrow the search to a certain group of analytes and then develop a method that allows the detection of as many of those compounds as possible.** Towards this end, we are developing ME-C^{4}D methods to simultaneously analyze inorganic and organic ions (i.e. calcium, sodium, perchlorate, amino acids, carboxylic acids etc.), as they are likely to be present at the same time on samples collected from the most relevant astrobiology targets like Mars, Enceladus, or Europa. Figure 3 shows a simulated separation demonstrating simultaneous detection of inorganic cations and amino acids.

This type of instrument also offers key capabilities for human flight applications. For example, we are currently working in collaboration with SBIR partners on the development of a miniaturized ME-C^{4}D instrument to monitor water quality in the ISS.

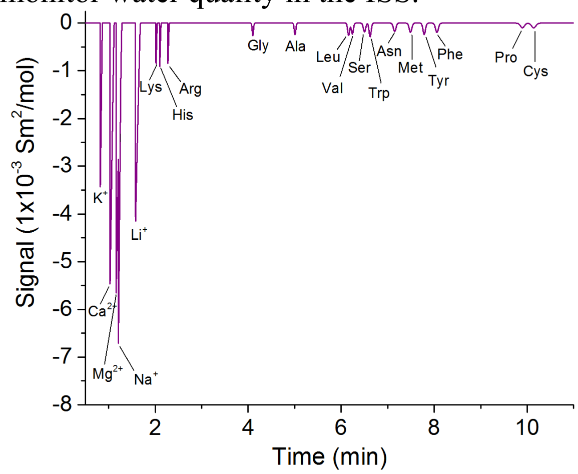

Figure 3. Simulated separation of cations and amino acids *on a 24 cm channel performed with PeakMaster 5.3. Separation buffer consisted of acetic acid 0.5 M. Concentrations of amino acids were set to small and inorganic ions to large. This example demonstrates that is possible to do simultaneous analysis but more importantly that even if inorganic ions are present at much higher concentrations than amino acids they don't hinder their detection*

References:

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