DESIGN AND INTEGRATION OF AN UNDERWATER OCEANS ANALYZER INTO THE EELS ROBOT SYSTEM.

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Introduction: Capillary electrophoresis (CE) is a scientific technique that is useful for studying two important goals: evaluating whether a place might be suitable for life to exist (habitability evaluation) and searching for signs of life itself (life detection). CE has some advantages over other methods of chemical analysis. It is good at separating polar compounds (compounds with an uneven distribution of electrical charge), can handle high levels of salt in a sample, it uses very little sample material, and it can be coupled to various detection techniques (contactless conductivity, laser-induced fluorescence, mass spectrometry, etc.). It is also known for being efficient at separating different substances. In this abstract, we describe a CE-based instrument that has been developed specifically for use in evaluating the habitability of other worlds. This instrument is small enough to fit in a special compartment on a robotic snake-like spacecraft called the Exobiology Extant Life Surveyor (EELS).

Overview of the instrument: The CE instrument has a cylindrical shape (as shown in Figure 1). It is 30 cm long and 10 cm in diameter. It is made up of four parts: a unit for storing special chemicals (reagents), a unit for controlling the flow of fluids, a unit for controlling the flow of air, and the main CE unit.

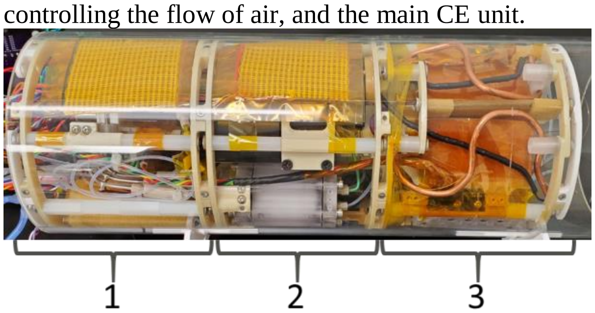

Fig. 1. A photograph of the designed CE instrument. Markings: (1) a unit for controlling the flow of fluids, (2) a unit for controlling the flow of air, and (3) the main CE unit. The unit for storing reagents is not shown.

Architectural and functional considerations: The fluidic selection/distribution unit has two special valves (rotor-stator valves) that control the flow of a chemical reagent. A pump (metering piston pump) pushes the liquid through the instrument at a specific rate. There are also three small valves (miniature solenoid valves) that can send liquid waste to a storage bag. The pneumatic selection/distribution unit has a pump (pneumatic pump) that sends gas through a tank and then to a valve (rotor-stator valve). The valve directs the gas to the right place. The CE unit has two high voltage power supplies that can create a voltage potential difference of 20 kV between two reservoirs (operated at low current, < 50 μA). A small amount of a sample is positioned in the middle of the separation channel (fused-silica capillaries) using a special valve (rotor-stator injection valve). When the high voltage (HV) is applied, substances in the sample with a positive charge (cations) will move in one direction, while those with a negative charge (anions) will move in the opposite direction. Both cations and anions can be detected at the same time using two special sensors (contactless conductivity detectors) positioned near the ends of the capillary tube where the separation is happening. These sensors can measure electrical conductivity without touching or altering the sample.

Procedural considerations: The CE instrument is set up to analyze substances that carry a positive or negative charge (cations and anions) (as shown in Figure 2). To do this, we use a solution of 5 M acetic acid as the "background electrolyte," which helps to facilitate separation of the different substances. We also need water and two other solutions (0.1 M hydrochloric acid and 0.1 M sodium hydroxide) to clean, rinse, and prepare the capillary tubes used in the instrument.

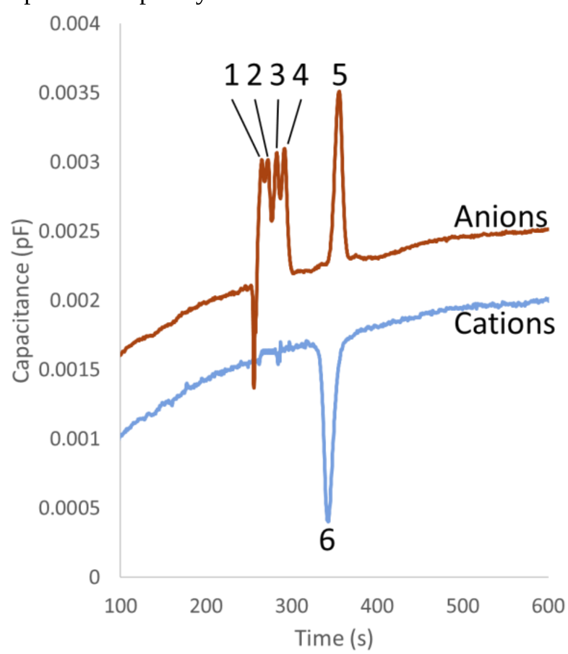

Fig. 2. A separation of a laboratory standard mixture. Markings: (1) Cl^-, (2) NO_3^-, (3) ClO_4^-, (4) ClO_3^-, (5) SO_4^{2-}, (6) Na^+.

If necessary, a sample that has been collected can be diluted using either a one-step or two-step process, depending on how much the sample needs to be diluted. The sample is transported to the injection valve using air pressure (pneumatically). However, the volume of the sample is defined by the injection cavity in the rotor-stator injection valve, so this method of injection is very reliable. To make sure that the high voltage being used in the instrument does not leak into the electronic parts and cause damage, we use a special process called "pneumatic high voltage decoupling" that involves a bubbletrap. This process removes any liquid from the tubes, leaving only gas behind. This helps to protect the sensitive electronic components of the instrument.

Scope: The CE instrument is designed to be used on its own. It can be controlled manually or run automatically using pre-programmed instructions (analytical protocols). Before starting an analysis, the instrument prepares the air system by purging all bubbletraps and removing any liquid that may be present. It also prepares the fluid system by delivering the initial portion of reagents to the waste. After finishing the analysis, the instrument goes into a low-power mode (idle mode) using a shutdown protocol. This includes cleaning all fluid lines, rinsing the separation capillary, removing any remaining liquid, purging the channels, and putting the system in an idle mode. The plan is to validate the instrument in the laboratory to make sure it is working correctly, evaluate different dilution factors, and analyze simulant samples. Also, in situ tests underwater will be performed. Ultimately, an instrument of similar design could be implemented on a future payload to an ocean world such as Enceladus or Europa to assess the habitability of the ocean and/or search for molecular evidence of life.

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