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Pulsed Chronopotentiometry with Polymer-Based Potassium-Selective Electrodes

Roland Long, Kebede Gemene
Department of Chemistry, Northern Kentucky University, Highland Heights, KY 41099

Introduction

The human body relies on the intricate balance of numerous electrolytes for all systems to function properly. One such electrolyte is potassium, which is necessary for muscular and nervous function, as well as heartbeat regularity. Excess potassium accumulates in blood, impairing the systems it normally orchestrates and leading to a variety of symptoms: myalgia, arrhythmia, and nausea, among others. This project aims to develop better materials and practices towards the measurement of potassium in blood for the early detection of hypertension. Effective measurement requires not only responsiveness in measurement, but selectivity. Measuring potassium alone is not necessarily useful for real-world applications. Rather, being able to measure potassium in the presence of other bodily cations, such as sodium or calcium, is necessary for the accurate diagnosis of potassium imbalance. Measuring potassium levels in blood requires determining the concentration of potassium both within the red blood cell (intracellular) and in plasma (extracellular). The desire is to be able to measure both efficiently in a single trial.

Methods

Initial experimentation used classical potentiometry to explore polymer-based ion-selective electrodes as a medium. Membranes for these experiments were composed of PVC as a structural agent, NPOE as a plasticizer, and an ion-exchanger. The experiments of focus, those selective for potassium, used pulsed chronopotentiometry for measurement. Membranes for chronopotentiometric experiments substituted ETH 500 (a neutral lipophilic salt) in place of ion-exchanger and included valinomycin, a potassium ionophore. Potentiometry measures membrane potential with zero applied current. Chronopotentiometry introduces the ability to apply a current tailored to the analyte in magnitude and charge. Therefore, it offers a more versatile means of interrogation.

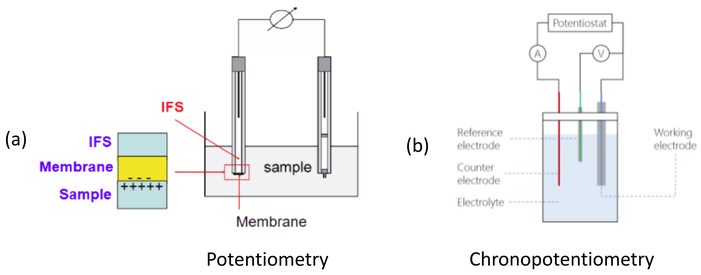

Figure 1. (a) Potentiometric electrochemical cell and working mechanism, (b) Chronopotentiometric electrochemical cell

Results

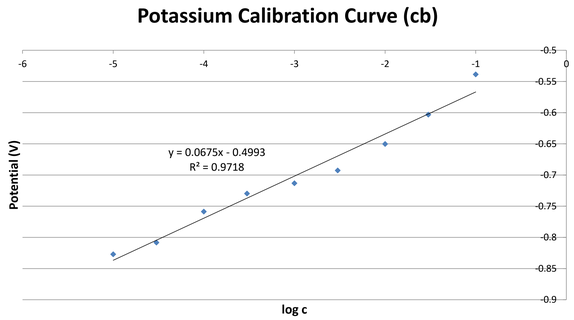

Figure 2. Calibration curve demonstrating high response to potassium concentration in a sodium-containing environment.

The above graph shows a calibration curve for response to potassium in a competitive buffer. The below describe depletion of known potassium concentrations. While depletion occurred in both environments, interference from sodium prevented differences in transition times between potassium concentrations. This can be seen by the overlapping peaks in Figure 3b.

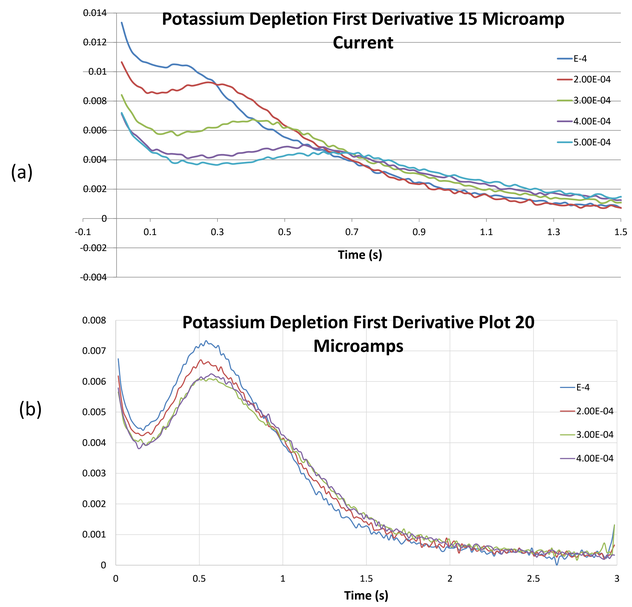

Figure 3. First derivative curves indicating transition times (peaks) for differing potassium concentrations a) in phosphate buffer and b) in buffer containing 0.01M sodium chloride. Transition time should hold a linear relationship with analyte concentration, a relationship not seen in the sodium-buffer.

Discussion

The membrane composition used for these tests included 6 mg valinomycin (2.5% by mass).

The ability of the electrodes to produce a suitable calibration curve in the presence of sodium suggests a certain degree of selectivity to potassium in competitive environments. However, the results of depletion experiments demonstrate interference from sodium at low concentrations of potassium. Given the applications in blood testing, a greater degree of selectivity is necessary for further study.

Increased concentration of ionophore has yielded improved selectivity in past experiments. This remains a possible course of modification should a new membrane composition be required.

Conclusion

This project aimed to develop ion-selective electrodes for use in measuring potassium in blood. The results yielded in competitive buffer are not yet sufficient to warrant blood testing. Interference from sodium must be lowered either through manipulation of testing environment by dilution or through altered membrane composition.

Future Work

- Explore the success of depletion in lower background concentrations of sodium chloride. Favorable responsiveness could warrant testing in diluted blood conditions. Continued interference would warrant revisions to membrane composition.
- Ideal blood-testing would see extracellular concentration measured in one step of a trial. During potentiostatic pulse, a surfactant and necessary dilutants would be added so that an accurate total plasma concentration could be measured simultaneously. In this way, the measurement of potassium could be consolidated to one run of measurements.

References

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