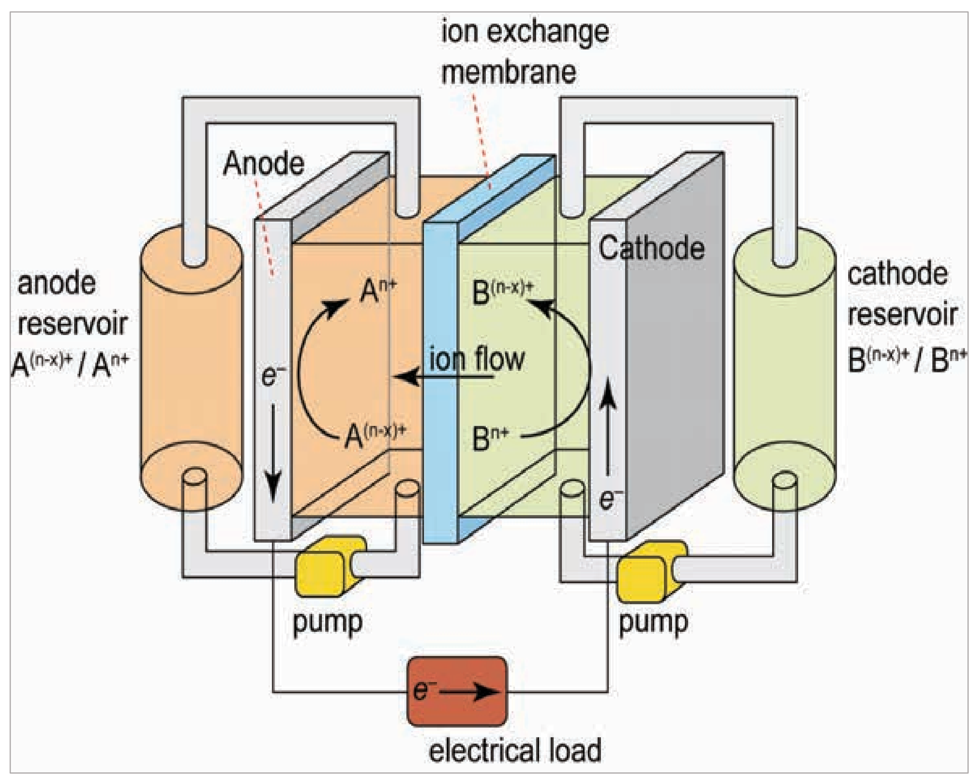
The Molecular Chemistry of Redox Flow Batteries

Joshua Hazelnis, Anjula M. Kosswattaarachchi, Timothy R. Cook*
Department of Chemistry, University at Buffalo, The State University of New York
858 Natural Sciences Complex, Buffalo NY 14260-3000

Abstract

Redox Flow Batteries (RFBs), which are identified as efficient large scale electrochemical energy storage devices can be a solution for the unpredictable nature associated with renewable energy sources. In a flow battery there are electrolyte solutions pumped out of external reservoirs to go over the cell phase of electrodes, which are in the main cell component. In the main cell, there are two compartments separating the positive and negative solutions. In order to avoid mixing of the two solution sides, there is an ion exchange membrane. The resistance of the ion exchange membrane plays a critical role in the overall cell voltage that can be obtained by the device. Usually the membrane can display different resistance after being pre-treated under various conditions. In light of determining the range of resistance for commonly used membranes, we have used electrochemical impedance spectroscopy to map out and determine resistance values over time.

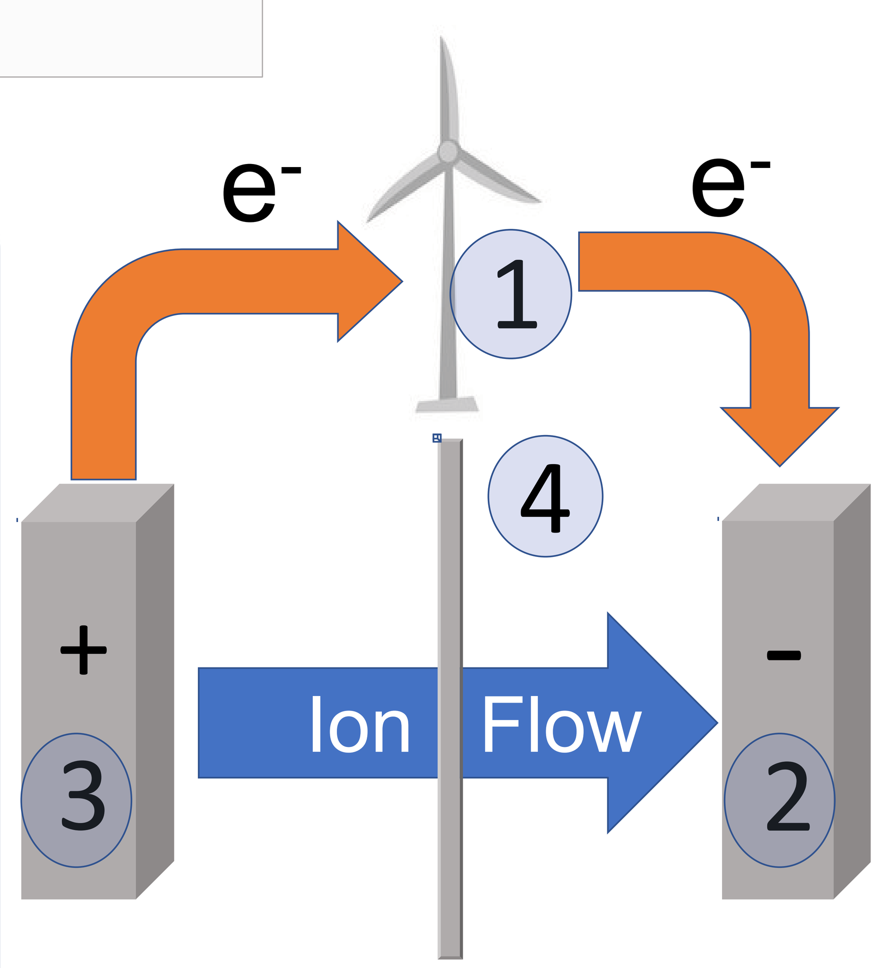
Introduction



A **redox-flow battery** is a rechargeable energy storage device wherein chemical charge carriers are stored in external reservoirs and pumped over electrode surfaces. A membrane separates the charge carriers, ideally preventing cross-contamination and short-circuiting.

How Charging the Battery Works

1. An Energy source charges the battery by moving negatively charged particles known as electrons. These electrons enter at the negatively charged side and leave at the positively charged side.
2. While charging, this solution is getting "reduced". This means it is gaining electrons, causing the charge to become more negative.
3. This side becomes "oxidized", meaning it loses electrons and becomes more positively charged, which increases the batteries' chemical potential.
4. While this takes place ions are exchanged in the form of H+ to balance out the lose of charge on the negative side. These ions are passed through an ion exchange membrane so that the solutions do not mix, but still allows for the circuit to be completed.



Charge diagram of a redox-flow battery

The Discharge Process

- When discharging the battery, the electron and ion flow is reversed.
- Instead of electrical energy being pumped into the battery it is pumped out.
- During this process, the "redox" reactions are reversed.

Membrane Importance

The membrane acts as a separator to prevent cross-mixing of the positive and negative electrolytes [solutions], while still allowing ions to complete the circuit during the passage of currents.[2]

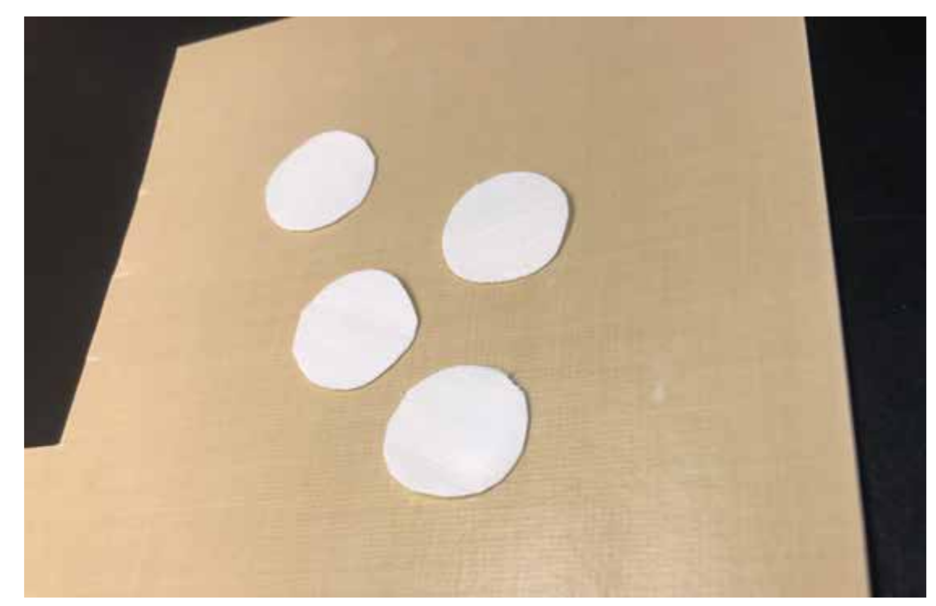
An ideal membrane should have:

- High ionic conductivity or ability to easily allow ions to pass through.
- Low water or solvent intake, which results in flooding of one side and dilution of the other.
- Excellent chemical and thermal stability to be able to charge and discharge under various conditions.
- Good ionic exchange capacity which is the overall strength and selectivity of the membrane. This also relates to the membranes lifespan.

Hypothesis

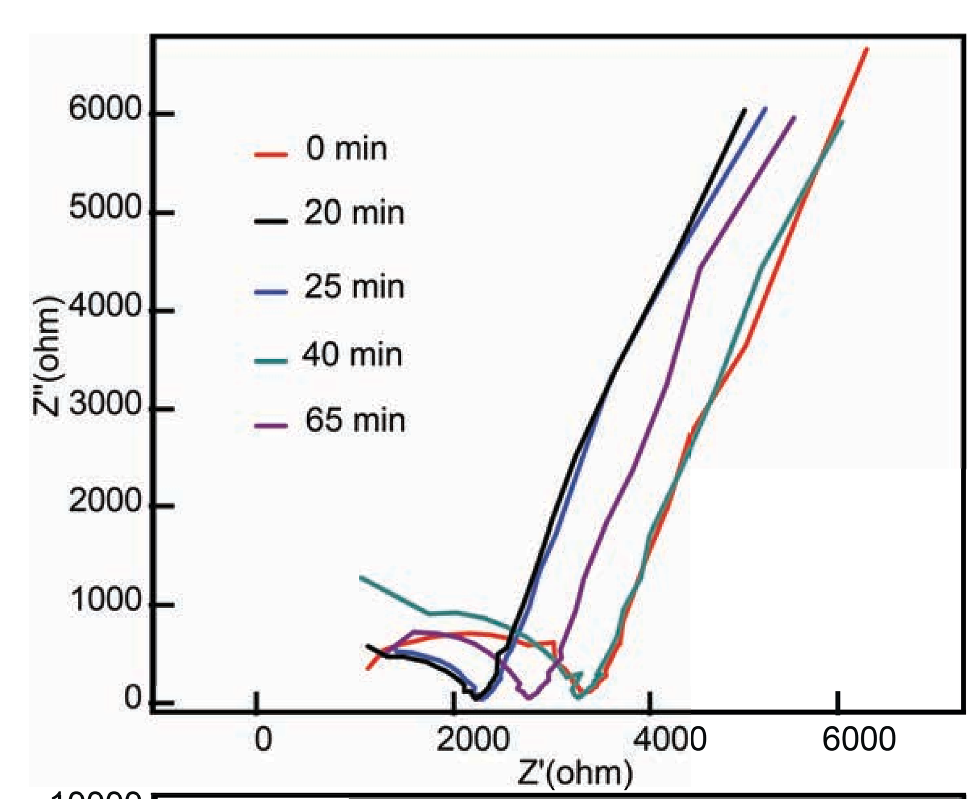
The hypothesis of my proposed work is that when a membrane is soaked in a given electrolyte solution there is a point that the resistance becomes constant. The resistance also depends on variable factors such as electrolyte type, solution concentration and the amount of time the membrane is soaked.

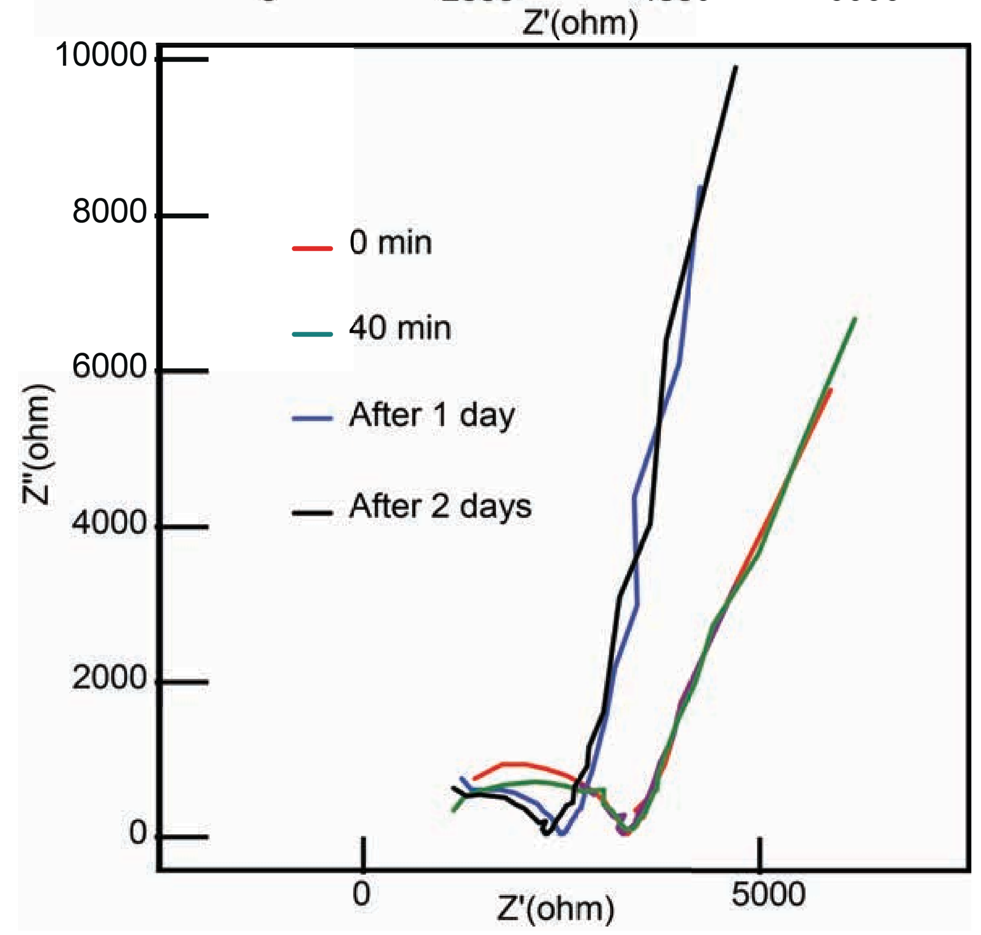
Electrochemical Methods



The method being used is Impedance spectroscopy using an H-cell setup, to analyze the resistance across a membrane over a period of time. Experimental conditions such as electrolyte concentration and solvent type are varied in order to test our hypothesis that resistance becomes constant over time.

Results





Experimental Conditions

- .05 M (tetrabutyl ammonium hexafluorophosphate ($TBAPF_6$) dissolved in acetonitrile electrolyte solution
- 5 mL of electrolyte solution on each side of the H-cell
- Frequency: .7 Hz to 2 MHz
- Anion Exchange Membrane

Conclusions

- In the initial stages of soaking the membrane in electrolyte solution, resistance is continually changing over time. Within the first 40 minutes, resistance can be observed oscillating between about 2100 Hz-3600 Hz.
- Initial testing confirms that the resistance becomes constant after an extended period of time. The question now is at what point in the 48 hour period of experimentation, did the resistance become constant.

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