Harnessing Energy with Controllable Chaos by Designing and Investigating Thermocell Redox Entropy

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Introduction

Energy is all around the universe, but the energy used by humans is not nearly as efficient as needed. More than 50% of the energy used by the US is lost due to low grade waste heat. This heat is from all types of mechanical/chemical energy. When charging a laptop, running a car, or walking on the ground, all these forms of energy use produces heat. That is energy that cannot be taken back. There is no option to grab onto the heat lost from a charger since that heat escapes into the universe.

What if there was a way to obtain that energy back? This is the focus of the project at hand. Harnessing entropy, controllable chaos, is the future. Using redox chemistry and chemical engineering, a flow cell was used to turn a temperature gradient into usable electricity. Imagine a sliver of the vast 50% of energy lost was able to be reused and put back into the machines that run the world.

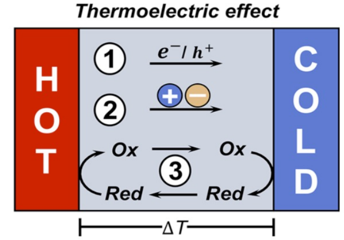
Theoretical Background

How Entropy is Related to Redox

$$\Delta S \propto \frac{Z_{ox}^2 - Z_{red}^2}{r}$$

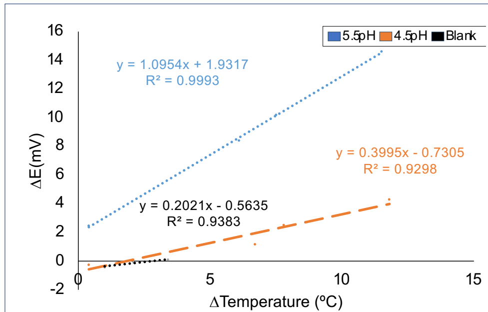
Entropy is directly correlated to the difference in the oxidative state squared and reduced state squared over radius

Types of Measurable Seebeck Effects



Within this project, the third option was used to obtain a Seebeck coefficient

Seebeck Calculations for pH



Methodology

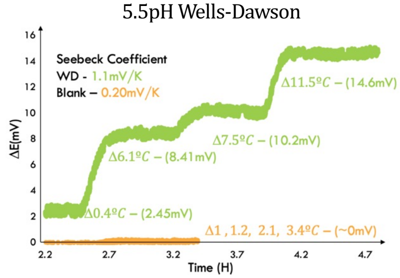
Before an experiment is run for the thermocell, the solutions are made for the trials and flushing of the thermocell. Washing the thermocell requires nano-pure water (40mL) to be placed into the scintillation flasks (20mL), and the power adapters (9V) pump the nano-pure water throughout both the hot and cold sides for 10 minutes. The washing is repeated three times in total.

Three pH solutions were made in total. The 5.5pH solution for Sodium acetate (0.346g, J.T. Baker, 99.8%) was dissolved in nano-pure water (48mL), and Acetic acid (1 drop, Fischer chemical, 99.7%) was added. The next 5.5pH solution was prepared with Potassium acetate (0.346g, Mallinckrolt Chemicals, 99.0%), and Acetic acid was dissolved in nano-pure water (65mL). The last pH solution was a 4.5pH made with Sodium acetate (0.346g) and acetic acid (2.5mL) dissolved together in nano-pure water (48mL). The Wells-Dawson solution was combined with the powder Wells-Dawson (1mmol, 0.096g) with nano-pure water (20mL). When the test was being run to a scintillation flask, 10mL of made pH solution would be added alongside 10mL of the 1mmol Wells-Dawson solution. The final mixture is a half split between Wells-Dawson. A partnered lab synthesized the Wells-Dawson, and the synthesis followed the literature.

A run for this experiment included a triplicate wash of the two pumps with nano-pure water. The selected solution would then be added to the scintillation flasks. The Potentiostat was connected to the thermocell, and an OCV (open circuit voltage) was set to record the experiment. Four temperatures are tested, and the voltage is allowed to equilibrate with each increase—these range from 4–10- hour experiments. The thermocell is periodically checked to ensure no leaks occur. The first day of experiments is to measure the voltage, and on the second day, a thermocouple is placed within the thermocell to collect the correct temperature that was seen the day before.

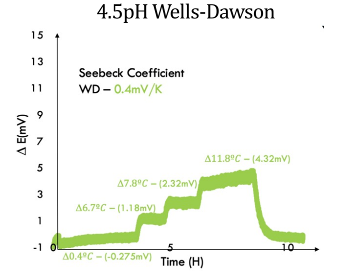
Seebeck Coefficient Dependance on pH

5.5pH Wells-Dawson



The 5.5pH Sodium Acetate/Acetic acid Wells-Dawson solution equilibrium points. This data is used to find the average voltage of each increase with temperature. The green line is the 5.5pH Sodium acetate/Acetic acid buffer, and the orange is the blank without the Wells-Dawson.

4.5pH Wells-Dawson

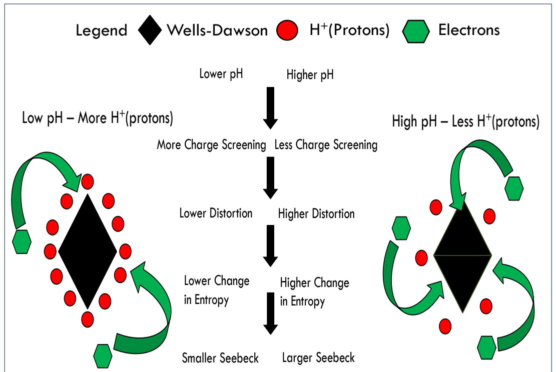


The 4.5pH Sodium Acetate/Acetic acid Wells-Dawson solution equilibrium points. This data is used to find the average voltage of each increase with temperature. Usually, fitting data to the graph is preferred, however showing the stark contrast from figure 2 helps with the ideas presented in the paper.

Conclusions

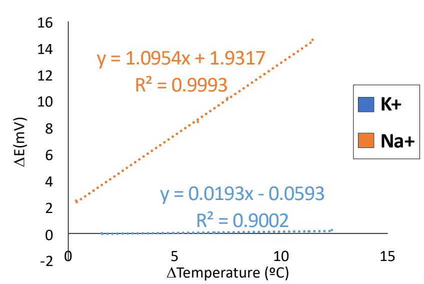
With the 5.5pH Sodium acetate and Acetic acid buffer with the Wells-Dawson achieving 1.1mV/K (0.2mV/K blank with no Wells-Dawson present), the goal of this project was reached. Cation size is the tip of the iceberg of what variables can be changed and worked upon. Further investigation into varying pH is strongly recommended for future people on this project. However, despite all that, a thermocell has been designed and shown immense promise for things to come. The applications of this are limitless, tapping into a 50% energy deficit that this country has not even thought about. With time, and many improvements, using polyoxometalate structures to harness the power of chaos can change how people use energy and the world for the better.

pH Dependency Theory



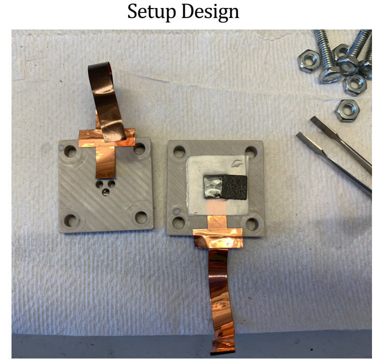
Future Work and Frame of Reference

Preliminary Cation Dependance



The 5.5pH Potassium Acetate/Acetic Acid Wells-Dawson solution is shown in blue. In contrast, the 5.5pH Sodium Acetate/Acetic Acid Wells-Dawson solution is in orange. Shows the Seebeck Coefficient's dependence on Cation size

Setup Design



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