Incorporating Low-Cost Instrumentation for Increased Electrochemistry Exposure in General Chemistry Laboratories

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ABSTRACT

Electrochemistry is an industrially, analytically, and medically important field of chemistry; however, electrochemistry concepts and techniques are rarely introduced in the general chemistry curriculum. Two factors contribute to this lack of incorporation. The first factor is that electrochemistry is widely viewed as non-intuitive, requiring additional physics preparation. The second factor is that largely reliable electrochemistry instrumentation is outside the budget of student laboratories. In this work, introductory electrochemistry experiments are being investigated for incorporation into the general chemistry curriculum. These guided-inquiry lab experiences will utilize a low-cost electrochemistry device—the CheapStat—that Dr. Bonham et al. have previously developed. This will allow the development of self-guided labs that use the CheapStat, where the student can learn independently instead of using limited time on a single classroom machine. These experiments will use electrochemistry to investigate relatable concepts, such as verifying the concentration of pain relievers in common cold medicine. It is hypothesized that students who complete these self-guided labs will gain a deeper insight into electrochemical theory and techniques. Currently, labs are being developed and verified to ensure they are reliably reproducible, engaging, and incorporate best practices for self-guided lab experiences. In the future, we plan to assess general chemistry laboratories that complete or do not complete these modules and assess the impact that they make on the educational experience and knowledge of electrochemistry.

OBJECTIVES FOR STUDENTS

To learn the components and functions of an electrochemical circuit.
To prepare and operate an electrochemical electrode plate.
To learn how to use the CheapStat properly.
To gain experience in performing calculations stoichiometrically.
To learn how to collect and read data from the CheapStat.
To learn how to make a graph based on the data received from the CheapStat.
To sequence and categorize the data and create a graph.
To identify the cause and effect of the duck shape made by the graph.

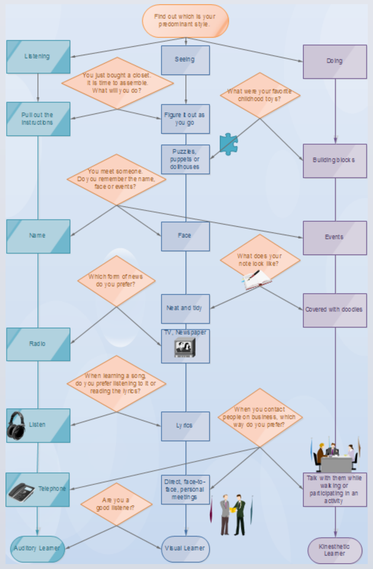

Fig.1 Flowchart of different learning styles.

PURPOSE

The purpose of this research is to help students better understand why they have a hard time learning electrochemistry and how to modify their understanding based on learning styles. Electrochemistry is essential because it is used to study current, potential, and conductivity. Learning electrochemistry is necessary for students who plan on getting chemistry degrees, because it is used in industry. Giving students initial experience on how to use potentiostat will give them a necessary competitive advantage.

ELECTROCHEMISTRY CHALLENGES

Electrochemistry is an extremely challenging subject for students. This is mostly due to the fact that students do not have prior knowledge of physics. Also because it is not covered in a significant timeframe in lectures. It is a valuable learning experience for students to understand the foundations of electrochemistry and how they relate to real life. It is not just important to teach students about the basis of electrochemistry, but also how to analyze data and how to relate it to graphs. The goal is to not give an experiment to students to regurgitate, but for them to learn real practical experience.

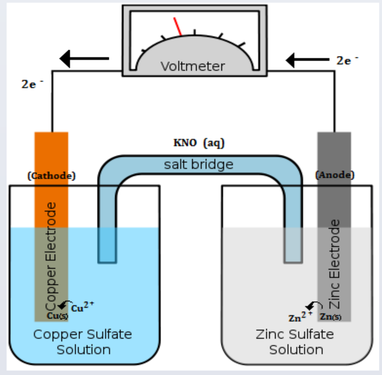

Fig. 2 Schematic of electron flow, which is from anode (reducing agent) to cathode (oxidizing agent). The salt bridge is used to keep the solution neutral. The solution to the right is therefore positively charged and the solution to the left is negatively charged. As the redox reaction occurs it is imperative that the electrode be cleaned throughout to prevent charge buildup.

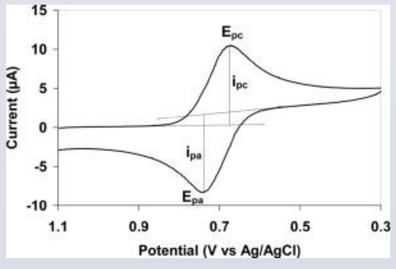

Fig. 3 Cyclic voltammetry is a common electro-analytical technique that can give redox potential and concentration (from observed current response). Applied potential is repeatedly increased and decreased, giving characteristic response shape.

OUR EXPERIMENTAL SYSTEM

This experiment uses a student-grade potentiostat device called the CheapStat to collect all data. The CheapStat is a cost effective instrument designed previously by our group that gives students the ability to experience and investigate electrochemistry –based analytical techniques.

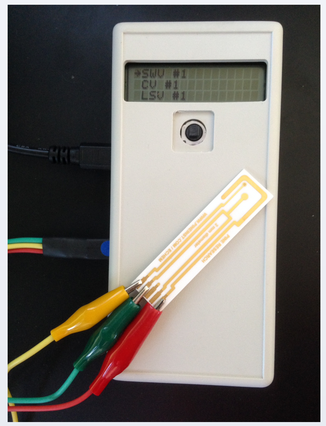

Fig. 4 The gold ceramic patterned microelectrode is attached by three alligator clips to the device. The yellow alligator clip is the working electrode. The red alligator clip is the counter electrode.

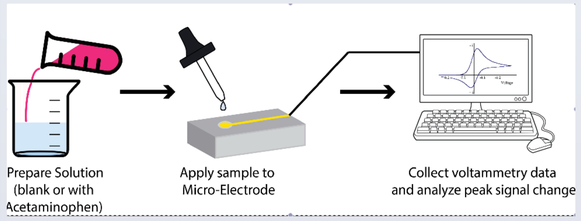

Fig. 5 Schematic of experiment workflow and data collection process.

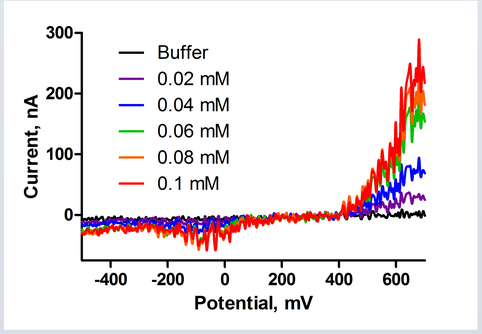

Fig. 6 Cyclic Voltametry results for acetaminophen standards obtained using the Cheapstat. There is a large increase in response at 600 mV as a function of concentration.

PROGRESS & FUTURE DIRECTIONS

A lab experiment for a future manual has been developed and is being edited. This experiment will help students better understand the basics of electrochemistry. We will partner with a faculty member to test out the experiment with the students. Three different quizzes will be distributed in order to test the student prior knowledge of electrochemistry: students with no exposure, students with traditional exposure, and students who complete the experiment. Based on making an experiment that students can relate to we hope that it will be incorporated into the General Chemistry lab manual.

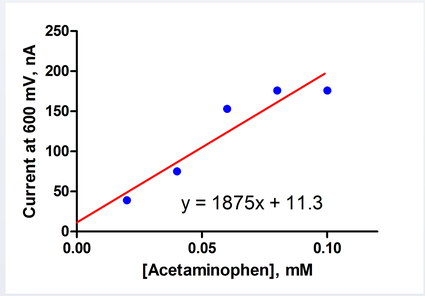

Fig. 7 Demonstration of creating a standard curve of acetaminophen concentration in solution. Students can then use this calibration curve to probe acetaminophen content of commercial pain relievers and sleep aids.

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