Electrochemical Cells

Inquiry Guidance and AP* Chemistry Curriculum Alignment

Introduction

Explore the fundamental role of electron transfer in oxidation and reduction reactions by studying the voltage of galvanic cells. What are the basic features of an electrochemical cell? How can reduction potentials be measured? What factors determine the ability of a galvanic cell to produce electricity? How does the voltage of a galvanic cell depend on concentration? Can this relationship be used to determine the solubility constant for a salt?

Opportunities for Inquiry

Understanding electrochemical cells requires students to synthesize knowledge from oxidation–reduction reactions, thermodynamics and equilibrium. This microscale lab activity provides a wonderful opportunity to apply conceptual knowledge and reasoning skills to build an enduring understanding of the principles of electrochemistry. The following strategies may be used to increase the level of student engagement in the design of electrochemical cells and measurements.

- Take away the data tables and post-lab questions! Replace worksheet calculations with a detailed overview of the design of the experiment. The biggest conceptual leap for students is identifying how to use the voltages they measure using zinc as the reference electrode to then construct an experimental table of standard reduction potential values versus the standard hydrogen electrode. Identifying or recognizing this relationship is certain to be an inquiry challenge for students!
- Divide the experiment into two parts—do Part 1 as a baseline activity with students following the prescribed procedure. Replace or extend Part 2 of the experiment to design a galvanic cell, also known as a battery, which will produce a specific voltage. Different groups can be given different metal anode and cathode combinations to work within this inquiry part of the lab. Choosing one of the half-cells as a standard, they can experiment by manipulating the concentration of the metal ion in the second half-cell. Plotting voltage as the dependent variable versus the metal ion concentration as the independent variable should allow them to produce a battery design with the target voltage. They may also "discover" the Nernst equation in the process!
- Electrochemical cells are usually connected in series to make real batteries. How can microscale cells consisting of an anode and a cathode be connected to build a series circuit? Do the voltages of the individual cells in the series "add up" to produce the final measured voltage across the series of cells? Is there a practical limit to the number of cells that can be connected?
- Lemon and other citrus fruit batteries are a popular demonstration. Give students various metal strips, such Cu, Zn, Fe, Pb, Ni, Sn, Cr, etc. Insert the metal electrodes into lemons, oranges or grapefruit and measure the voltages with different combinations of positive and negative leads. What do the voltages mean? Is there a pattern or trend relating to the table of standard reduction potentials?

Alignment with AP Chemistry Curriculum Framework—Big Idea 3

Enduring Understandings and Essential Knowledge

Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid–base, and oxidation–reduction reactions. (Enduring Understanding 3B)

3B3: In oxidation–reduction (redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced.

Chemical and physical transformations may be observed in several ways and typically involve a change in energy. (Enduring Understanding 3C)

3C3: Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.

Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal. (Enduring Understanding 6A)

6A4: The magnitude of the equilibrium constant, *K*, can be used to determine whether the equilibrium lies toward the reactant side or product side.

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Chemical equilibrium plays an important role in acid–base chemistry and in solubility. (Enduring Understanding 6C)

6C3: The solubility of a substance can be understood in terms of chemical equilibrium.

Learning Objectives

3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.

3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws.

3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

6.7 The student is able, for a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium.

6.21 The student can predict the solubility of a salt, or rank the solubility of salts, given the relevant K_{sp} values.

Science Practices

2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

2.3 The student can estimate numerically quantities that describe natural phenomena.

4.3 The student can collect data to answer a particular scientific question.

5.1 The student can analyze data to identify patterns or relationships.

6.1 The student can justify claims with evidence.

6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

The *Electrochemical Cells—AP Chemistry Classic Laboratory Kit* is available from Flinn Scientific, Inc.

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