Electrochemistry: Galvanic Cells and the Nernst Equation

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

- construct galvanic cells and develop an electrochemical series based on potential differences between half-cells.
- understand the Nernst Equation.

Procedure Overview

- an electrochemical series is determined with reference to Sn. The half cells constructed are: Sn (s)/$SnCl_2$; Nichrome/$FeSO_4$, $Fe(NO_3)_3$; Cu (s)/$Cu(NO_3)_2$, and Zn (s)/$ZnSO_4$.
- the Nernst Equation is explored using different concentrations of copper sulfate solution and 1 *M* solution of zinc sulfate. A graph of voltage vs. log([Cu2+]) is plotted and used to determine concentration of an unknown copper solution.

Name ______________________________ Section ________ Date _____________________

ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Report Sheet

Part I: Galvanic cells and the electrochemical series

Voltage Readings

Sample #	Red: Metal	Black: Metal	Voltage(mV)
1			
2			
3			
4			
5			
6			

Electrochemical Series Table

Half-reaction	Cell voltage compared to Sn^{2+}/Sn half-cell (mV)
________________________	____
________________________	____
________________________	____
________________________	____

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ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Report Sheet (page 2)

Part II: The Nernst Equation

Cell #	$[Cu^{2+}]$	$[Zn^{2+}]$	E_{cell} observed	E_{cell} calculated
1	1.0	1.0		
2	0.10	1.0		
3	0.010	1.0		
4	0.0010	1.0		
5	0.00010	1.0		
Unknown		1.0		N/A

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ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Questions/Problems

1. According to your Electrochemical Series Table, which half-cell reaction has the greatest tendency toward reduction (to gain electrons)?

2. Which half-cell has the greatest tendency toward oxidation?

3. Based on your Electrochemical Series Table, what would you predict for the voltage of a copper/zinc cell? How does the *measured* voltage of this cell compare with your prediction? Show your calculations.

4. What would you predict for the voltage of Cu/Fe and Fe/Zn cells? Compare the observed voltages with your calculated values. Show your calculations.

5. In Part II of your experiment, how do your values for $E_{cell\ (observed)}$ and $E_{cell\ (calculated)}$ compare? If they differ significantly, can you offer any explanation for the differences? Provide the equation used to calculate $Ecell_{(calculated)}$.

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ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Questions/Problems (page 2)

6. Using the following Standard Reduction Potential Table:

Half-cell					(volts)
Ag^{+}	+	e-	⇔	$Ag_{(s)}$	+ 0.80 V
Cr^{3+}	+	3 e-	⇔	$Cr_{(s)}$	+ 0.74 V

consider a galvanic cell consisting of the Ag^{+} (1 *M*) / Ag and the Cr^{3+} (1 *M*) / Cr half-cells.

a. Which half-cell undergoes reduction?

b. Write an equation for the reaction that occurs at the anode and the reaction that occurs at the cathode.

c. What is the cell potential, E_{cell}, for the galvanic cell?

7. Use the Nernst Equation to determine the cell potential, E_{cell}, of the galvanic cell consisting of the two half-cells:

Ag^{+} (0.0010 *M*) + e- ⇔ $Ag_{(s)}$ Cr^{3+} (0.1 *M*) + 3 e- ⇔ $Cr_{(s)}$

ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Suggested Answers to Questions/Problems

1. According to your Electrochemical Series Table, which half-cell reaction has the greatest tendency toward reduction (to gain electrons)?

   The Fe^{3+}/Fe^{2+} half cell reaction.

2. Which half-cell has the greatest tendency toward oxidation?

   The Zn^{2+}/Zn (s) half cell reaction.

3. Based on your Electrochemical Series Table, what would you predict for the voltage of a copper/zinc cell? How does the *measured* voltage of this cell compare with your prediction? Show your calculations.

   614 mV + (+300 mV) = 914 mV
   The measured voltage was 1050 mV, thus the calculated voltage is lower than the measured voltage by 146 mV.

4. What would you predict for the voltage of Cu/Fe and Fe/Zn cells? Compare the observed voltages with your calculated values. Show your calculations.

   Cu/Fe: 960 mV + (614 mV) = 346 mV
   The observed voltage is lower than the calculated voltage by 16 mV.

   Fe/Zn: 960 mV + (+300 mV) = 1260 mV
   The observed voltage is higher than the calculated voltage by 40 mV.

5. In Part II of your experiment, how do your values for $E_{cell\ (observed)}$ and $E_{cell\ (calculated)}$ compare ? If they differ significantly, can you offer any explanation for the differences? Provide the equation used to calculate cell (calculated).

   E_{cell} = ***1.1 V (0.0591/2) log($[Zn^{2+}] / [Cu^{2+}]$)***
   The observed and calculated values are all within 10 mV or less of each other.

ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Suggested Answers to Questions/Problems (page 2)

6. Using the following Standard Reduction Potential Table:

Half-cell	**(volts)**
$Ag^+ + e \Leftrightarrow Ag$	+0.80 V
$Cr^{3+} + 3e \Leftrightarrow Cr$	-0.74 V

consider a galvanic cell consisting of the Ag+ (1 *M*) / Ag and the Cr^{3+} (1 *M*) / Cr half-cells.

a. Which half-cell undergoes reduction?

Ag+ (1 M) / Ag (s)

b. Write an equation for the reaction that occurs at the anode and the reaction that occurs at the cathode.

Anode: Cr (s) –> Cr3+ + 3 e

Cathode: Ag+ + e –> Ag (s)

c. What is the cell potential, E_{cell}, for the galvanic cell?

$\boldsymbol{E_{cell} = 0.80\ V + 0.74\ V = 1.54\ V}$

7. Use the Nernst Equation to determine the cell potential, E_{cell}, of the galvanic cell consisting of the two half-cells:

Ag^+ (0.0010 *M*) + e $\Leftrightarrow$ $Ag_{(s)}$ Cr^{3+} (0.1 *M*) + 3 e $\Leftrightarrow$ $Cr_{(s)}$

$\boldsymbol{E_{cell} = 1.38\ V}$

Tips and Traps

Students should avoid handling the filter papers or metal strips with hands.
Tweezers should be rinsed and dried between solutions to avoid contamination.

2. Copper and zinc strips should be sanded on scratch paper on the desk top to avoid scratching the desk top, and rinsed well.

3. Any combination of small containers can be used in place of the Chem Carrou-Cell™.

4. Chem Carrou-Cell™ is available from Freeman, Cooper & Co., San Francisco, CA 94133.

Sample MicroLAB Program for this Experiment

The instructor will need to set up this experiment ahead of time and save it in the **Saved Experiments** folder, or give the students a handout to let them set up the program themselves.

Experiment name: **electropot.vs.kbd.experiment**

Sensors: **Keyboard** (Metal #): X axis, Col. A, DD on top, units = none; Voltage: Y1 axis, Col B, DD on bottom, units = volts.

Special program:
Read Sensors
Repeat upon receiving keyboard input
Until Stop Button is pressed

Comment: The voltage does not need to be recalibrated.

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ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Sample Data

Part I: Galvanic cells and the electrochemical series

Voltage Readings

Sample #	Red: Metal	Black: Metal	Voltage(mV)
1	Cu	Sn	610
2	Zn	Sn	-460
3	Fe	Sn	960
4	Fe	Cu	330
5	Fe	Zn	1300
6	Cu	Zn	1050

Electrochemical Series Table

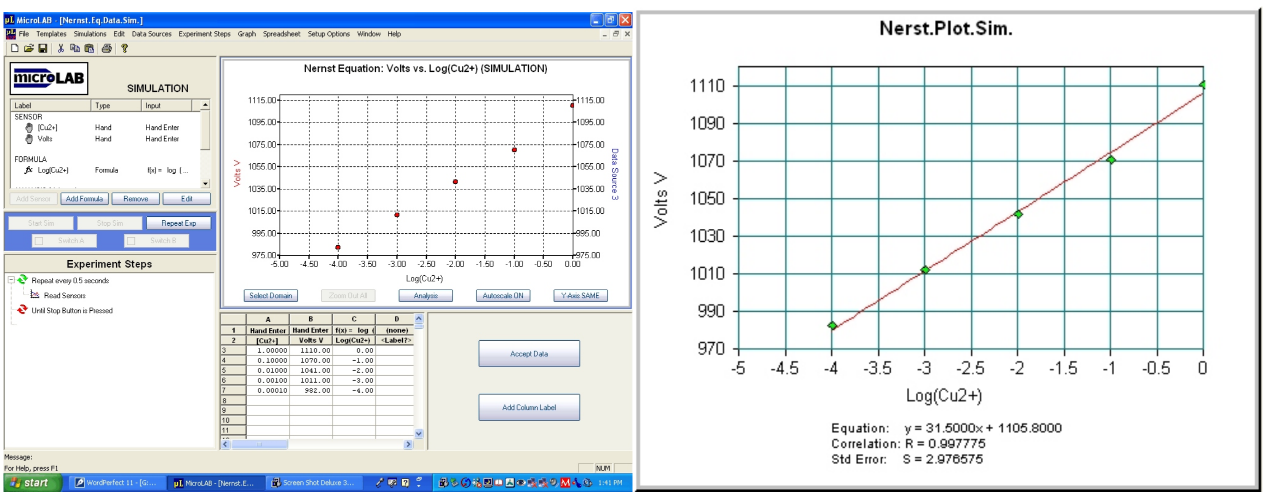
Half-reaction	Cell voltage compared to Sn^{2+}/Sn half-cell (mV)
$Fe^{3+} + e \Leftrightarrow Fe^{2+}$	960 mV
$Cu^{2+} + 2e \Leftrightarrow Cu_{(s)}$	614 mV
$Sn^{2+} + 2e \Leftrightarrow Sn_{(s)}$	0 mV
$Zn^{2+} + 2e \Leftrightarrow Zn_{(s)}$	-300 mV

Sample Data (page 2)

Part II: The Nernst Equation

Cell #	$[Cu^{2+}]$	$[Zn^{2+}]$	E_{cell} observed	E_{cell} calculated
1	1.0	1.0	1110 mV	1100 mV
2	0.10	1.0	1067 mV	1070 mV
3	0.010	1.0	1035 mV	1041 mV
4	0.0010	1.0	1005 mV	1011 mV
5	0.00010	1.0	984 mV	982 mV
Unknown	0.21	1.0	1082 mV	N/A

Simulated ***MicroLAB*** Main Screen and Nernst Plot from above data.



ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION

Laboratory Preparation (per student station)

Equipment

- 600 ml beaker
  50 ml beaker
  tweezers
  12 well
  one pair of red and black alligator clip leads

Supplies

- filter paper strips
  sandpaper
  tile

Chemicals

Exact quantities needed are listed below. A minimum 50% excess is recommended.

- copper metal: six, 5 cm strips
- tin foil: one, 5 cm strip
- nichrome wire: one, 5 cm strip
- zinc metal: two, 5 cm strips
- 5 ml of 1.0 *M* $Cu(NO_3)_2$
- 10 ml of 0.10 *M* $Cu(NO_3)_2$
- 5 ml of 0.010 *M* $Cu(NO_3)_2$
- 5 ml of 0.0010 *M* $Cu(NO_3)_2$
- 5 ml of 0.00010 *M* $Cu(NO_3)_2$
- 10 ml of 0.10 *M* KNO_3
- 5 ml of 0.10 *M* $SnCl_2$
- 5 ml of 0.10 *M* $(Fe^{2+}/Fe^{3+})SO_4$ (50/50 mixture)
- 5 ml of 0.10 *M* $ZnSO_4$
- 5 ml of 1.0 *M* $ZnSO_4$
- various unknowns $Cu(NO_3)_2$ (0.05 *M* - 0.75 *M*)

Safety and Disposal

pour waste solutions into specially designated containers