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Section: 128-XX

**ELECTROCHEMISTRY: GALVANIC CELLS AND THE NERNST EQUATION**

A **galvanic cell** separates a redox reaction into its two half-reactions so that electrons are transferred through an external circuit (eg, a battery) rather than by direct contact (eg, corrosion). The **Nernst equation** describes cell voltage under non-standard conditions.

In this experiment you will:

* use *electrochemistry* terminology and concepts
* look up and use *Standard Reduction Potentials* to determine spontaneity
* apply the *Nernst Equation* in nonstandard situations
* measure reduction potentials for an *electrochemical series*
* understand the concept of a *reference electrode*
* measure a *concentration cell* series and determine an unknown concentration
* describe a *practical application* of electrochemistry
* gain experience entering data and calculations into an *electronic document* or notebook

This experiment relies upon the Electrochemical Cells simulator available at

[**http://web.mst.edu/~gbert/Electro/Electrochem.html**](http://web.mst.edu/~gbert/Electro/Electrochem.html)

written by Dr. Gary L. Bertrand at the University of Missouri-Rolla.

Make a copy of this document, follow the instructions, record all your responses in your document, export the final version as a pdf, and upload the pdf file to your course Moodle section by the due date.

**1. Background Concepts.** Go to the Electrochemical Cells simulator. Click on the Background link, and review the material. Answer the following questions for a galvanic cell with the reaction

Zn(s) + Cu2+(aq) -> Zn2+(aq) + Cu(s)

1 A. Is Zn being oxidized or reduced? Why? Is Zn the anode or cathode?

<insert answer here>

1 B. Is Cu2+ being oxidized or reduced? Why? Is Cu the anode or cathode?

<insert answer here>

1 C. From the table of Standard Reduction Potentials (upper left of Simulator), write down the two half-reactions involved in this redox reaction *as reductions*. Also write down the Eo values for each reduction reaction from the table. Replace the “<text>” and “#” with your entries.

Zn2+(aq) + <text>Eo(Zn/Zn2+) = #

Cu2+(aq) + <text> Eo(Cu/Cu2+) = #

In subsequent equations, the states of matter, (s) or (aq), will be omitted since they can be presumed from the charge of the species, ie, ions are aqueous and neutral species are solids.

1 D. Calculate the Standard Electrochemical Potential of the electrochemical cell Eocell for the reaction. Show all work by replacing "#" in the equations below with your values. Include units.

Eocell = Eocathode − Eoanode

 = # − ( # )

 = #

1 E. What is the sign of Eocell in 1D? Is the above reaction spontaneous as written?

<insert answer here>

1 F. Assume a galvanic cell is constructed with [Zn2+] = 0.1 M and [Cu2+] = 0.0001 M. Use the Nernst Equation

E = Eocell − ( 0.05916 V / n ) \* log Q

to calculate the voltage E of the cell. Show all work by replacing "#" in the equations below with your values.

E = Eocell − ( 0.05916 V / n ) \* log Q

E = Eocell − ( 0.05916 V / n ) \* log ( [Product Ion] / [Reactant Ion] )

E = ( # ) − ( 0.05916 V / # ) \* log ( # / # )

E = # − #

E = #

**2. Use of the Simulator**

**2 A. Instrument Validation.** Go to the Electrochemical Cells simulator. Set "Level" (bottom right) to 0. Select the "Electrode on Left" as Zn and "Solution on Left" as zinc nitrate. Select the "Electrode on Right" as Cu and "Solution on Right" as copper nitrate. Leave both concentrations at 1.00 M. Click "Measure Cell Voltage" (bottom left), and record Eocell below. Set [Zn2+] = 0.1 M and [Cu2+] = 0.0001 M, click "Measure Cell Voltage", and record E below. Compare the simulator results to your calculation in 1D and 1F above. (Hint: They should be close.)

Eocell = #

E = #

All instruments, including the simulator, have accuracy and precision limitations. The simulator’s accuracy is ±0.02V and precision is ±0.001 V. Do the results of 1D, 1F, and 2A agree to within the simulator’s accuracy? Explain.

<insert answer here>

**2 B. Same Concentrations.** Set "Level" to 1. Click "New Problem" several times to randomize the displayed electrodes. This will make your answer different from other students. Then record the following values:

Electrode on Left: <text> Concentration on Left: #

Electrode on Right: <text> Concentration on Right: #

Write down the two reduction half-reactions for the electrodes and their Standard Reduction Potentials:

<insert answer here>

Write the overall balanced redox reaction in the spontaneous direction by reversing one half-reaction and summing the two half reactions so that the e- terms cancel out. Show work. (You may also need to multiply one half-reaction by a constant to get the electrons to balance, but this does not change the Standard Reduction Potential value.) Explain which half-reaction is reversed so that the reaction is spontaneous.

<insert answer here>

Use the Nernst Equation to calculate the expected cell voltage. Show all work by replacing "#" in the equations below with your values.

E = Eocell − ( 0.05916 V / n ) \* log Q

E = ( Eocathode − Eoanode) − ( 0.05916 V / n ) \* log ( [Product Ion] / [Reactant Ion] )

E = ( # − # ) − ( 0.05916 V / # ) \* log ( # / # )

E = # − #

E = #

Click "Check Answer", enter your final result into the dialog box, and click OK. What value does the simulator report? If significantly different, check your above calculation.

Esimulator = #

**2 C. Different Concentrations.** Set "Level" to 4. Click "New Problem" several times. Then record the following values:

Electrode on Left: <text> Concentration on Left: #

Electrode on Right: <text> Concentration on Right: #

Write down the two reduction half-reactions for the electrodes and their Standard Reduction Potentials:

<insert answer here>

Combine the reduction half-reactions to indicate the spontaneous reaction. Show work.

<insert answer here>

Use the Nernst Equation to calculate the expected cell voltage. Show all work by replacing "#" in the equations below with your values.

E = Eocell − ( 0.05916 V / n ) \* log Q

E = ( # − # ) − ( 0.05916 V / # ) \* log ( # / # )

E = # − #

E = #

Click "Check Answer", enter your final result into the dialog box, and click OK. What value does the simulator report? If significantly different, check your above calculation.

Esimulator = #

**2 D. Build a Battery.** Set "Level" to 3. Click "New Problem" several times. Write down the target Eo:

Construct a cell with the ANODE on the Left and Eo = #

Look at the table of standard reduction potentials in the Background to select an "Electrode on Left" with its matching cation solution and an "Electrode on Right" with its matching cation solution to create this voltage. Click "Check Answer". If incorrect, revise your Electrodes until the voltage on your meter agrees with the target Eo. Write down

Electrode on Left (Anode): <text>

Electrode on Right (Cathode): <text>

Calculate Eocell for this arrangement. Show all work by replacing "#" in the equations below with your values:

Eocell = Eocathode − Eoanode

 = # − #

 = #

What value does the simulator report?

Esimulator = #

**3. Electrochemical Series and References.**

You have been provided with a reference electrode (Ref) and 4 sample electrodes (#1, #2, #3, #4). List these metals here:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ref | #1 | #2 | #3 | #4 |
| M | M | M | M | M |

**3 A. Voltage Measurements.** Set "Level" to 0. Set the Electrode on Left to be your Ref electrode. Set the Electrode on Right to be your #1 electrode. Match solutions and leave Concentration at 1M. Measure the Cell Voltage, and record your results below. Repeat for your #2, #3, and #4 electrodes.

|  |  |
| --- | --- |
| Cell | Voltage |
| Ref/#1 | # |
| Ref/#2 | # |
| Ref/#3 | # |
| Ref/#4 | # |

**3 B. Qualitative Observations.** Write down your #1 … #4 metals in order of decreasing cell voltage:

M > M > M > M

How does the order of these metals here compare to the order of metals in the table of standard reduction potentials?

<insert answer here>

**3 C. Quantitative Observations.**

i. Use the table of Standard Reduction Potentials to calculate the standard voltage of cell #1/#2, ie, #1 as the anode and #2 as the cathode:

Eocell = Eocathode − Eoanode

 = # − #

 = #

ii. Use the voltages in the table in 3A above to calculate the following quantity:

Voltage of Ref/#2 - Voltage of Ref/#1 = # − # = #

iii. Use the simulator construct the electrochemical cell #1/#2, measure its voltage, and report it below:

Esimulator(#1/#2) = #

iv. How do the answers of i, ii, and iii compare?

<insert answer here>

**3 D. Predictions.**

i. Use the table in 3A above to predict the standard voltage of cell #3/#4,ie, #3 as the anode and #4 as the cathode. Show work.

Eocell = # − # = #

Use the simulator to construct the electrochemical cell #3/#4, measure its voltage, and report it below:

Esimulator(#3/#4) = #

ii. Without using the table of standard reduction potentials, predict the standard voltage of cell #4/#3 (note the change in order, and therefore in anode and cathode!). Show work.

Eocell = #−- # = #

Use the simulator construct the electrochemical cell #4/#3, measure its voltage, and report it below:

Esimulator(#4/#3) = #

iii. What happens to the measured voltage when you switch the leads?

<insert answer here>

**3 E. Conclusions.**

An electrochemical cell requires two electrodes. In electrochemistry these are often called the reference electrode and the indicator electrode. Standard reduction potentials are measured using the standard hydrogen electrode (SHE) as reference. Unfortunately, this is a difficult electrode to work with, so electrochemists often use the saturated calomel electrode (SCE) or the silver-silver chloride electrode (Ag/AgCl) as reference instead.

Does using a different reference electrode affect the measured voltage? Explain.

<insert answer here>

Does the reference affect the relative reducing power of a cation? Explain.

<insert answer here>

Does the reference affect the calculated cell voltages for #1/#2 and #3/#4? Explain.

<insert answer here>

**4. Concentration Cells**

**4 A. Voltage Measurements**. Set "Level" to 0. Set the Electrode on Left to be your Ref metal. Also set the Electrode on Right to be your Ref metal. Provide matching solutions. Set both Concentrations to 1 M, measure the Cell Voltage, and record your result below. Change the Concentration on the Left to 0.1 M, measure the Cell Voltage, and record your result below. Repeat for 0.01 M, 0.001 M, and 0.0001 M on the Left.

|  |  |  |
| --- | --- | --- |
| Left Concentration (M) | Right Concentration (M) | Cell Voltage (V) |
| 1 | 1 | # |
| 0.1 | 1 | # |
| 0.01 | 1 | # |
| 0.001 | 1 | # |
| 0.0001 | 1 | # |

**4 B. Linear Fit.** Use Excel or Google Sheets to make a plot of

y = Cell Voltage

Versus

x = log (Q) = log( Left Concentration / Right Concentration )

Fit your data with a Trendline, and display the equation. Paste a screenshot of the plot below. Hint: For help on Trendline on a Google Sheet, see <https://www.mrwaynesclass.com/labs/reading/trendlinesInGoogle.html>

<insert screenshot here>

**4 C. Comparison to Nernst Equation.** Recognizing that the Nernst Equation

E = Eocell − ( 0.05916 V / n ) \* log Q

Has the form of a straight line

y = b + m \* x

we see that the theoretical value of slope of a plot of y = E versus x = log Q is

m = - 0.05916 V / n

Compare the value of the slope from the Nernst equation to the slope from your concentration cell. (Hint: They should be close.)

slope (Nernst equation) = − 0.05916 V / # = #

slope(concentration cell) = #

**4 D. Solving for Unknown Concentration.** You have been provided with a virtual solution of unknown concentration of Ref cation. Placing the Electrode on Left into that solution, you measure the cell voltage to be **0.042 V**. Using the Trendline fit of your data, calculate the concentration of the solution. Show all work. Hint: Both intercept and slope have units of V.

E = Eocell − ( 0.05916 V / n ) \* log Q

0.042 V = intercept + slope \* log ( [Left Conc] / [Right Conc] )

<insert work here>

**5. Electrochemistry Applications.**

Electrochemistry has many practical applications. In one paragraph, give one application, provide a description, and state the specific electrochemical reaction that is involved. You may also provide one picture. Cite works consulted.

<insert paragraph here>