Experiment 4. Galvanic Cells, the Nernst Equation

Experimental Procedure
Lab 402

Overview

The cell potentials for a number of galvanic cells are measured and the redox couples are placed in order of decreasing reduction potentials. The effects of changes in ion concentrations on cell potentials are observed and analyzed.

Perform the experiment with a partner. At each circled superscript [1-12] in the procedure, stop and record your observation on the *Report Sheet*. Discuss your observation with your lab partner and your instructor.

A. Reduction Potentials of Several Redox Couples

1. COLLECT THE ELECTRODES, SOLUTIONS, AND EQUIPMENT.

1) *Obtain four small (~50 mL) beaker and fill them three-fourths full of the 0.1 M solutions as shown in Figure 32.3. Share these solutions with other groups of chemists in the laboratory.*

2) Polish strips of copper, zinc, magnesium, and iron metal with sand paper, rinse briefly with dilute (~1 M) HNO_3 (Caution!), and rinse with deionized water.

3) The polished metals, used as electrodes, should be bent to extend over tip of their respective beakers. Check out a multimeter (Figure 32.4) with two electrical wires attached to alligator clips.

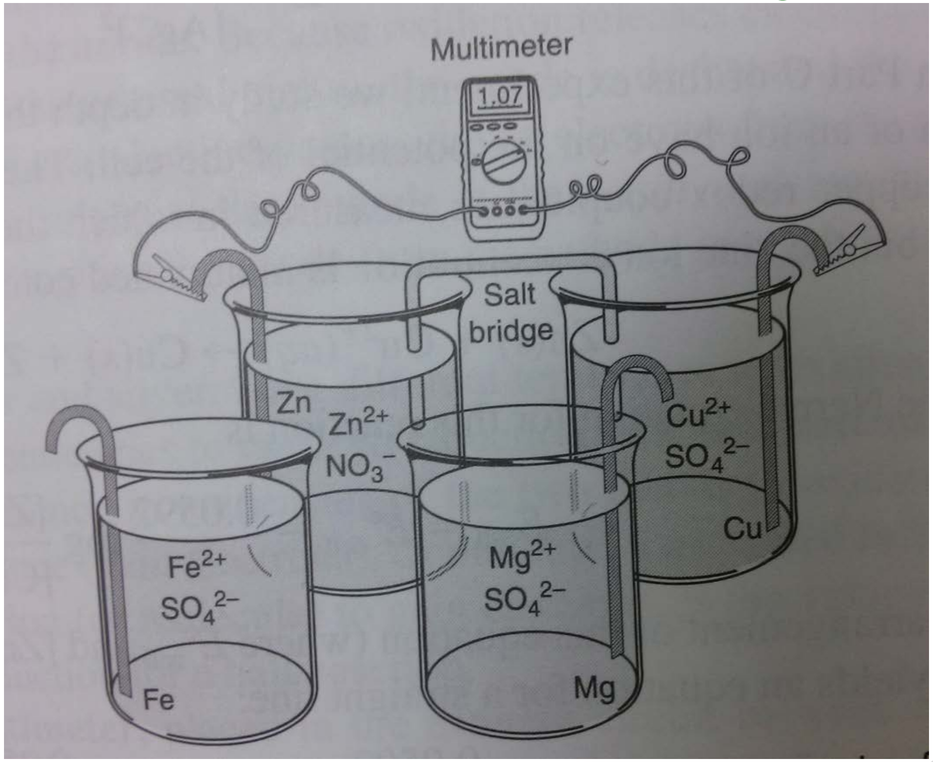
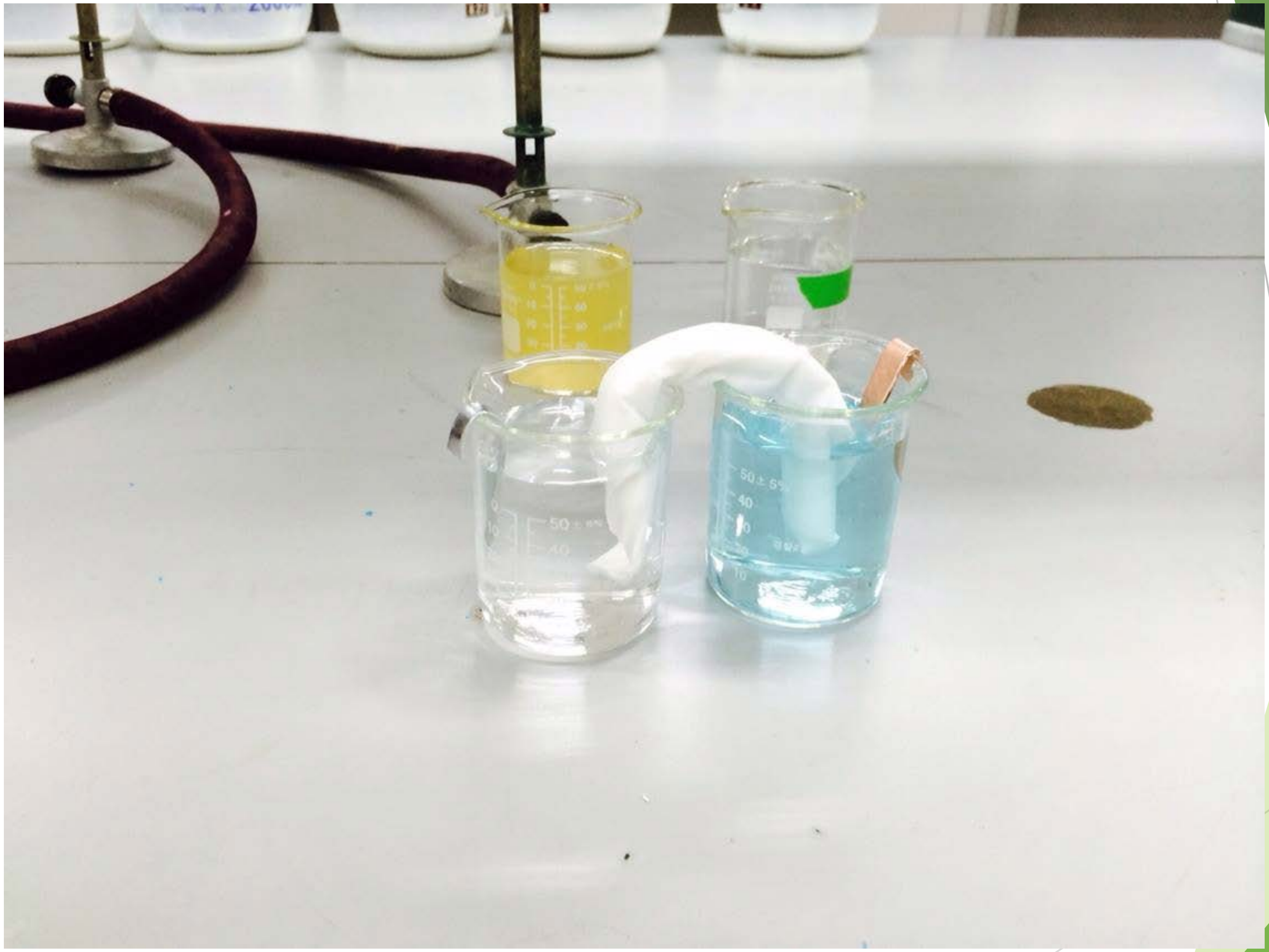


Figure 32.3 Setup for measuring the cell potentials of six galvanic cells

2. Set up the copper-zinc cell.

1) *Place a Cu strip (electrode) in the $CuSO_4$ solution and a Zn strip (electrode) in the $Zn(NO_3)_2$ solution.*
2) *Roll and flatten a piece of filter paper; wet the filter paper with a 0.1 M KNO_3 solution.*
3) *Fold and insert the ends of the filter paper into the solutions in two beakers; this is the salt bridge shown in picture next page. Set the multimeter to the 2000-mV range or as appropriate.*
4) *Connect one electrode to the negative terminal of the multimeter and the other to the positive terminal.*



3. Determine the copper-zinc cell potential.

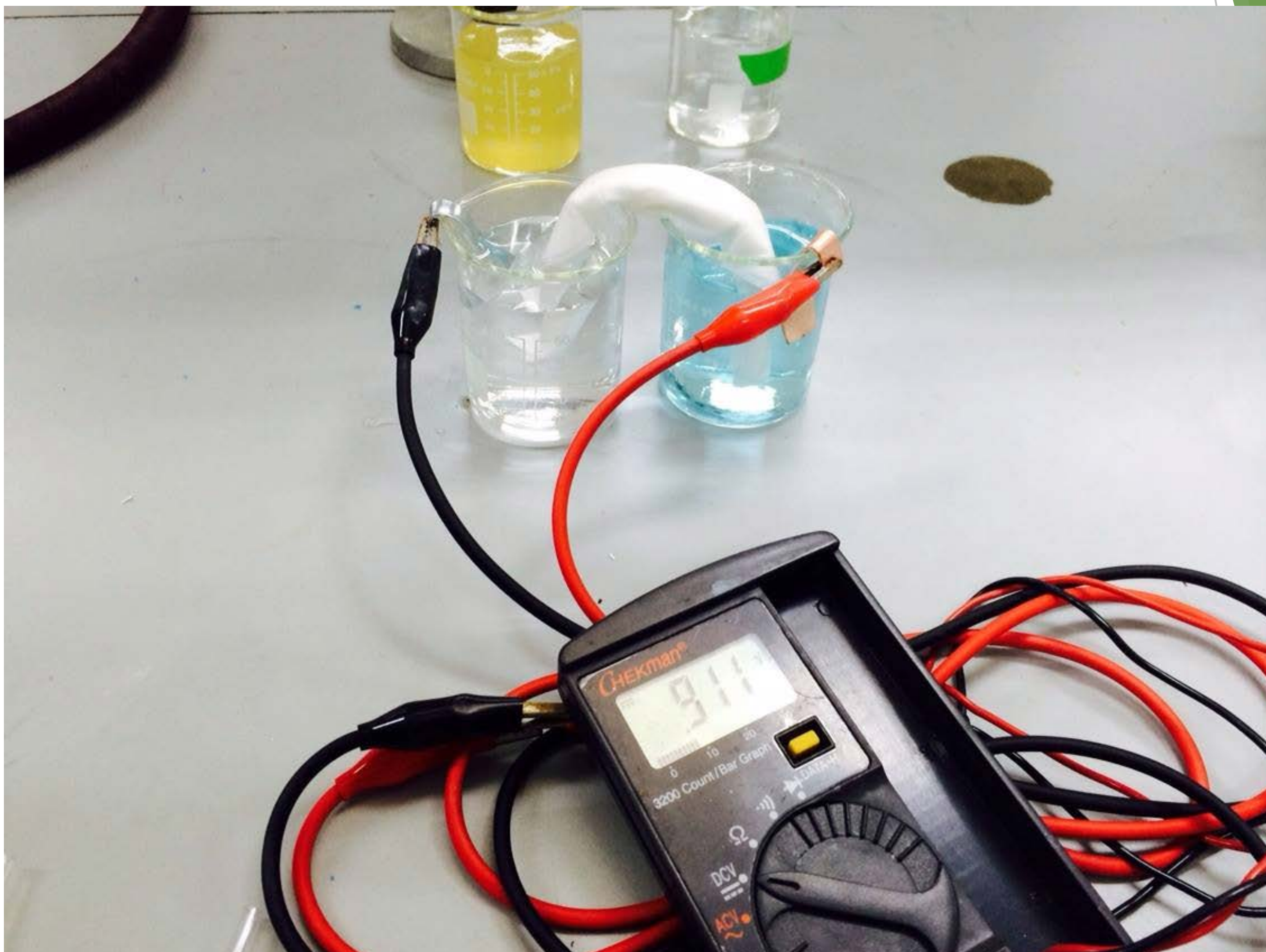
1) *If the multimeter reads a negative potential, reverse the connections to the electrodes. Read and record the (positive) cell potential. Identify the metal strips that serve as the cathode (positive terminal) and the anode.*
2) *Write an equation for the half-reaction occurring at each electrode. Combine the two half-reactions to write the equation for the cell reaction.*[1]

4. Repeat for the remaining cells.

1) *Determine the cell potentials for all possible galvanic cells that can be constructed from the four redox couples.*

2) *Refer to the Report Sheet for the various galvanic cells. Prepare a new salt bridge for each galvanic cell.*[2]

Galvanic Cell	E_{cell} Measured
Cu-Zn	
Cu-Mg	
Cu-Fe	
Zn-Mg	
Fe-Mg	
Zn-Fe	


CHEKMAN
3200 Count / Bar Graph
DCV
ACV

5. Determine the relative reduction potentials.

Assuming the reduction potential of the Zn^{2+}(0.1 M)/Zn redox couple is -0.79 V, determine the reduction potentials of all other redox couples. [3]

6. Determine the reduction potential of the unknown redox couple.

Place a 0.1 M solution and electrode obtained from your TA in a small beaker. Determine the reduction potential, relative to the Zn^{2+} (0.1 M)/Zn redox couple, for your redox couple. [4]

Galvanic Cell	E_{cell} Measured	For the Redox Couple	Reduction Potential (Experimental)	Reduction Potential (Theoretical)
Cu-Zn		Cu^{2+} /Cu		
Zn-Fe		Fe^{2+}/Fe		
Zn-Zn	0	Zn^{2+}/Zn	-0.79 V	-0.79
Zn-Mg		Mg^{2+}/Mg		
Zn-Unknown, X		X^{2+}, X		

B. Effect of Concentration Changes on Cell Potential

1. Effect of different molar concentrations.

1) *Set up the galvanic cell shown in Figure 32.5, using 1 M $CuSO_4$ and 0.001 M $CuSO_4$ solutions. Immerse a polished copper electrode in each solution. Prepare a salt bridge (Part A.2) to connect the two half-cells.*
2) *Measure the cell potential. Determine the anode and the cathode. Write an equation for the reaction occurring at each electrode.[5]*

2. Effect of complex formation.

1) *Add 2-5 mL of 6 M NH_3 to the 0.001 M $CuSO_4$ solution until any precipitate redissolves. (Caution: Do not inhale NH_3.)*
2) *Observe and record any changes in the half-cell and the cell potential.*[6]

3. Effect of precipitate formation.

1) Add 2-5 mL of 0.2 M Na_2S to the 0.001 M $CuSO_4$ solution now containing the added NH_3. What is observed in the half-cell and what happens to the cell potential? Record your observations.[7]

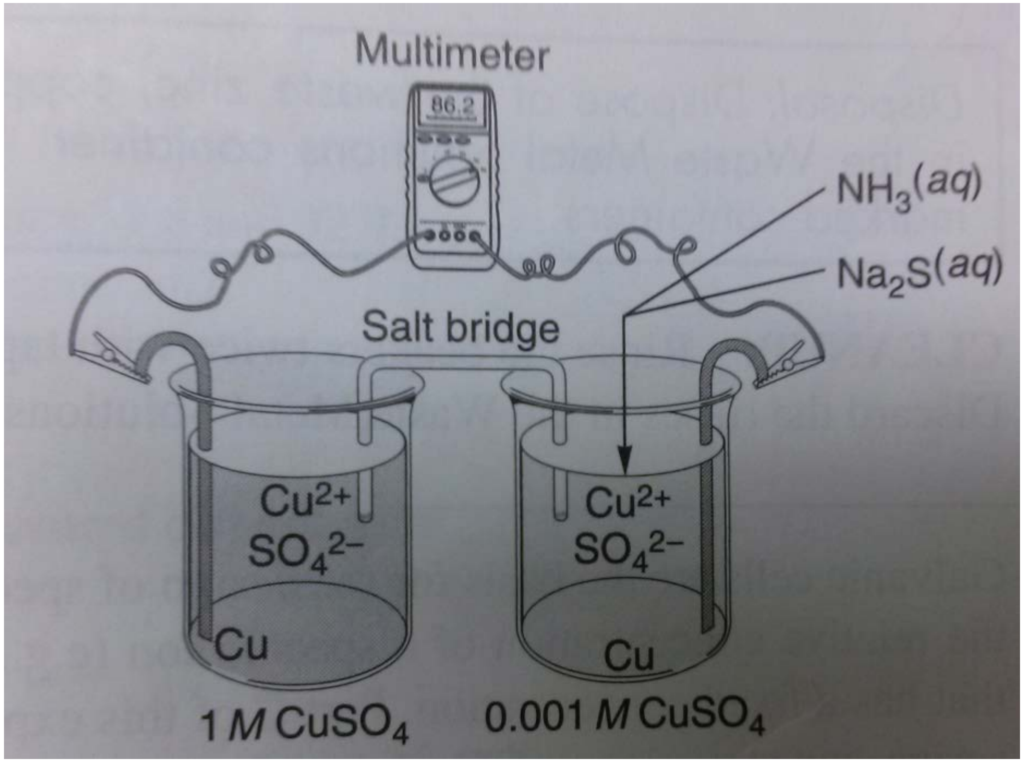


Figure 32.5 Setup for measuring the cell potentials of a Cu^{2+} concentration cell

C. The Nernst Equation and an Unknown Concentration

1. PREPARE THE DILUTED SOLUTIONS.

1) *Prepare solutions 1 through 4 as shown in Figure 32.6 using a 1-mL pipet and 100-mL volumetric flasks. Be sure to rinse the pipet with the more concentrated solution before making the transfer. Use deionized water for dilution to the mark in the volumetric flasks.*
2) *Calculate the molar concentration of the Cu^{2+} ion for each solution and record.[8]*

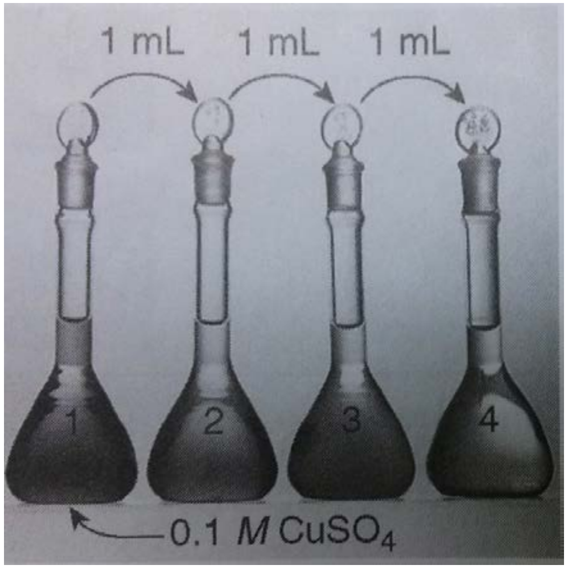


Figure 32.6 Successive quantitative dilution, starting with 0.1 M $CuSO_4$

2. Measure and calculate the cell potential for solution 4.

1) *Set up the experiment as shown in Figure 32.7, page 356, using small (~50 mL) beakers. The Zn^{2+} /Zn redox couple is the reference half-cell for this part of the experiment.*
2) *Connect the two half-cells with a new salt bridge. Reset the multimeter to the lowest range (~200 mV).*
3) *Connect the electrodes to the multimeter and record the potential difference, $E_{cell,expt}$.[9]*
4) *Calculate the theoretical cell potential $E_{cell,expt}$. (Use a table of standard reduction potentials and the Nernst equation.)[10]*

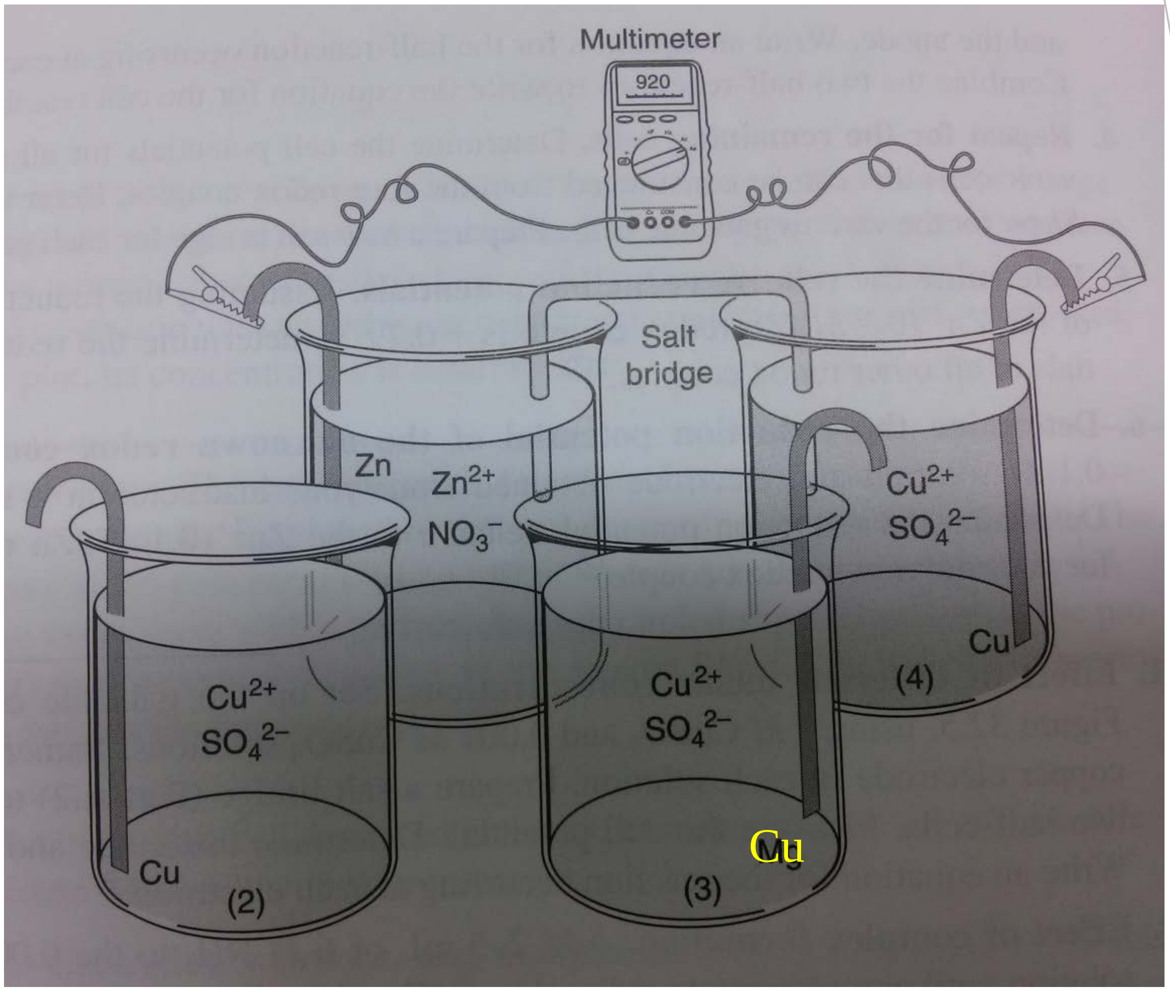


Figure 32.7 Setup to measure the effect that diluted solutions have on cell potentials

Solution Number	Concentration of $Cu(NO_3)_2$	E_{cell}, (Experimental)	$-\log[Cu^{2+}]$, pCu
1	0.1 mol/L		1
2			
3			
4			

3. Measure and calculate the cell potential for solutions 3 and 2. *Repeat Part C.2 with solutions 3 and 2, respectively. A freshly prepared salt bridge is required for each cell.*

4. Plot the date. *Plot $E_{cell,expt}$ and $E_{cell,calc}$ (ordinate) versus pCu (abscissa) on the same piece of linear graph paper (page 362) or by using appropriate software for the four concentrations of $CuSO_4$ (see data from Part A.3 for the potential of solution 1). Have your TA approve your graph.* [11]

5. Determine the concentration of the unknown.

1) *Obtain a $CuSO_4$ solution with an unknown copper ion concentration from your TA and set up a like galvanic cell. Determine E_{cell} as in Part C.2.*
2) *Using the graph, determine the unknown copper(II) ion concentration in the solution.[12]*

Students should thoroughly clean the electrodes, multimeter, and all connectors before returning this equipment.

Cleanup

Rinse the beakers twice with tap water and twice with deionized water. Discard the rinses in the Waste Metal Solutions container.