Lab 7: Establishing a Table of Reduction Potentials: Micro-Voltaic Cells

The main objective of this experiment is to establish the reduction potentials of five unknown metals relative to an arbitrarily chosen metal. This will be done by measuring the voltage, or potential difference, between various pairs of half-cells.

A voltaic cell utilizes a spontaneous oxidation-reduction reaction to produce electrical energy. Half-cells are normally produced by placing a piece of metal into a solution containing a cation of the metal (e.g., Cu metal in a solution of $CuSO_4$ or Cu^{2+}). In this micro-version of a voltaic cell, the half cell will be a small piece of metal placed into 3 drops of solution on a piece of filter paper. The solution contains the cation of the solid metal. Figure 1 shows the arrangement of half-cells on the piece of filter paper. The two half-reactions are normally separated by a porous barrier or a salt bridge. Here, the salt bridge will be several drops of aqueous $NaNO_3$ placed on the filter paper between the two half cells. Using the computer as a voltmeter, the (+) lead makes contact with one metal and the (–) lead with another. If a positive voltage is recorded on the screen, you have connected the cell correctly. The metal attached to the (+) lead is the cathode (reduction) and thus has a higher, more positive, reduction potential. The metal attached to the (–) lead is the anode (oxidation) and has the lower, more negative, reduction potential. If you get a negative voltage reading, then you must reverse the leads.

By comparing the voltage values obtained for several pairs of half-cells, and by recording which metal made contact with the (+) and (–) leads, you can establish the reduction potential sequence for the five metals in this lab.

OBJECTIVES

In this experiment, you will establish the reduction potentials of five unknown metals relative to an arbitrarily chosen metal.

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Vernier Voltage Probe
one glass plate, 15 × 15 cm, or one Petri dish, 11.5 cm diameter
one piece of filter paper, 11.0 cm diameter
1 × 1 cm metals M_1, M_2, M_3, M_4 and M_5
1 M $NaNO_3$
1 M solutions of M_1^{2+}, M_2^{2+}, ..., and M_5^{2+}
sand paper
forceps

PROCEDURE

1. Obtain and wear goggles.

2. Connect the Voltage probe to the computer interface. Prepare the computer for data collection by opening the file “28 Micro-voltaic Cells” from the *Chemistry with Vernier* folder of Logger*Pro*.

3. Obtain a piece of filter paper and draw five small circles with connecting lines, as shown in Figure 1. Using a pair of scissors, cut wedges between the circles as shown. Label the circles M_1, M_2, M_3, M_4, and M_5. Place the filter paper on top of the glass plate.

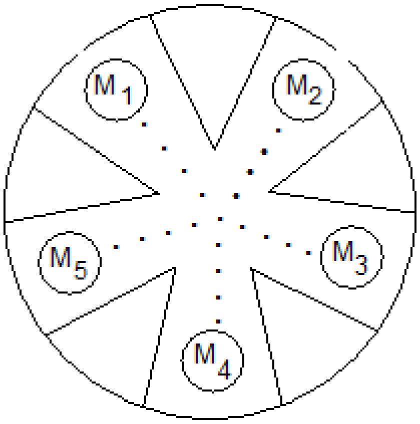

Figure 1

4. Obtain 5 pieces of metal, M_1, M_2, M_3, M_4, and M_5. Sand both surfaces of each piece of metal. Place each metal near the circle with the same number.

5. Place 3 drops of each solution on its circle (M_1^{2+} on M_1, etc.). Then place the piece of metal on the wet spot with its respective cation. The top side of the metal should be kept dry. Then add several drops of 1 M $NaNO_3$ to the line drawn between each circle and the center of the filter paper. Be sure there is a continuous trail of $NaNO_3$ between each circle and the center. You may have to periodically dampen the filter paper with $NaNO_3$ during the experiment. **CAUTION:** *Handle these solutions with care. Some are poisonous and some cause hard-to-remove stains. If a spill occurs, ask your teacher how to clean up safely.*

6. Use metal M_1 (the one that is obviously copper) as the reference metal. Determine the potential of four cells by connecting M_1 to M_2, M_1 to M_3, M_1 to M_4, and M_1 to M_5. This is done by bringing the (+) lead in contact with one metal and the (–) lead in contact with the other. If the voltage displayed in the meter is negative then reverse the leads.

   With a positive voltage displayed, wait about 5 seconds to take a voltage reading, and record the value in Data Table 1. Also record which metal is the (+) terminal and which is (–). Use the same procedure and measure the potential of the other three cells, continuing to use M_1 as the reference electrode.

7. Go to Step 1 of Processing the Data. Use the method described in Step 1 to rank the five metals from the lowest (–) reduction potential to the highest (+) reduction potential. Then *predict* the potentials for the remaining six cell combinations.

8. Using the computer and Voltage Probe, measure the potential of the six remaining half-cell combinations. If the $NaNO_3$ salt bridge solution has dried, you may have to re-moisten it. Record each measured potential in Data Table 3.

9. When you have finished, use forceps to remove each of the pieces of metal from the filter paper. Rinse each piece of metal with tap water. Dry it and return it to the correct container. Remove the filter paper from the glass plate using the forceps, and discard it as directed by

your teacher. Rinse the glass plate with tap water, making sure that your hands do not come in contact with wet spots on the glass.

PROCESSING THE DATA

1. After finishing Step 6 in the procedure, arrange the five metals (including M_1) in Data Table 2 from the lowest reduction potential at the top (most negative) to the highest reduction potential at the bottom (most positive). Metal M_1, the standard reference, will be given an arbitrary value of 0.00 V. If the other metal was correctly connected to the *negative* terminal, it will be placed *above* M_1 in the chart (with a negative $E°$ value). If it was connected to the positive terminal, it will be placed below M_1 in the chart (with a positive $E°$ value). The numerical value of the potential relative to M_1 will simply be the value that you measured on the computer. Record your results in Data Table 2.

   Then calculate the predicted potential of each of the remaining cell combinations shown in Data Table 3, using the reduction potentials you just determined (in Data Table 2). Record the predicted cell potentials in Data Table 3. Return to Step 8 in the procedure and finish the experiment.

2. Calculate the % error for each of the potentials you measured in Step 8 of the procedure. Do this by comparing the measured cell potentials with the predicted cell potentials in Data Table 3.

3. (Optional) You can determine the identity of metals M_2 through M_5 using a reduction potential chart in your textbook. Remember that hydrogen, H_2, has a reduction potential of 0.00 V on this chart. Locate copper, M_1, on the chart, and then determine the likely identity of each of the other metals using your experimental reduction potential sequence in Data Table 2. Note: One of the metals has a 1^+ oxidation state; the remainder of the metals have 2^+ oxidation states.

DATA TABLE 1

Voltaic Cell (metals used)	Measured Potential (V)	Metal Number of (+) Lead	Metal Number of (–) Lead
M_1 / M_2			
M_1 / M_3			
M_1 / M_4			
M_1 / M_5			

DATA TABLE 2

Metal (M_X)	Lowest (–) Reduction Potential, *E*° (V)
	Highest (+) Reduction Potential, *E*° (V)

DATA TABLE 3

	Predicted Potential (V)	Measured Potential (V)	Percent Error (%)
M_2 / M_3			
M_2 / M_4			
M_2 / M_5			
M_3 / M_4			
M_3 / M_5			
M_4 / M_5			