Investigating Electrochemical Cells

Purpose

The purpose of this experiment is to measure the electrochemical potentials between iron and four other metals and use them to construct a table of standard reduction potentials. The table will be used to predict the potentials for cells created by pairing the four metals and the predictions will be tested experimentally.

Introduction

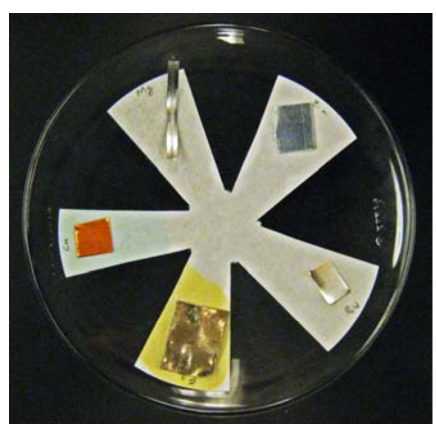
In electrochemistry, a voltaic cell uses the Gibbs free energy of a spontaneous oxidation-reduction reaction to do electrical work. The force that drives electrons from the anode to the cathode of the voltaic cell is the electromotive force or cell potential (E). The potential for an atom or atoms to lose electrons is called its oxidation potential and the potential for an atom or atoms to gain electrons is called its reduction potential. Tables of reduction potentials normally assign the standard hydrogen electrode (SHE) as an electrode with a potential of 0.0V and all other potentials are reported relative to that standard. Using these reduction potentials, one can calculate the cell potential for any combination of oxidation and reduction reaction. The assignment of the hydrogen electrode as the standard, although the choice was made for sound reasons, is somewhat arbitrary.

In this experiment, you will construct a table of reduction potentials using a different standard: the iron electrode. The $Fe|Fe^{3+}$ half-cell will be chosen as the standard and assigned a relative potential of 0.0V. You will measure the potential of four other metals relative to this electrode. If a metal has a reduction potential that is positive relative to the $Fe|Fe^{3+}$ electrode, it will be reduced and it will oxidize the $Fe|Fe^{3+}$ electrode. If a metal has a reduction potential that is negative relative to the $Fe|Fe^{3+}$ electrode, it will be oxidized and it will reduce the $Fe|Fe^{3+}$ electrode. By carefully measuring the voltages between the $Fe|Fe^{3+}$ electrode and four other metal electrodes and determining the direction of electron flow, you will construct a table of reduction potentials with five entries. You will then use these reduction potentials to calculate the cell potentials for different combinations of the four metals and test your prediction by measuring the potentials in the laboratory.

Chemicals and Equipment

Chemicals		**Equipment**
1M $NaNO_3$		Computer with Go-Link and voltage probe
1M Fe^{3+} solution	Fe metal strip	Filter paper, cut into 5 spokes
1M Mg^{2+} solution	Mg metal strip	Watch glass
1M Zn^{2+} solution	Zn metal strip	Sandpaper
1M Ag^{+} solution	Ag metal strip	Forceps
1M Cu^{2+} solution	Cu metal strip	Droppers
		Optional: Plastic mini clamps

Experimental Procedure

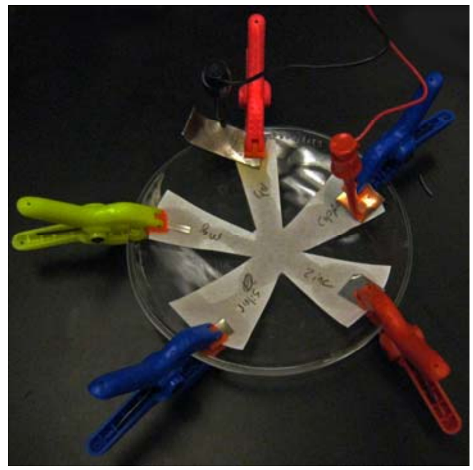


1. A piece of filter paper has been cut for you such that five "spokes" are connected to a common center. Each spoke will hold one metal and a 1M solution of its aqueous ion. Label each of the five spokes for the five metals iron, magnesium, zinc, silver, and copper.

2. Place the filter paper on a watch glass, put a few drops of a 1M solution of each metal ion on its spot at the end of a spoke, and place a piece of the corresponding polished metal on each spot.

3. Make a line with 1M $NaNO_3$ from each metal spot to the center of the paper. You want all spots to be connected by a line of $NaNO_3$ through the center of the filter paper, as diagrammed. You will probably need to re-wet these $NaNO_3$ lines periodically throughout the experiment.

4. Set up a computer with a voltage probe to measure voltages using the voltage. Clear the readings of any stray voltages. When you touch the two ends of the voltage probe together, the voltage reading should be zero. If it is not, reset the voltages to zero.. If the reading still does not reach zero, note the voltage and subtract it from all of the voltage readings that you make with your instrument. **Note:** It may be necessary to use small plastic clamps to make good contact between the metal pieces and the filter paper.



5. Measure the voltage between the iron metal strip and each of the other metal strips (Fe-Ag, Fe-Cu, Fe-Zn, Fe-Mg). If the voltage reading is negative, reverse the leads so that the reading is positive. Wait about 5 second for the voltage reading to stabilize, and then take your voltage reading. Try not to wait too long until you make your reading as the voltages will drop somewhat with time. Record your voltages. *Carefully note which metal was in contact with the black lead of the LabPro and which was in contact with the red lead. This is important!*

6. Make sure that the $NaNO_3$ lines on your filter paper are still wet. If they have dried, re-wet them with 1M $NaNO_3$.

7. Measure the potential between each metal and the other metals on the filter paper (Ag-Cu, Ag-Zn, Ag-Mg, Cu-Zn, Cu-Mg, Zn-Mg). Again, *note which metal was in contact with the black lead of the LabPro and which was in contact with the red lead*. This is how you will determine which metal is being oxidized and which is being reduced.

Data Analysis

1. Construct a table of reduction potentials with the $Fe|Fe^{3+}$ electrode as the standard as shown below. **When your voltage reading is positive, the metal touching the *red* probe lead is the *cathode* and it is being reduced and the metal touching the *black* probe lead is the *anode* and it is being oxidized.** The metal that is being reduced should be placed higher on the table since it has a higher oxidation potential. The reduction potential for the metal that is being reduced is higher (more positive) than the metal that is being oxidized. When you are finished, the metal with the highest reduction potential relative to the standard iron electrode will be on the top of the table and the metal with the lowest reduction potential will be on the bottom.

Reduction reaction	Reduction potential
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	0.0V

2. Using ***your*** table of standard reduction potentials relative to the iron electrode (the table in the textbook will NOT WORK! It is based on the SHE as the standard electrode!), calculate the potential between each metal and each other metal (Ag-Cu, Ag-Zn, Ag-Mg, Cu-Zn, Cu-Mg, Zn-Mg). To do this, subtract the reduction potential of the anode from that of the cathode.

3. Compare these values to the potentials that you measured in your experiment. Calculate the percent error in your measurements. Try to account for any error that you observe.

4. Calculate the standard Gibbs free energy of each cell. Which of your cells is able to do the most electrical work?

5. Calculate the equilibrium constant for each cell. What do the magnitudes of the equilibrium constants tell you about these electrochemical reactions?