DATE: NAME: CLASS:

CHAPTER 13

HANDOUT

BLM 13.1.4

Investigation 13.A: Measuring Cell Potentials of Voltaic Cells

In this investigation, you will build some voltaic cells and measure their cell potentials

Question

What factors affect the cell potential of a voltaic cell?

Prediction

Predict the values of the cell potentials for the cells that you build. Give reasons for your predictions. For those measured cell potentials that are not approximately the same as your predictions, do you think the values will be larger or smaller than your predicted values? Explain your reasoning.

Safety Precautions

- Handle the nitric acid solution with care.
- Immediately wash any spills on your skin of the nitric acid, nickel(II) nitrate, or any other solutions with copious amounts of water. Inform your teacher.
- Wash your hands when you have completed the investigation.

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Materials

- 1 Styrofoam™ or clear plastic egg carton with 12 wells
- 5 mL of 0.1 mol/L solutions of each of the following:
  – $Mg(NO_3)_2(aq)$
  – $Cu(NO_3)_2(aq)$
  – $Al(NO_3)_3(aq)$
  – $Ni(NO_3)_2(aq)$
  – $Zn(NO_3)_2(aq)$
  – $SnSO_4(aq)$
  – $Fe(NO_3)_3(aq)$
  – $AgNO_3(aq)$
  – $HNO_3(aq)$
- 5 mL of saturated NaCl(aq) solution
- 5 cm strip of Mg ribbon
- 1 cm × 5 cm strips of each of the following: Cu(s), Al(s), Ni(s), Zn(s), Sn(s), Fe(s), and Ag(s)
- 15 mL of 1.0 mol/L KNO_3
- 5 cm of thick graphite pencil lead or a graphite rod
- sandpaper
- 25 cm clear aquarium rubber tubing (Tygon®; internal diameter: 4–6 mm)
- cotton batting
- disposable pipette
- black and red electrical leads with alligator clips
- voltmeter set to a scale of 0 V to 20 V
- paper towel
- marker

Procedure

1. Use tape or a permanent marker to label the outside of nine wells of your egg carton with the nine different half-cells. Each well should correspond to one of the eight different metal|metal ion pairs:
   $Mg(s)|Mg^{2+}(aq)$, $Cu(s)|Cu^{2+}(aq)$, $Al(s)|Al^{3+}(aq)$, $Ni(s)|Ni^{2+}(aq)$, $Zn(s)|Zn^{2+}(aq)$, $Sn(s)|Sn^{2+}(aq)$, $Fe(s)|Fe^{3+}(aq)$, and $Ag(s)|Ag^{+}(aq)$. Label the ninth well $H^{+}(aq)|H_2(g)$.

2. Label the nine columns in the following chart to match the nine half-cells. Label the nine rows in the same way. You will use this chart to record the cell potentials you obtain when you connect two half-cells to build a voltaic cell. You will also identify which half-cell contains the anode and which half-cell contains the cathode for each voltaic cell you build. (You may not need to fill out the entire chart.)

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3. Sand each of the metals to remove any oxides.

4. Pour 5 mL of each metal salt solution into the appropriate well of the egg carton. Pour 5 mL of the nitric acid into the well labelled $H^+|H_2$.

5. Prepare your salt bridge as follows:
(a) Roll a small piece of cotton batting so that it forms a plug about the size of a grain of rice. Place the plug in one end of your aquarium tubing, but leave a small amount of the cotton hanging out, so you can remove the plug later.
(b) Fill a disposable pipette as full as possible with the 1 mol/L $KNO_3(aq)$ electrolyte solution. Fit the tip of the pipette firmly into the open end of the tubing. Slowly inject the electrolyte solution into the tubing. Fill the tubing completely, so that the cotton on the other end becomes wet.
(c) With the tubing completely full, insert another cotton plug into the other end. There should be no air bubbles. (You will have to repeat this step from the beginning if you have air bubbles.)

6. Insert each metal strip into the corresponding well. Place the graphite rod in the well with the nitric acid. The metal strips and the graphite rod are your electrodes. (**Note:** The graphite electrode is very fragile. Be gentle when using it.)

7. Attach the alligator clip on the red lead to the red probe of the voltmeter. Attach the black lead to the black probe.

8. Choose two wells to test. Insert one end of the salt bridge into the solution in the first well. Insert the other end of the salt bridge into the solution in the second well. Attach a free alligator clip to the electrode in each well. You have built a voltaic cell.

9. If you get a negative reading, switch the alligator clips. Once you obtain a positive value, record it in your chart. The black lead should be attached to the anode (electrons flowing into the voltmeter). Record which metal is acting as the anode and which is acting as the cathode in this voltaic cell.

10. Remove the salt bridge and wipe any excess salt solution off the outside of the tubing. Remove the alligator clips from the electrodes.

11. Repeat Procedure Steps 8 to 10 for all other combinations of electrodes. Record your results.

12. Re-attach the leads to the silver and magnesium electrodes, and insert your salt bridge back into the two appropriate wells. While observing the reading on the voltmeter, slowly add 5 mL of saturated $NaCl(aq)$ solution to the $Ag(s)|Ag^+(aq)$ well to precipitate $AgCl(s)$. Record any changes in the voltmeter reading. Observe the $Ag(s)|Ag^+(aq)$ well.

13. Rinse off the metals and the graphite rod with water. Dispose of the salt solutions into the heavy metal salts container your teacher has set aside. Rinse out your egg carton. Remove and discard

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the plugs of the salt bridge, and dispose of the KNO_3(aq) solution in the heavy metal salts container because it is contaminated with heavy metals. Return all materials to their appropriate locations.

Analysis

1. For each cell in which you measured a cell potential, identify:

(a) the anode and the cathode

(b) the positive and negative electrodes

2. For each cell in which you measured a cell potential, write a balanced equation for the reduction half-reaction, the oxidation half-reaction, and the overall cell reaction.

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3. For any one cell in which you measured a cell potential, describe:
(a) the direction in which electrons flow through the external circuit

(b) the movements of ions in the cell

4. Use your observations to decide which of the metals used as electrodes is the most effective reducing agent. Explain your reasoning.

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5. List all the reduction half-reactions you wrote in Question 2 so that the metallic elements in the half-reactions appear in order of their strength as reducing agents. Put the least effective reducing agent at the top of the list and the most effective reducing agent at the bottom.

6. In which part of your list from Question 5 are the metal ions that are the best oxidizing agents? Explain.

7. How well did your observed cell potentials fit your predicted cell potentials?

8. Were your measured values of cell potentials larger or smaller than your predictions? Does this observation fit with your predictions?

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9. List some possible factors that might have caused your measured values to differ from your predicted values for cell potentials.

10. (a) When saturated sodium chloride solution was added to the silver nitrate solution (in Procedure Step 12), what reaction took place? Explain.

(b) Does the concentration of an electrolyte affect the cell potential of a voltaic cell? How do you know?

(c) How do your observations about concentration help you to explain your answers to Questions 8 and 9?

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Conclusion

11. Identify factors that affect the cell potential of a voltaic cell.

12. Explain the difference between “cell potential” and “standard cell potential.”

Application

13. Predict any factors, other than those you were able to observe, that you think might affect the cell potential of a voltaic cell. Describe an investigation you could use to test your prediction.