Electrochemical Cells: Lab

Introduction

An electrochemical cell is constructed from two half-cells. One half-cell contains both the oxidized and the reduced form of the oxidizing agent. The other half-cell contains the corresponding forms of the reducing agent. The half-cells are connected by the means of a salt bridge or a porous container filled with a non-reactive salt solution through which ions can migrate. A salt bridge may also be prepared by soaking a filter paper in saturated solution of an electrolyte such as $KNO_{3(aq).}$

A wire completes the external circuit through which electron transfer takes place. The flow of electrons from the anode to the cathode may be detected with an instrument called a galvanometer (sensitive ammeter), but we shall use voltmeter to measure potential difference between the electrodes.

The cell voltage (emf or E° value if 1.0 mol dm^{-3} solutions are used) is a quantitative measure of the spontaneity of the electrochemical cell. In this experiment, you will construct such cells to determine their emf's. When you measure the potential difference between the electrodes of each cell, the polarity of each electrode is indicted by the positive sign and the negative sign on the voltmeter (or red and black terminals respectively). Thus, you can determine at which electrode electrons are needed and at which electrode electrons are produced. From this, you can work out the direction in which the overall reaction proceeds.

The two solutions in the electrochemical cell maintain their electric neutrality when cations from the salt bridge migrate into the cathode compartment, and the anions migrate into the anode compartment.

Reactions of voltaic cells are spontaneous and exergonic. They take place with the *release* of energy. This energy can be put to use if the cell is set up correctly.

Objectives

1. To construct and measure the voltage of several electrochemical cells.
2. To compare the measured emf's of electrochemical cells to predicted values calculated from a half reactions table.
3. To investigate the effect of changes in ionic concentration on the emf of a cell.

Safety

$CuSO_4$(aq) is harmful.
Concentrated NH_3 is very irritating to the eyes, avoid inhaling the vapour.
Lead compounds are poisonous.

Apparatus and Materials

0.1mol dm^{-3} $Cu(NO_3)_2$, 0.1 mol dm^{-3} $Zn(NO_3)_2$, 0.1 mol dm^{-3} $Pb(NO_3)_{2,}$
0.1 mol dm^{-3} Mg $(NO_3)_2$, strips of Cu, Zn, Pb and Mg, 3 M (saturated) $KNO_{3\ (aq)}$, 0-5 DC resistance voltmeter, alligator clamps, cotton wool, glass tubing, filter paper strips, glass u-tube, porous pot, emery paper, 4 beakers-50 cm^3

Procedure

PART I: Electrochemical Cells

1. Clean each metal strip using a separate piece of emery paper, to avoid cross-contamination of the metal strips.

2. Place each metal strip in separate beaker. Hold each strip vertically against the inside of the beaker so that about 2 cm projects above the rim. Fold the projection down over the rim of the beaker and clamp it in position with a crocodile clip.

3. Pour about 20 cm^3 of the appropriate salt solution into each beaker so that each metal strip dips into a solution of its own ions. Make sure the crocodile clips keep dry.

4. Prepare a salt bridge by soaking a strip of filter paper in saturated $KNO_{3(aq)}$. Let the surplus solution drain off by hanging the strip over another beaker.

5. Connect the metal electrodes to a high resistance voltmeter, and complete the circuit with a salt bridge.

6. If the reading on the voltmeter is negative, reverse the connections to obtain a positive reading. Record the potential difference reading in the Data Table I, given below.

7. Remove the salt bridge as soon as possible and throw it away. Disconnect the voltmeter.

8. Repeat steps 4 to 7 for the other two cells.

PART II: Concentration Effect on Cell Voltage

1. Set up the beaker with the $Zn \mid Zn^{+2}$ half cell as shown in Diagram I below. The cell you are studying is:

$$Zn_{(s)} \mid Zn+^{2}_{(aq)} \parallel Cu^{+2}_{(aq)} \mid Cu_{(s)} .$$

2. Add concentration $NH_{3(aq)}$ solution to the $Zn(NO_3)_{2(aq)}$ until no more voltage change is observed. Record the voltage in Data Table II.

3. Clean the beaker and replace the $Zn \mid Zn^{+2}$ with $Pb \mid Pb^{+2}$ half cell. The cell you are studying is:

$$Pb_{(s)} \mid Pb^{+2}_{(aq)} \parallel Cu^{+2}_{(aq)} \mid Cu_{(s)}$$

4. Add 10 cm^3 of sodium sulphide solution and record the voltage in Data Table II. Dispose of the lead residue in the disposal container in the fume hood.

Data Table I: Electrochemical Cells

Cell	Experimental voltage, (V)	Anode (-)	Cathode (+)	Theoretical Voltage, E° (V)
copper - zinc				
lead - copper				
magnesium - copper				
zinc - lead				

Data Table II: Effect of Concentration Changes on Voltage of the Cell

Voltage for $Zn_{(s)} \mid Zn^{+2}_{(aq)} \parallel Cu^{+2}_{(aq)} \mid Cu_{(s)}$ = V

Voltage for $Pb_{(s)} \mid Pb^{+2}_{(aq)} \parallel Cu^{+2}_{(aq)} \mid Cu_{(s)}$ = V

Temperature = °C
Atmospheric Pressure = kPa

Discussion Questions

1.Voltages listed for voltaic cells are given in terms of standard cell potential, write the equation which refers to the standard reference electrode.

2. Calculate the theoretical standard state cell voltages for each cell constructed in this experiment.

3. Write the balanced equations for the spontaneous cell reactions.

4. Arrange the observed emf's obtained in this experiments, from the highest to lowest.

5. Compare the experimental emf values to your theoretical ones and calculate the percentage error for each.

6. Explain the changes in the emf's observed in Part II. Include equations for any reactions that occur.

7. What would the effect be on the cell voltage if the concentrations of the electrochemical cells used in this experiment were 0.5 mol dm^{-3} instead of 1.0 mol dm^{-3}?

8. Predict the E° value of an electrochemical cell constructed from the combination of a lead and a silver half cell.