Lab: Four-Way Galvanic Cell

FOR THE TEACHER

Summary
In this lab, students will build a simple galvanic cell to measure cell potential and will compare their data to theoretical calculations. Students will become more familiar with cells during this opportunity to investigate and compare numerous electrochemistry reactions.

Grade Level
High School

AP Chemistry Curriculum Framework
This lab activity supports the following units, topics, and learning objectives:

- **Unit 4: Chemical Reactions**
  - **Topic 4.2:** Net Ionic Equations
    - **TRA-1.B:** Represent changes in matter with a balanced chemical or net ionic equation: a. For physical changes. b. For given information about the identity of the reactants and/or product. c. For ions in a given chemical reaction.
  - **Topic 4.7:** Types of Reactions
    - **TRA-2.A:** Identify a reaction as acid-base, oxidation-reduction, or precipitation.
  - **Topic 4.9:** Oxidation-Reduction (Redox) Reactions
    - **TRA-2.C:** Represent a balanced redox reaction equation using half-reactions.
- **Unit 9: Applications of Thermodynamics**
  - **Topic 9.7:** Galvanic (Voltaic) and Electrolytic Cells
    - **ENE-6.A:** Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.
  - **Topic 9.9:** Cell Potential Under Nonstandard Conditions (Extension activity only)
    - **ENE-6.C:** Explain the relationship between deviations from standard cell conditions and changes in the cell potential.

Objectives
By the end of this lab, students should be able to

- Understand reduction and oxidation half reactions that take place in electrochemistry.
- Learn that voltage is the “potential difference” between two reactions.
- Understand that two chemical reactions take place in order to give a voltage.
- Interpret the activity series in terms of elements that are more or less easily oxidized.
- Build simple galvanic cells and measure cell potential.

Chemistry Topics
This lab supports students’ understanding of

- Electrochemistry
- Galvanic cells
- Half-reactions
- Reduction
- Oxidation
- Anode
- Cathode
Time
Teacher Preparation: 20 minutes
Lesson: 75 minutes

Materials
- Copper, magnesium, lead, and zinc metal strips
- 1 L of each solution:
  - 1 M solution of copper nitrate
  - 1 M solution of magnesium nitrate
  - 1 M solution of lead nitrate
  - 1 M solution of zinc nitrate
  - 1 M solution of potassium nitrate
- Voltmeter for each group
- Pipettes
- Wax paper

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.

Teacher Notes
- Students should be familiar with drawing electrochemical cells, predicting voltage, and direction of electron flow. Students will need to understand this information for the start of their laboratory experience. An example is shown.
- The six cells students will investigate in this lab are: Cu/Zn, Cu/Mg, Cu/Pb, Zn/Mg, Zn/Pb, and Mg/Pb. Students will determine the cathode, anode, electrical potential, theoretical voltage, and write the balanced redox reaction in the pre-lab section.
- Students are highly encouraged to work together and follow the directions of the laboratory experience. I do not model the lab beforehand, as I expect students to work together in a small group.
- Students will be required to access information from the internet throughout the lab.
- In my class this lab is done through Google Classroom/Drive which results in one document submitted with all participant names.
• **Extensions ideas:**
  o Students could repeat the Lab Experience with different concentrations of solutions. Two petals could be the same metal/solution, but one solution could be 1.0 M and the other 0.5 M. Students could compare the effect of concentration on electron flow.
  o Students could explore further by creating fruit batteries, potato batteries, and juice/coke batteries. This could be left open-ended to allow students to pursue what interests them the most.
  o Students could further research the development of the battery, and learn more about the type of battery used in their cell phone.

**FOR THE STUDENT**

**Lesson**

**Four-Way Galvanic Cell**

**Background**
Everything on earth stores and uses energy to stay alive. The sun produces all the energy used in our lives; however, we also produce and store energy which is described as electrochemistry. Through the understanding of electrochemistry, chemical reactions can make batteries which are important to us. Can you imagine not having the clock on the wall, a flashlight, a cell phone, or a car?

Batteries store chemical energy and convert it to electrical energy by connecting the positive (cathode) and the negative (anode) terminals. When the terminals are connected, electricity is produced from the flow of electrons due to the chemical reaction taking place inside the battery.

**Materials**
- Copper, magnesium, lead, and zinc metal strips
- 1 M solution of copper nitrate
- 1 M solution of magnesium nitrate
- 1 M solution of lead nitrate
- 1 M solution of zinc nitrate
- 1 M solution of potassium nitrate
- Voltmeter
- Pipets
- Wax paper

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.

**Prelab Questions**
You have been learning about electrode potentials and electrochemical cells. Determine the theoretical electrode potential for cells containing combinations of: Mg, Zn, Cu, and Pb using the standard information provided in the table below. Show your work as required, including the half-reactions that yield a final positive voltage for the final net ionic equation.
### Standard Reduction Potential Half-Reactions

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$</td>
<td>0.34V</td>
</tr>
<tr>
<td>$\text{Mg}^{2+} + 2e^- \rightarrow \text{Mg}$</td>
<td>-2.38V</td>
</tr>
<tr>
<td>$\text{Pb}^{2+} + 2e^- \rightarrow \text{Pb}$</td>
<td>-0.13V</td>
</tr>
<tr>
<td>$\text{Zn}^{2+} + 2e^- \rightarrow \text{Zn}$</td>
<td>0.76V</td>
</tr>
</tbody>
</table>

1. Show all of your work in the table below:

<table>
<thead>
<tr>
<th>Cell</th>
<th>Half Reactions and Final Net Ionic Equation Yielding Positive Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu and Zn</td>
<td></td>
</tr>
<tr>
<td>Cu and Mg</td>
<td></td>
</tr>
<tr>
<td>Cu and Pb</td>
<td></td>
</tr>
<tr>
<td>Zn and Mg</td>
<td></td>
</tr>
<tr>
<td>Zn and Pb</td>
<td></td>
</tr>
<tr>
<td>Mg and Pb</td>
<td></td>
</tr>
</tbody>
</table>

2. Based on your answers calculated in the table above, summarize your answers in the table below:

<table>
<thead>
<tr>
<th>Summary Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Cu and Zn</td>
</tr>
<tr>
<td>Cu and Mg</td>
</tr>
<tr>
<td>Cu and Pb</td>
</tr>
<tr>
<td>Zn and Mg</td>
</tr>
<tr>
<td>Zn and Pb</td>
</tr>
<tr>
<td>Mg and Pb</td>
</tr>
</tbody>
</table>

3. Research the term *Galvanic Cell* and provide a brief explanation:
4. Who invented the first battery?

**Procedure**

*Construct a 4-Way Galvanic Cell*

1. Construct a 4-way galvanic cell from filter paper as shown below:

2. Label one section Mg, another Cu, another Pb, and the last Zn.
3. Make two cuts across the top of each petal to hold the metals as shown below:

4. Place the cell on a piece of wax paper.
5. Using a pipette, add 5-10 drops of KNO₃ to the center of the filter paper to act as the salt bridge for the redox reactions.
6. Next, add 5 drops of copper sulfate solution to the filter paper holding the copper electrode; 5 drops of lead nitrate solution to the filter paper holding the lead electrode; 5 drops of zinc nitrate to the filter paper holding the zinc electrode; and 5 drops of magnesium nitrate to the filter paper holding the magnesium electrode.
7. Refer to your pre-lab summary data table where you have already identified the possible cathode and anodes. Transfer your calculated values to the data table below. You will use the voltmeter to compare the experimental values with your calculated values.

8. Turn your voltmeter on by turning the dial three places to the left so it is pointing at 20 DCV. The screen should read 0.00.

9. Test the first cell of Cu and Zn. You will notice one of the probes is red and the other black. Place one of the probes on the copper metal and the other probe on the zinc metal.

Investigate:
1. Does the voltmeter report a positive or negative value?

2. What happens to the voltmeter reading when the probes are switched?

3. If the voltmeter reports a negative value, the probes need to be switched. Why?

4. Does the red probe identify a cathode or anode?

5. Does the black probe identify a cathode or anode?

6. Does the cathode determine where reduction or oxidation takes place?

7. Does the anode determine where reduction or oxidation takes place?

8. Which direction are the electrons flowing? Cathode to anode or anode to cathode?

10. Record the correct voltmeter reading in the data table for the Cu and Zn combination.

11. Continue to collect the voltage readings with the five remaining cells.

12. Rinse your metals with water, dry the metals, and throw away the filter paper galvanic cell.
Data

<table>
<thead>
<tr>
<th>Cell</th>
<th>Electrode Potential Calculated (Found in Table 1)</th>
<th>Electrode Potential Indicated by Voltmeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu and Zn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu and Mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu and Pb</td>
<td></td>
<td></td>
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<tr>
<td>Zn and Mg</td>
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<td>Zn and Pb</td>
<td></td>
<td></td>
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<tr>
<td>Mg and Pb</td>
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</tr>
</tbody>
</table>

Analysis

1. Did your calculated values match the voltmeter readings? Explain your thoughts on this.

2. Which combination produced the most volts according to the voltmeter?

3. Does the combination identified in #2 produce the most volts according to your calculations?

4. What are some sources of error in this experiment? Be sure to justify why these factors would cause an error.