Answer Key: Galvanic Cell Exploration

Pre-Activity Warm-up Questions  
(Answers also in notes section of PowerPoint)
Cd → Cd^{+2} + 2 e⁻ (oxidation)
Ni^{+2} + 2 e⁻ → Ni    (reduction)
Oxidizing agent (species that gets reduced) : Ni^{+2}
Reducing agent (species that gets oxidized): Cd

Activity 1  
Metal Reactivity Lab: Expected Results

<table>
<thead>
<tr>
<th>Metal Reactivity</th>
<th>Ag (s)</th>
<th>Zn (s)</th>
<th>Cu (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag⁺ (aq)</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Zn^{+2} (aq)</td>
<td>No Reaction</td>
<td></td>
<td>No Reaction</td>
</tr>
<tr>
<td>Cu^{+2} (aq)</td>
<td>No Reaction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
1. Based on your observations, rank the three metals in order of reactivity from most easily oxidized to least easily oxidized. Ease of oxidation  Ag<Cu<Zn
2. Based on your results, rank the three metal cations in order of ease of reduction from most easily reduced to least easily reduced.
Ease of reduction:  Ag⁺>Cu^{+2}> Zn^{+2}
3. After each group has completed the activity, we will discuss how we can predict ease of oxidation/reduction for a particular metal. You can predict how easily a metal will be reduced/oxidized based on the standard reduction potentials. The more positive the reduction potential for the cation, the more easily it is reduced to the neutral metal form. The more less positive the reduction potential for the cation, the more easily the neutral metal form is oxidized to the cation.
Activity 2
Galvanic Cell Simulation Activity: Expected Results

Galvanic Cell Predictions

<table>
<thead>
<tr>
<th>Cell combination</th>
<th>Anode</th>
<th>Cathode</th>
<th>Direction of electron flow</th>
<th>Direction of salt bridge cation flow</th>
<th>Direction of salt bridge anion flow</th>
<th>Cell potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag/Ag⁺ (aq) with Zn/Zn²⁺ (aq)</td>
<td>Zn/Zn²⁺ (aq)</td>
<td>Ag/Ag⁺ (aq)</td>
<td>To the left (towards Ag/Ag⁺)</td>
<td>To the left (towards Ag/Ag⁺)</td>
<td>To the right (towards Zn/Zn²⁺)</td>
<td>1.56</td>
</tr>
<tr>
<td>Ag/Ag⁺ (aq) with Cu/Cu²⁺ (aq)</td>
<td>Cu/Cu²⁺ (aq)</td>
<td>Ag/Ag⁺ (aq)</td>
<td>To the left (towards Ag/Ag⁺)</td>
<td>To the left (towards Ag/Ag⁺)</td>
<td>To the right (towards Cu/Cu²⁺)</td>
<td>0.46</td>
</tr>
<tr>
<td>Cu/Cu²⁺ (aq) with Zn/Zn²⁺ (aq)</td>
<td>Zn/Zn²⁺ (aq)</td>
<td>Cu/Cu²⁺ (aq)</td>
<td>To the left (towards Cu/Cu²⁺)</td>
<td>To the left (towards Cu/Cu²⁺)</td>
<td>To the right (towards Zn/Zn²⁺)</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Analysis
Complete the following for each cell you examined

1. Write the overall balanced net equation for the redox reaction
   - Zn (s) + 2 Ag⁺ (aq) → 2 Ag (s) + Zn²⁺ (aq)
   - Cu (s) + 2 Ag⁺ (aq) → 2 Ag (s) + Cu²⁺ (aq)
   - Zn (s) + Cu⁺² (aq) → Cu (s) + Zn²⁺ (aq)

2. Write the cell line notation for the cell
   - Zn(s)|Zn²⁺(aq)||Ag⁺ (aq)||Ag(s)
   - Cu(s)|Cu²⁺(aq)||Ag⁺ (aq)||Ag(s)
   - Zn(s)|Zn²⁺(aq)||Cu⁺² (aq)||Cu(s)

3. A student was going to build the silver and zinc cell that you investigated above, but had silver acetate not silver nitrate. Would this change affect the cell potential? Explain your response.
   No, it would not have an impact since the nitrate or acetate is only a spectator ion. Since the molar ratio between the silver and the spectator ion are the same in both cases, both a 1 M solution of aqueous silver nitrate and a 1M solution of aqueous silver acetate contain the same concentration of Ag⁺ ions (1M)

After each group has completed the simulation, we will discuss how to represent galvanic cells using equations and diagrams.
Application Questions: Sample Responses

Tasks:
1. Sketch a galvanic cell made by the following:
   Ni (s) electrode in 1.0 M Ni^{2+} (aq)
   Ag (s) electrode in 1.0 M Ag^{+} (aq)
   
   NOTE: Your sketch should include the following pieces of information
   a. Cell potential  0.28 + 0.80 = 1.08 V
   b. Direction of electron flow see below
   c. Anode and cathode labels see below
   d. Direction of salt bridge anion flow see below
   e. Direction of salt bridge cation flow see below

   Image adapted from: https://upload.wikimedia.org/wikipedia/commons/6/63/CNX_Chem_17_02_Galvanicel.png

2. Write the balanced reaction for this cell (assume it is in a neutral solution)
   \[ \text{Ni} (s) + 2\text{Ag}^+ (aq) \rightarrow \text{Ni}^{2+} (aq) + 2 \text{Ag} (s) \]

3. Write the cell line notation for this cell
   \[ \text{Ni(s)}|\text{Ni}^{2+}(aq)||\text{Ag}^+ (aq)|\text{Ag(s)} \]

4. Predict the weight (lighter, heavier, or the same) of the Ni (s) and Ag(s) metal strips after the cell has been running for a period of time.
   Ni would become lighter and Ag would become heavier

5. Explain your thinking for each one. If it is heavier, what has been added? From where? By what process? If it is lighter, what has been removed? By what process?
   Ni would become lighter as some of the neutral atoms on the strip are oxidized to Ni^{2+} and enter the solution.
   Ag would become heavier as some of the cation atoms in the solution are reduced to Ag and are added to the strip.
6. Predict the concentration (higher, lower or the same) of the Ni\(^{+2}\) (aq) and Ag\(^+\) (aq) solutions after the cell has been running for a period of time. Ni\(^{+2}\) solution would become more concentrated and Ag\(^+\) solution would become less concentrated.

7. Explain your thinking for each one. If it is more concentrated, how did this happen? If it is more dilute, how did this happen?

Ni\(^{+2}\) solution would become more concentrated as some of the neutral atoms on the strip are oxidized to Ni\(^{+2}\) and enter the solution. Ag\(^+\) would become less concentrated as some of the cation atoms in the solution are reduced to Ag and are added to the strip, leaving the solution.