Wastewater Recovery: Lab Simulation

**Background**
This experiment will focus on single replacement reactions. In a single replacement reaction, one element replaces another in a compound.

When writing equations or predicting products for these reactions, it must be remembered that not all equations proceed as written. For example, in the reaction between copper and silver ions: \( Cu + AgNO_3 \rightarrow Ag + Cu(NO_3)_2 \), the reaction proceeds as written. The reverse reaction, \( Ag + Cu(NO_3)_2 \rightarrow Cu + AgNO_3 \), however, does not occur spontaneously.

Not all elements are equal in their ability to replace other elements. In order to predict products of single replacement reactions or to predict if they will occur at all, a method is needed. An activity series allows one to make such predictions. After observing or carrying out a series of reactions, you will construct an activity series for some elements.

The following simulation (by Tom Greenbowe) allows you to test several metals with different aqueous solutions. You will choose a single metal to place in the solutions and observe in which solutions a reaction occurs. If the single metal is stronger than the metal in the compound in solution, the metal in the compound will be displaced and the metal strip of the single metal that you insert will become coated with the displaced metal.

The metals used in the simulations have the following colors:

<table>
<thead>
<tr>
<th>Activity 1</th>
<th>Activity 2</th>
<th>Activity 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg = light gray</td>
<td>Iron = light gray</td>
<td>Iron = light gray</td>
</tr>
<tr>
<td>Copper = copper</td>
<td>Copper = copper</td>
<td>Lead = dark gray</td>
</tr>
<tr>
<td>Zinc = dark gray</td>
<td>Zinc = dark gray</td>
<td>Nickel = light gray</td>
</tr>
<tr>
<td>Silver = silver</td>
<td>Lead = dark gray</td>
<td>Tin = light gray</td>
</tr>
</tbody>
</table>

Now, go to the simulation website and follow the instructions given below: [http://intro.chem.okstate.edu/1515F01/Laboratory/ActivityofMetals/home.html](http://intro.chem.okstate.edu/1515F01/Laboratory/ActivityofMetals/home.html)

**Activity 1**
- Click START.
- You will get a dialogue box that tells you NOT to hit the back button. Say OK.
- Click on Activity 1
- You will be given a series of solutions containing different compounds. Note that they are all nitrates. What is different about them is the metal. \( Mg(NO_3)_2 \), \( Zn(NO_3)_2 \), \( Cu(NO_3)_2 \), \( AgNO_3 \).
- You will also be given a list of the same single metals from which to choose. \( Mg \), \( Zn \), \( Cu \), \( Ag \)
- Choose Mg and click the left hand blue box to insert magnesium strips down into each solution. Note that the magnesium is light gray in color.
• It will take a minute for the reaction to occur, if one is going to occur. When the reactions are complete, you will get a red message telling you to remove them metal strips. Click on the lower left hand box to remove the strips.
• Observe each metal strip. If the metal was reactive enough to replace the metal in the solution, the strip is coated with the metal that was in solution. If it was NOT reactive enough, no reaction occurred.
• Fill in your results for Mg in Data Table 1. If no reaction occurs, put NR in the box. If a reaction DOES occur, put YES in the box.
• Repeat the steps above for Cu, Zn, and Ag and fill in Data Table 1.

Data Table 1: Activity 1

<table>
<thead>
<tr>
<th></th>
<th>Mg(NO₃)₂</th>
<th>Zn(NO₃)₂</th>
<th>Cu(NO₃)₂</th>
<th>AgNO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Click on the “Molecular Scale Reactions” box. Read the directions and complete. Below draw your observations in a step by step format.

Questions
1. Which metals can Mg replace?
2. Which metals can Cu replace?
3. Which metals can Zn replace?
4. Which metals can Ag replace?
5. Which metal is the most reactive in this series of metals?
6. Which metal is the least reactive in this series of metals?
7. Which metal is most reactive because it can replace more metals, Cu or Zn?
8. Fill in the Activity Series box to the right for Activity 1 metals. The most reactive metal goes on the top and the least reactive metal goes on the bottom.
Activity 2
- Now click on **Activity 2**. Notice that some of the solutions have changed and some of the single metals have changed.
- Follow the same procedure as with Activity 1. Test each single metal in each solution.
- Fill in Data Table 2. If no reaction takes place, put NR in the box. If a reaction does take place, put YES in the box.

Data Table 2: Activity 2

<table>
<thead>
<tr>
<th></th>
<th>Fe(NO₃)₂</th>
<th>Pb(NO₃)₂</th>
<th>Ni(NO₃)₂</th>
<th>Sn(NO₃)₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Click on the “Molecular Scale Reactions” box. Read the directions and complete. Below draw your observations in a step by step format.

Questions
9. Which metals can Fe replace?
10. Which metals can Pb replace?
11. Which metals can Ni replace?
12. Which metals can Sn replace?
13. Which metal is the most reactive in this series of metals?
14. Which metal is the least reactive in this series of metals?
15. Which metal is most reactive because it can replace more metals, Ni or Sn?
16. Fill in the Activity Series box to the right for Activity 2 metals. The most reactive metal goes on the top and the least reactive metal goes on the bottom.
Activity 3
- Now click on Activity 3. Notice that some of the solutions have changed and some of the single metals have changed.
- Follow the same procedure as with Activity 1. Test each single metal in each solution.
- Fill in Data Table 3. If no reaction takes place, but NR in the box. If a reaction does take place, put YES in the box.

Data Table 3: Activity 3

<table>
<thead>
<tr>
<th></th>
<th>Fe(NO₃)₂</th>
<th>Zn(NO₃)₂</th>
<th>Cu(NO₃)₂</th>
<th>Pb(NO₃)₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Click on the “Molecular Scale Reactions” box. Read the directions and complete. Below draw your observations in a step by step format.

Questions
17. Which metals can Fe replace?
18. Which metals can Cu replace?
19. Which metals can Zn replace?
20. Which metals can Pb replace?
21. Which metal is the most reactive in this series of metals?
22. Which metal is the least reactive in this series of metals?
23. Which metal is most reactive because it can replace more metals, Fe or Pb?
24. Fill in the Activity Series box to the right for Activity 3 metals. The most reactive metal goes on the top and the least reactive metal goes on the bottom.
Creating a Larger Activity Series
The Activity Series Boxes for activities 1 – 3 are placed side by side below. **Re-list** each activity series in each box. *Then, combine the lists, placing all of the elements in one large activity series list in the last box.*

<table>
<thead>
<tr>
<th>Activity Series #1</th>
<th>Activity Series #2</th>
<th>Activity Series #3</th>
<th>Total Activity Series</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Questions**

25. Which metal is the **MOST** reactive?

26. From the lab, what evidence do you have that it is most reactive?

27. Which metal is the **LEAST** reactive?

28. From the lab, what evidence do you have that it is the least reactive?