Name _____ Date _____ Class _____

LAB 9.1 LABORATORY MANUAL

Single-Replacement Reactions

Use with Section 9.2

A single-replacement chemical reaction is one in which one substance from a compound is replaced by another substance. A generic equation for such a reaction is as follows.

$$A + BC \longrightarrow AC + B$$

The reactivity of a substance depends on its ability to gain or lose electrons. It is possible to arrange the elements into a series based upon their reactivity. Such a list is called an activity series.

While there are many types of replacement reactions, we will concern ourselves with two different kinds. In one type, a more active metal replaces a less active metal from solution. Consider the reaction between zinc and copper(II) sulfate.

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

In this reaction, the more active zinc replaces the less active copper from solution. The reaction is evident because the blue color of the copper sulfate solution slowly turns colorless and a deposit of copper can be seen to form on the strip of zinc.

A second type of replacement reaction involves the replacement of hydrogen from acid by a metal. Consider the reaction between zinc and hydrochloric acid.

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

The zinc metal is active enough to replace the hydrogen from the acid. Bubbles of hydrogen gas can be seen rising to the surface, and the piece of zinc is consumed. On the other hand, if the less active metal, copper, is placed into a hydrochloric acid solution, no reaction will take place.

In this activity, you will use a few metals, their compounds, and dilute hydrochloric acid to show single-replacement reactions and construct an activity series.

Problem

What elements will replace other elements in single-replacement reactions? How can the results of these reactions be used to form an activity series?

Objectives

- **Classify** reactions as single-replacement chemical reactions.
- **Use numbers** to write balanced equations for single-replacement reactions.
- **Sequence** metals into an activity series.

Materials

zinc (1-cm × 3-cm strips) (3)
copper (1-cm × 3-cm strips) (2)
lead (1-cm × 3-cm strip)
sandpaper
0.2*M* lead (II) nitrate ($Pb(NO_3)_2$)
0.2*M* copper (II) sulfate ($CuSO_4$)
0.2*M* magnesium sulfate ($MgSO_4$)
0.2*M* silver nitrate ($AgNO_3$)
3*M* hydrochloric acid (HCl)
test tubes (6)
test-tube rack

Name _____ Date _____ Class _____

LAB 9.1 LABORATORY MANUAL

Safety Precautions

- **Always wear safety goggles, a lab apron, and gloves.**
- **Dispose of chemical wastes as directed by your teacher.**
- **Lead nitrate and copper(II) sulfate are moderately toxic by ingestion or inhalation.**
- **Magnesium sulfate may irritate the eyes.**
- **Silver nitrate solution is highly toxic and will stain skin or clothing.**
- **Hydrochloric acid is corrosive to skin, is toxic, and reacts with metals.**

Pre-Lab

1. What is a single-replacement reaction?
2. Explain what determines the reactivity of a metal.
3. Distinguish between a more active metal and a less active metal.
4. Read the entire laboratory activity. Form a hypothesis about how an activity series can be formulated. Record your hypothesis in the next column.

Procedure

1. Number six clean test tubes 1 through 6.
2. Use sandpaper to thoroughly clean one piece of lead, two pieces of copper, and three pieces of zinc.
3. For steps 4–9, observe and record any indication of a chemical reaction in **Data Table 1.** If no sign is noticeable immediately, wait about 10 minutes and then reexamine the test tube.
4. Place the lead strip into test tube #1 and add 10 mL of 0.2*M* copper(II) sulfate solution.
5. Place a strip of copper into test tube #2 and add 10 mL of 0.2*M* silver nitrate.
6. Place a strip of copper into test tube #3 and add 10 mL of 3*M* hydrochloric acid.
7. Place a strip of zinc into test tube #4 and add 10 mL of 0.2*M* lead(II) nitrate solution.
8. Place a strip of zinc into test tube #5 and add 10 mL of 0.2*M* magnesium sulfate solution.
9. Place a strip of zinc into test tube #6 and add 10 mL of 3*M* hydrochloric acid.

Hypothesis

_____

_____

_____

_____

_____

Cleanup and Disposal

1. Dispose of materials as directed by your teacher.
2. Return all lab equipment to its proper place.
3. Report any broken or damaged equipment.
4. Wash your hands thoroughly before leaving the lab.

Data and Observations

Data Table 1	
Test-tube number	**Indication of a chemical reaction**
1	
2	
3	
4	
5	
6	

Analyze and Conclude

1. **Measuring and Using Numbers** Complete and balance each of the equations in **Data Table 2.** If no reaction was observed, write *no reaction*.

Data Table 2	
Test-tube number	**Chemical equation**
1	$Pb + CuSO_4 \rightarrow$
2	$Cu + AgNO_3 \rightarrow$
3	$Cu + HCl \rightarrow$
4	$Zn + Pb(NO_3)_2 \rightarrow$
5	$Zn + MgSO_4 \rightarrow$
6	$Zn + HCl \rightarrow$

2. **Observing and Inferring** Identify which element was more active and which element was less active in each of the six tests conducted. Summarize the information in **Data Table 3** by writing the symbol of the element in the appropriate space.

Data Table 3		
Test-tube number	**Symbol of more active element**	**Symbol of less active element**
1		
2		
3		
4		
5		
6		

3. **Collecting and Interpreting Data** Of the three metals, Pb, Cu, Zn, which is the most active?

4. **Collecting and Interpreting Data** Of the three metals, Pb, Cu, Zn, which is the least active?

5. **Drawing a Conclusion** Cite the experimental evidence that indicated which of the three metals, PH, Cu, Zn, was most active and which metal was least active.

6. **Sequencing** Arrange the metals Pb, Cu, Zn, Ag, and Mg in order of activity, from least active to most active.

7. **Sequencing** Is hydrogen more active or less active than Cu, Zn, Ag, and Mg?

8. **Drawing a Conclusion** Cite the experimental evidence used to establish the location of hydrogen in this activity series.

9. **Predicting** What additional test would be necessary to establish the exact position of hydrogen in this activity series?

10. **Error Analysis** Compare your activity series to one in a textbook or reference book. Explain any differences.

Real-World Chemistry

1. Explain why acids are not stored in steel containers.
2. Sodium is a very active metal. Explain why sodium is only found in compounds in nature.
3. Explain why magnesium metal, rather than copper metal, might be used to study the effect of concentration of hydrochloric acid on rates of reactions.