EXPERIMENT 11:
SINGLE DISPLACEMENT REACTIONS

Introduction: In this experiment you will investigate several types of single displacement reactions and develop a relative order of reactivity of several metals and hydrogen. This relative order is called an activity series or electromotive series.

Background: The reactivity of an element is related to its tendency to lose or gain electrons. A generalized single displacement reaction looks like this:

$$A(s) + BC(aq) \rightarrow B(s) + AC(aq)$$

where metal (A) comes in contact with a solution of a metal salt, or an acid, or water (BC). Metal (B) and a metal salt (AC) are formed **if** A is the more active metal. But **if** metal B is more active than element A, no reaction occurs. Some examples:

Example 1: Some metals are so active that they can replace the hydrogen from water.

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Na loses an electron (is oxidized), and H gains electrons (is reduced). Soluble NaOH and H_2 gas are formed. So**, Na** is more active than **hydrogen**, since Na replaces hydrogen.

Example 2: Many metals, not as active as Na, can replace the hydrogen in acids.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

Mg loses 2 electrons (is oxidized), and H gains electrons (is reduced). Soluble $MgCl_2$ and hydrogen gas (H_2) are formed. Thus **Mg** is more active than **hydrogen**, since Mg replaces hydrogen.

Some metals, like Hg do not react with acids, for example:

$Hg(l) + HCl \rightarrow$ **No Reaction,** so the **Hg** is less active than **hydrogen**.

Example 3: In this example a metal is combined with a solution of a metal salt.

$$Mn(s) + CuSO_4(aq) \rightarrow MnSO_4(aq) + Cu(s)$$

Mn metal loses electrons (is oxidized), and the copper ion gains electrons to become copper metal. Thus**, Mn** metal is more active than **Cu** metal but less than **Al** since Mn does not replace Al:

$$Mn(s) + AlCl_3(aq) \rightarrow \textbf{No Reaction}$$

So, both the observed reactions and lack of reactions can be used to draw conclusions about relative activities. In the above example, they can be ranked: **Al > Mn > Cu**

Materials Needed

Equipment	Chemicals
24-well plate Magnifying glass	Solids: Strips of copper, lead, and zinc Solutions: 3M sulfuric acid 0.1 M copper(II) nitrate, $Cu(NO_3)_2$ 0.1 M lead(II) nitrate, $Pb(NO_3)_2$ 0.1 M magnesium sulfate, $MgSO_4$ 0.1 M silver nitrate, $AgNO_3$

Procedure

In this experiment you will use small-scale methods.

Part A: Reaction of metal and water

Your instructor will demonstrate the reaction between sodium metal and water. Before your instructor begins the demonstration, please check the questions in the report section so you will make the appropriate observations.

Part B: Reaction of metals with acids and with metal salt solutions

You will work in pairs for this experiment. Obtain a 24-well plate from your instructor or from the stockroom. Place it on a sheet of white paper. Obtain the solutions you need and the solid elements from **REAGENT CENTRAL**.

Fill wells 1 to 6 with the following solutions. Each well should be about ½ full of solution (about 8-10 drops)

Well 1: Silver nitrate, $AgNO_3$
Well 2: Copper(II) nitrate, $Cu(NO_3)_2$
Well 3: Lead(II) nitrate, $Pb(NO_3)_2$
Well 4: Magnesium sulfate, $MgSO_4$
Well 5 and well 6: 3 M sulfuric acid, H_2SO_4, in both of these wells.

Clean the metal pieces with fine sandpaper to expose fresh metal surfaces. Place a copper strip in well 1, lead in well 2, zinc in both well 3 and 4, copper in well 5 and another piece of zinc in well 6.

Observe the contents of each well carefully and record any evidence of chemical reaction. Use the magnifying glass to look for the evolution of a gas (bubbles) or appearance of a metallic deposit on the surface of the metal. Deposited metals are often black or gray. Some of these reactions may be slow or difficult to observe. Take your time.

Safety and Waste Disposal

Safety: Always wear safety goggles. Some acids are unsafe and toxic. If you get acid on your skin, wash it off immediately.

Waste Disposal: Remove the metal strips with your forceps and place them on a piece of paper towel. Pour the solutions in each well into containers in the hood. Several of these solutions contain heavy metals that should not go down the drain. Rinse the used metals with water and place them in labeled containers in the hood. Do not allow the metal strips to go into the sink or into the heavy metal waste bottle.

EXPERIMENT 11: REPORT Name _____

SINGLE DISPLACEMENT REACTIONS Section _____

Part A: Reaction of an active metal with water (a demonstration)

1. Describe the metal, sodium (Na).

2. Describe what happened when sodium was added to the water.

3. Write an equation for the reaction between sodium and water.

4. Describe what happened when a burning splint was brought to the mouth of the test tube in which sodium reacted with water.

5. Write an equation for the reaction that happened when the burning splint was brought to the mouth of the test tube.

Part B. Describe what happened in each well if a reaction happened and write an equation for each. Write ***"NR"*** if no reaction was observed.

Well 1	**Observations**	**Equation** **___ Cu + ___ $AgNO_3$ →**
Well 2		
Well 3		
Well 4		
Well 5		
Well 6		

Questions and Conclusions

Complete the following table. It will help you organize your observations. Write the **symbols of the two elements** whose reactivities are being compared in each well.

Well #	1	2	3	4	5	6
Greater Activity						
Lesser Activity						

Based upon the comparisons in the above table, draw further conclusions below:
1. Arrange Pb, Mg, and Zn in order of activities, listing the most active first.

_____>_____>_____

1. Arrange Cu. Ag, and Zn in order of their activities, listing the most active first.

_____>_____>_____

2. Arrange Mg, H, and Ag in order of their activities, listing the most active first.

_____>_____>_____

3. Now arrange the five metals in decreasing order of activity.
   _____ > _____ > _____ > _____ > _____

4. Explain why the position of hydrogen cannot be assigned exactly. Then explain what additional test(s) would be required to determine the exact position of hydrogen in the activity series of the elements in the study?

5. Would silver react with hydrochloric acid? Why or why not?

6. Would magnesium react with sulfuric acid? Why or why not?