EXPERIMENT #11
SINGLE-REPLACEMENT REACTIONS

Purpose:

1. To study some typical single replacement reactions
2. To develop an activity series for a limited number of elements

Principles:

The chemical reactivity of elements varies over a wide range. Some elements, like sodium and fluorine, are so reactive that they are never found in the free, uncombined state in nature. Other elements like xenon and platinum are nearly inert and can be made to react with other elements only under special conditions.

The reactivity of an element is related to its tendency to **lose** or **gain electrons**.

In principle, it is possible to arrange nearly all the elements into a single series in order of their reactivates. A series of this kind indicates which free elements are capable of replacing other elements from their compounds. Such a list is known as an **activity** or **electromotive** series.

To illustrate the preparation of an activity series we will experiment with a small group of selected elements and their compounds.

A generalized single replacement react ion is represented in the form:

$$A + BZ \rightarrow AZ + B$$

Element A is the more active metal and replaces element B from the compound BZ. But if element B was a more active metal than element A, no reaction will occur.

Let us consider two specific examples, using copper and mercury:

Example 1
A few drops of mercury metal are added to a solution of copper (II) chloride. In this example no change is observed even after the solution has been standing for a prolonged time; Hence, we conclude that there is no react ion.

$$Hg_{(l)} + CuCl_{2(aq)} \rightarrow no\ reaction$$

From this evidence we conclude that mercury will not replace copper in copper compounds, and therefore mercury is a less active metal than copper.

Example 2
A strip of metallic copper is immersed in a solution of mercury (II) chloride. In this example the copper strip is soon coated with metallic mercury and the solution becomes pale blue-green (the color of Cu^{2+} ions in aqueous solution).

$$Cu_{(s)} + HgCl_{2(aq)} \rightarrow Hg_{(l)} + CuCl_{2(aq)}$$

From this evidence we conclude that copper will replace mercury in mercury compounds. Therefore copper is more reactive than mercury and is before mercury in the activity series.

The single replacement equation given above shows that in terms of ionic charges, the chloride ion remains unchanged, but the ionic charge of mercury has changed from 2+ to 0, and the ionic charge of copper has changed from 0 to 2+.

Expressed in another way, the actual reaction that occurred was the replacement of a mercury ion (Hg^{2+}) by a copper atom (Cu^0).

Notes

1. With some o the combinations used in these experiments the reactions may be slow or difficult to detect. If you see no immediate evidence of reaction, view the reaction under the microscope (if available) or wait for about 10 minutes and then reexamine the appearance of the reactants.
1. Evidence of reaction will be either evolution of a gas or the appearance of a metallic deposit on the surface of the metal strip. Metals deposited from a solution are often black or grayish (in the case of copper very dark reddish-brown) and bear little resemblance to commercially prepared metals.
2. If in doubt about the outcome of the reaction you may want to look for evidence of reaction (metallic deposit, evolution of gas, or nothing) by using the magnifying power of the microscope. Place the spot-plate horizontally under the magnifying lens of the microscope and position it so that you can view the edge of the metallic piece, since it is there that the reaction usually starts.

Procedure

Please note that this is a qualitative experiment.

For each of the tests to be performed ensure that the piece of metal reactant is placed in a single spot plate depression and make sure that it is completely covered with the liquid reactant (it takes about 25 drops).

Observe the contents of each spot plate depression carefully and record any evidence of chemical reaction.

- Gas evolved
- Solid formed
- Color change
- No reaction

The reactants are as follows:

1. **Copper** strip and a **silver nitrate** solution (0.2 M)
2. **Lead** strip and a **copper (II) nitrate** solution (0.1 M)
3. **Zinc** strip and a **lead (II) nitrate** solution (0.1 M)
4. **Zinc** strip and a **magnesium sulfate** solution (0.1 M)
5. **Copper** strip and a **sulfuric acid** solution (0.1M)
6. One piece of mossy **zinc** and a **sulfuric acid** solution (0.1M)

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Name:_____

Date:_____

Partner:_____

Evidence of a Reaction	**Equations** ✓ Balanced chemical equation with **state designations** *i.e.* $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_{2O(l)}$ ✓ Word equation with correct names for **both reactants and products** *i.e. Hydrogen + Oxygen → Water*
1.	*Chemical Equation* $Cu_{(s)} + AgNO_{3(aq)} \rightarrow$
	Word Equation
2.	*Chemical Equation* $Pb_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow$
	Word Equation
3.	*Chemical Equation* $Zn_{(s)} + Pb(NO_3)_{2(aq)} \rightarrow$
	Word Equation
4.	*Chemical Equation* $Zn_{(s)} + MgSO_{4(aq)} \rightarrow$
	Word Equation
5.	*Chemical Equation* $Cu_{(s)} + H_2SO_{4(aq)} \rightarrow$
	Word Equation
6.	*Chemical Equation* $Zn_{(s)} + H_2SO_{4(aq)} \rightarrow$
	Word Equation

Questions

1. Complete the following table by writing the symbols of the two elements being compared in each test:

	Tube Number					
	1	2	3	4	5	6
Greater Activity						
Lesser Activity						

2. Arrange Pb, Mg, and Zn in order of their activities **using the above information**, listing the most active first.

   (1) _____ (2) _____ (3) _____

3. Arrange Cu, Ag, and Zn in order of their activities **using the above information**, listing the most active first.

   (1) _____ (2) _____ (3) _____

4. Arrange Mg, H. and Ag in order of their activities **using the above information**, listing the most active first.

   (1) _____ (2) _____ (3) _____

5. Arrange all five of the metals (excluding hydrogen) in an activity series **using the above information**, listing the most active first.

   (1) _____ (2) _____ (3) _____ (4) _____ (5) _____

6. Answer the following question basis or the evidence developed in this experiment:

   a. Would metallic silver react with dilute sulfuric acid? ***(Provide reasoning for why or why not.)***

   b. Would metallic magnesium react with dilute sulfuric acid? ***(Provide reasoning for why or why not.)***