

Experiment 10

Single Replacement Reactions

Discussion

The chemical reactivity of elements varies over an immense range. Some, like sodium and fluorine are so reactive that they are never found in the free or uncombined state in nature. Others, 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; that is, to be oxidized or reduced. In principle it is possible to arrange nearly all the elements into a single series in order of their reactivities. 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 reaction is represented in the form



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

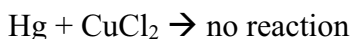
Let us consider two specific examples, using copper and mercury.

Example 1. A few drops of mercury metal are added to a solution of copper (II) chloride (CuCl_2).

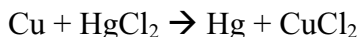
Example 2. A strip of metallic copper is immersed in a solution of mercury (II) chloride (HgCl_2).

In example 1 no change is observed even after the solution has been standing for a prolonged time, and we conclude that there is no reaction. In example 2 the copper strip is soon coated with metallic mercury and the solution becomes pale green. From this evidence we conclude that mercury will not replace copper in copper compounds, but copper will replace mercury in mercury compounds. Therefore copper is a more reactive metal than mercury and is above mercury in the activity series. In terms of chemical equations these facts may be represented as

Example 1

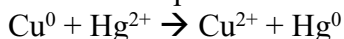


Example 2



The second equation shows that, in terms of oxidation numbers, the chloride ion remained unchanged, mercury changed from +2 to 0, and copper changed from 0 to +2. The +2 oxidation state of copper is normally formed in solution.

Expressed another way, the actual reaction that occurred was the replacement of a mercury ion by a copper atom. This can be expressed more simply in equation form:



In contrast to double replacement reactions, single replacement reactions involve changes in oxidation number and therefore are also classified as oxidation-reduction reactions.

Procedure

1. With some of the combinations used in these experiments the reactions may be slow or difficult to detect. If you see no immediate evidence of reaction, set the tube aside and allow it to stand for about 10 minutes, then reexamine it.
2. Evidence of reactions will be either evolution of a gas or 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.
3. Obtain three pieces of sheet zinc, two of copper, and one of lead. Clean the metal pieces with fine sandpaper or emery cloth to expose fresh metal surfaces. Place six clean test tubes in a rack and number or position-code them, then add the following reagents:

- | | |
|---------|--|
| Tube 1: | Copper strip and about 4 mL of silver nitrate |
| Tube 2: | Lead strip and about 4 mL copper (II) nitrate |
| Tube 3: | Zinc strip and about 4 mL lead (II) nitrate |
| Tube 4: | Zinc strip and about 4 mL magnesium sulfate |
| Tube 5: | Copper strip and about 4 mL dilute sulfuric acid |
| Tube 6: | Zinc strip and about 4 mL dilute sulfuric acid |

4. Observe the contents of each tube carefully and record any evidence of chemical reaction. Record your observations in Table I.

5. Write the complete unbalanced reaction for each combination that has evidence of a reaction.

Table I.

Evidence of Reaction Describe any evidence of reaction; if no reaction was observed, write "None."	Equation Complete the following reaction, if no reaction was observed, write "None."
1.	$\text{Cu} + \text{AgNO}_3 \rightarrow$
2.	$\text{Pb} + \text{Cu}(\text{NO}_3)_2 \rightarrow$
3.	$\text{Zn} + \text{Pb}(\text{NO}_3)_2 \rightarrow$
4.	$\text{Zn} + \text{MgSO}_4 \rightarrow$
5.	$\text{Cu} + \text{H}_2\text{SO}_4 \rightarrow$
6.	$\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow$

QUESTIONS AND PROBLEMS

1. Complete the following table by writing the symbols of the two elements whose reactivities are 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, listing the most active first.

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

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

5. Arrange all five of the metals (excluding hydrogen) in order of their activities, listing the most active first.

6. On the basis of the reactions observed in the six test tubes, explain why the position of hydrogen cannot be fixed exactly with respect to all of the other elements listed in the activity series in Question 5.

7. What additional test(s) would be needed to establish the exact position of hydrogen in the activity series of the elements listed in Question 5?

8. On the basis of the evidence developed in this experiment:

(a) Would silver react with dilute sulfuric acid? Why or why not?

(b) Would magnesium react with dilute sulfuric acid? Why or why not?