Activity of Metals

Demonstration and Inquiry

Introduction

Chemical reactions are not formulas on a piece of paper—they are dynamic and exciting events! The demonstration of aluminum with copper(II) chloride showcases many exciting "signs" of a chemical reaction. It may also generate many questions about why metals react, how they react, and the ease with which some metals react and others do not. How could this general reaction be used to determine the relative reactivity of different metals?

Concepts

- Chemical reactions
- Activity of metals
- Single replacement reactions
- Oxidation and reduction

Background

The usefulness of metals in structural and other applications depends on their physical and chemical properties. Although iron is the most common metal used in manufacturing, it must be protected against corrosion because iron rusts easily. Copper is used in electrical wiring because it conducts electricity extremely well and resists corrosion better than many metals. Gold is a highly valuable jewelry metal because it is essentially unreactive. A ranking of metals in order of their tendency to undergo oxidation or corrosion, that is, to lose electrons and form metal ions, is called an *activity series*.

Inquiry Approach

The purpose of this guided-inquiry activity is observe the reaction of aluminum with copper(II) chloride, explore the evidence for the changes that take place in this chemical reaction, and design an experiment to investigate patterns or trends in the reactivity of metals.

Demonstration Questions

1. Observe and record the "signs" of a chemical reaction when aluminum metal is added to a solution of copper(II) chloride. Be as specific as possible!
2. (a) What are the possible or likely products of the reaction of aluminum metal and copper(II) chloride? (b) Describe the evidence (observations) supporting the identification of these products. (c) What are some additional tests or experiments that could be used to confirm the identity of the products?
3. Write a balanced chemical equation for the reaction of aluminum and an aqueous solution of copper(II) chloride.
4. No evidence of a chemical reaction is observed when a piece of copper metal is placed in aluminum chloride or aluminum nitrate solution. Which metal, aluminum or copper, is a more "active" metal?

Inquiry Design and Procedure

1. Form a working group with two other students and discuss the following questions relating to the reactivity of metals.
   - Would you expect common metals such as iron or tin to react with copper(II) chloride? How about silver metal? Explain.
   - Based on general knowledge of the properties and uses of metals, rank the following metals in order of their predicted activity: aluminum copper, gold, iron, magnesium, silver, sodium, tin, zinc.
   - The reaction of aluminum with copper(II) chloride is classified as a *single replacement reaction*. Write a simple descriptive definition of a single replacement reaction based on this reaction.
   - "Single replacement reactions will occur spontaneously in one direction only." Explain why this statement is true.
2. Complete the following "if, then" statement to predict how the activity of metals can be studied. If a _________ active

metal is placed in a solution containing the __________ of a _________ active metal, then the metal will ________ and a new ___________ will be observed.

3. Read the list of *Materials* that may be provided along with the *Safety Precautions* for their use. Design an experiment to determine the activity of copper, iron, magnesium, silver, and zinc.
4. Write a detailed, step-by-step procedure for the experiment. (The experiment should be done on a microscale level using about 1 mL of each solution and small pieces of metals in a well plate.) Verify the procedure and the required safety precautions with your instructor.
5. What are some variables that might affect the test results? How can these variables be controlled?
6. Carry out the experiment and record observations in an appropriate data table or worksheet.

Materials

Copper strips, Cu

Copper(II) sulfate solution, $CuSO_4$, 0.2 M, 4 mL

Iron strips, Fe

Iron(II) sulfate solution, $FeSO_4$, 0.2 M

Magnesium ribbon, Mg

Magnesium nitrate solution, $Mg(NO_3)_2$, 0.2 M

Silver nitrate solution, $AgNO_3$, 0.2 M

Zinc strips, Zn

Zinc sulfate solution, $ZnSO_4$, 0.2 M

Distilled water and wash bottle

Forceps or tweezers

Marking Pen

Paper towels

Pipets, Beral-type

Reaction plate, 24-well

Sandpaper (optional)

Scissors

Toothpicks (optional)

Safety Precautions

Silver nitrate is slightly toxic by ingestion and will stain skin and clothing. Copper(II) nitrate and iron(II) sulfate are toxic by ingestion. Metal pieces may have sharp edges—handle with care. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the lab. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Post-Lab Questions

1. Which metals reacted with the most and the fewest metal ion solutions, respectively?
2. Because silver metal is expensive, it was not provided in this experiment. Based on the observed reactions of Cu, Fe, Mg, and Zn with silver nitrate, explain why it was not necessary to test silver in order to determine its activity.
3. Rank the metals Cu, Fe, Mg, Ag, and Zn in order from most active (first) to least active (last).
4. Write a balanced, net ionic equation for each observed reaction of a metal with a metal ion. *Hint:* The general form of the net ionic equation is shown below—remember to balance the charges.

$$M(s) + N^{x+}(aq) \rightarrow M^{y+}(aq) + N(s)$$

Teacher's Notes for Guided Inquiry

Metal Activity

Materials for Demonstration

Aluminum foil, 6" × 12"
Copper(II) chloride solution, 0.5 M, 150 mL
Beaker, tall-form, borosilicate glass, 600-mL
Graduated cylinder, 250-mL
Stirring rod
Thermometer

Safety Precautions

Copper(II) chloride solution is toxic by ingestion. Hydrogen is produced in the demonstration—keep flammable materials away from the demonstration area. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Demonstration Procedure

1. Measure 150 mL of 0.5 M copper(II) chloride solution in a graduated cylinder and pour the solution into the borosilicate-glass beaker.
2. Cut a piece of aluminum foil approximately 60 × 120. Loosely roll the foil into a cylinder that will fit into the beaker. (Do not wad up the foil tightly into a ball.)
3. Place the aluminum foil into the beaker, using a stirring rod to push it down into the solution.
4. Observe the "signs" of a chemical reaction in this demonstration (including temperature).

Disposal

Consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Allow the copper to settle in the bottom of the beaker. If state and local regulations allow, excess copper(II) chloride solution may be decanted and disposed according to Flinn Suggested Disposal Method #26b. Alternatively, copper phosphate may be precipitated from the solution by adding excess sodium phosphate. The resulting solid, as well as copper metal and leftover aluminum, may be disposed in the solid trash according to Flinn Suggested Disposal Method #26a.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter
Content Standard F: Science in Personal and Social Perspectives, natural resources

Teaching Tips

- Student preparation is essential for success in a student-directed inquiry lab. To ensure a safe lab environment, it is critical that the teacher review students' materials lists and procedures, including safety precautions.
- The temperature of the reaction mixture in the demonstration of aluminum foil with copper(II) chloride solution increases from room temperature to nearly 60 °C—perform the demonstration in borosilicate glass beakers or cylinders.
- Copper(II) sulfate does not react with aluminum. Adding sodium chloride causes the reaction to proceed. A possible explanation for this unexpected result is that Cl^- ions act as a catalyst. Aluminum metal is normally protected against

oxidation by a coating of aluminum oxide, which is chemically inert and impermeable. Cl^- ions may diffuse into the oxide coating to form soluble aluminum chloride, which dissolves and provides an entry path for Cu^{2+} ions to attack the underlying metal.

Answers to Demonstration Questions

1. Observe and record the "signs" of a chemical reaction when aluminum metal is added to a solution of copper(II) chloride. Be as specific as possible!

   The reaction of aluminum and copper(II) chloride is very vigorous—the reaction mixture gets very hot as heat is released, the blue color due to the Cu(II) ions fades, the aluminum foil disintegrates, a reddish brown solid appears, and gas bubbles are given off.

2. (a) What are the possible or likely products of the reaction of aluminum metal and copper(II) chloride?

   The most likely products appear to be copper metal and a soluble compound or derivative of aluminum.

   (b) Describe the evidence (observations) supporting the identification of these products.

   The new solid that appears is dark reddish brown, similar to copper. The aluminum metal appears to disappear, suggesting that it is converted to a soluble form or new compound.

   (c) What are some additional tests or experiments that could be used to confirm the identity of the products?

   The identity of the copper could be verified by filtering the solid and determining its density. The soluble compound of aluminum could be identified by evaporating the filtrate and isolating the residue.

3. Write a balanced chemical equation for the reaction of aluminum and an aqueous solution of copper(II) chloride.

   $2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Cu(s)$

4. No evidence of a chemical reaction is observed when a piece of copper metal is placed in aluminum chloride or aluminum nitrate solution. Which metal, aluminum or copper, is a more "active" metal?

   Aluminum appears to be a more active metal than copper because it reacts and the latter does not.

Sample Results

Metal	$CuSO_4$	$FeSO_4$	$Mg(NO_3)_2$	$AgNO_3$	$ZnSO_4$
Cu		NR	NR	Gray crystals on Cu surface. Soln turns green.	NR
Fe	Dark ppt on Fe surface. Soln turns green/gray.		NR	Small amount of dark precipitate (powder).	NR
Mg	Dark ppt forms. Soln bubbles, turns green/gray.	Coating, precipitate on Mg surface. A few bubbles.		Large amount of flaky dark ppt. Dark gray soln.	Soln bubbles and dark precipitate forms.
Zn	Dark ppt forms. Soln slowly turns green.	Soln turns cloudy. A few grains of precipitate.	NR	Large amount of flaky dark ppt. Dark gray soln.	

Reference

This activity has been adapted from *Oxidation and Reduction*, Volume 16 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor, Flinn Scientific: Batavia IL (2004).

The materials for *Activity of Metals* are available as a traditional Student Laboratory Kit from Flinn Scientific, Inc.

Catalog No.	Description
AP7177	Single Replacement Reactions and Metal Activity—Student Laboratory Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.