Name **Period** **Date**

19. Single Replacement Reactions

Driving Questions

Some metals are more reactive than others. Gold does not react with acid, but magnesium in the same acid bubbles vigorously, producing explosive hydrogen gas. Is it possible to predict which metals will react in different solutions?

Background

Chemical reactions can be classified into four major types: synthesis, decomposition, single replacement, and double replacement reactions. Classification allows chemists to understand and predict a variety of reactions based on patterns and not on memorization.

A single replacement reaction takes place between a metal in its elemental form and a different metal dissolved in solution as an ion. Whether the metals are able to exchange forms depends on the relative strengths of the two metals involved in the potential reaction. If the metal in its elemental form is “more active” than the metal in solution, a reaction takes place in which the metal ion in solution becomes its elemental form and the original metal becomes the ion. This occurs due to a transfer of electrons from the elemental metal to the metal in solution. This is known as a reduction-oxidation, or redox, reaction. The metal losing electrons to become an ion is being oxidized, while the metal gaining electrons to change into its elemental form is being reduced.

An activity series is a list of elements arranged in order of relative reaction strength. Those elements “higher” on the list react and displace metals beneath them, becoming ions in solution. If the element is beneath the metal in solution, no reaction takes place.

Table 1: Activity series of metals

	Name	Symbol
	Lithium	Li
	Potassium	K
	Calcium	Ca
	Sodium	Na
Decreasing reactivity ↓	Magnesium	Mg
	Aluminum	Al
	Zinc	Zn
	Iron	Fe
	Lead	Pb
	(Hydrogen)	(H)
	Copper	Cu
	Mercury	Hg
	Silver	Ag
	Platinum	Pt
	Gold	Au

Materials and Equipment

For each student or group:

- Data collection system
- Colorimeter
- Sensor extension cable
- Glass cuvette with cap
- Balance, centigram
- Test tube, 20-mm x 150-mm
- Test tube rack
- Graduated cylinder, 100-mL
- Sand paper or steel wool
- Non-abrasive cleaning tissue
- 0.5 M Silver nitrate solution, 30.0 mL
- Copper wire, 20.0 cm
- Paper towels

Safety

Add these important safety precautions to your normal laboratory procedures:

- The silver nitrate ($AgNO_3$) solution may temporarily stain your skin when exposed to bright light. If the solution contacts your skin, wash it with soap and water immediately.
- Both the silver nitrate and copper(II) ions are hazardous to the environment and should not be disposed of down the drain. Make sure you follow the teacher's instructions about how to properly dispose of the chemicals.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

◯	◯	◯	◯	◯
Suspend the coiled copper wire in the test tube and then fill the test tube with silver nitrate solution.	Clean a piece of copper wire with steel wool or sandpaper and then find the mass of the copper.	Use a colorimeter to determine the absorbance of the solution that remained in the test tube after the copper was removed.	Remove the copper wire from the test tube, wipe off the silver deposits, and measure the mass of the copper wire.	Allow the reaction between the copper wire and silver nitrate to proceed for 15 to 20 minutes.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

1. ☐ Clean a 20-cm piece of heavy copper wire using steel wool or sand paper.

2. ☐ Why must the copper wire be cleaned before the experiment begins?

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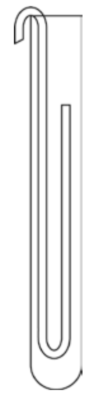
3. ☐ Use a centigram balance to determine the mass of the copper to the nearest 0.01 g, and record the mass below.

Mass of copper before the reaction (g): ______________________



4. ☐ Form the lower part of the wire into an elongated u-shape, and bend the wire to form a hook at the opposite end.

5. ☐ Suspend the u-shaped copper in the test tube by hanging the hooked end of the copper over the side of the test tube. Do not let the copper wire touch the bottom of the test tube. Place the test tube in a test tube rack.

6. ☐ Measure 30.0 mL of 0.5 M silver nitrate solution and pour it into the test tube containing the copper wire.

7. ☐ Use three adjectives to describe the silver nitrate solution.

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8. ☐ Allow the reaction to proceed undisturbed for 15 to 20 minutes.

9. ☐ Why must you wait for at least 15 to 20 minutes?

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10. ☐ Remove the copper wire from the silver nitrate solution. Save the solution.

11. ☐ Use a paper towel to wipe the silver deposits off the copper wire. Dispose of the silver in the proper receptacle according to your teacher's instructions.

12. ☐ Use the centigram balance to find the mass of the copper wire after the chemical reaction. Record the mass to 0.01 g below.

Mass of copper after the reaction (g): ______________________

13. ☐ Why is this procedure likely to give an inaccurate mass?

14. ☐ Start a new experiment on the data collection system. �(1.2)

15. ☐ Connect the colorimeter to the data collection system using a sensor extension cable. �(2.1)

16. ☐ Monitor the Absorbance of Orange (610 nm) Light in a digits display. �(6.1)

17. ☐ Calibrate the colorimeter by following the steps below:

    a. Fill a cuvette with distilled water and cap it.

    b. Holding the cuvette by the lid, wipe the outside of the cuvette with a non-abrasive cleaning tissue.

    c. Place the cuvette in the colorimeter and close the lid.

    d. Push the green calibrate button on the colorimeter.

    e. When the light turns off, the calibration is complete and the cuvette can be removed from the colorimeter.

18. ☐ Rinse the cuvette with some of the solution saved in the test tube by following the steps below:

    a. Fill the cuvette with some of the solution that is saved in the test tube.

    b. Dispose of the solution you just poured into the cuvette according to the teacher's instructions.

19. ☐ Fill the cuvette with more solution from the test tube and cap the cuvette.

20. ☐ Why was the cuvette rinsed (filled and then emptied) with the solution from the test tube?

21. ☐ Describe any changes to the solution compared to the original solution that was in the test tube. What may have caused these changes?

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22. ☐ Use a non-abrasive cleaning tissue to wipe the outside of the cuvette containing the solution from the test tube, and then place the cuvette inside the colorimeter. Close the lid of the colorimeter.

23. ☐ Why is it necessary to wipe the outside of the cuvette before placing it in the colorimeter?

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24. ☐ Why is it necessary to close the lid of the colorimeter before recording the data values?

____

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25. ☐ Record the value for the absorbance below.

Absorbance of Orange (610 nm) Light: ____________________

26. ☐ Remove the cuvette and properly dispose of the solution according to the teacher's instructions.

27. ☐ Clean up the lab station according to the teacher's instructions, including any special instructions for disposing of the silver deposit and copper(II)/silver nitrate solution.

Data Analysis

1. ☐ Calculate the mass of copper consumed in the reaction using the mass of the copper wire measured before the reaction after the reaction.

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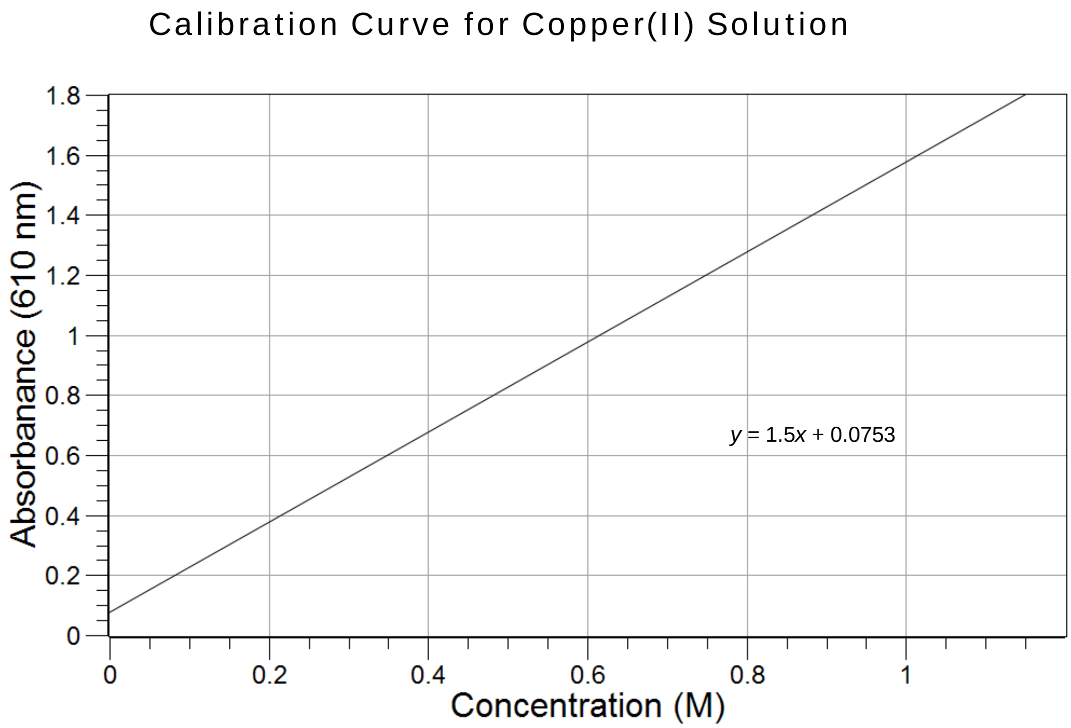
2. ☐ Using the calibration curve for copper(II) ions in solution provided below and your absorbance reading for the solution in the test tube, determine the concentration of copper(II) ions in the solution.



3. ☐ Based on the concentration of copper ions in solution determined above, calculate the number of moles of copper(II) ions (as copper(II) nitrate) in the final solution. Remember, the volume of the solution was 30.0 mL.

4. ☐ Based on the previous calculation and the stoichiometry of the reaction given below, calculate the mass of metallic copper that reacted with the silver nitrate solution.

$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

Analysis Questions

1. **You have found the mass of copper consumed using two different methods. What are the two methods and how do the results compare?**

2. **List some possible sources of error with each method.**

3. **Predict the mass of silver produced in the reaction.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **During the Middle Ages, alchemists searched unsuccessfully for a way to "transmute" or change one element into another, most notably lead into gold. Was copper transmuted into silver in this experiment? Why or why not?**

2. **How can you account for the color change of the solution?**

3. **Using the activity series table in the Background section, predict the outcome of this experiment if you used a gold wire instead of a copper wire. Explain your prediction.**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **What can be predicted using an activity series?**

   A. The amount of energy released by a chemical reaction
   B. The electronegativity values of elements
   C. The melting points of elements
   D. Whether or not a reaction will occur

2. **If one metal is lower than a second in the activity series, then it:**

   A. Replaces the ions of the second metal in solution
   B. Loses electrons more readily than the second metal
   C. Loses electrons less readily than the second metal
   D. Forms positive ions more readily than the second metal

3. **What happens when lead is added to nitric acid?**

   A. No reaction occurs
   B. Hydrogen is released
   C. Lead oxide forms
   D. Oxygen is released

4. **What happens when iron is added to a solution of lead(II) sulfate?**

   A. No reaction occurs
   B. Hydrogen is released
   C. Lead oxide forms
   D. Lead will deposit on the surface of the iron

5. **What happens when zinc is added to a solution of magnesium chloride?**

   A. No reaction occurs
   B. Hydrogen is released
   C. Zinc chloride forms
   D. Magnesium will deposit on the surface of the zinc

Key Term Challenge

Fill in the blanks from the list of words in the Key Term Challenge Word Bank.

1. A ________________________ reaction occurs when one element replaces another element in a compound. You can predict whether or not one metal will replace another metal by use of an ________________________. Metals that are ________________________ in the activity series replace metals that are ________________________ them. In these types of reactions, one element changes into its ionic form and the other element changes into its elemental form. This process involves a transfer of electrons from one substance to another and is referred to as a ________________________. If an element loses electrons, it is being ________________________. If an element gains electrons, it is being ________________________.

Key Term Challenge Word Bank

Paragraph 1

above

activity series

beneath

decomposition

double replacement

higher

lower

neutralization reaction

oxidized

redox reaction

reduced

single replacement

strength table

synthesis