

## Purpose

Explore different types of chemical reactions in a laboratory procedure.

## Student Guide

The student guide is provided during the instruction and both the virtual experiment and the in-laboratory (“wet”) experiment, both of which follow the same lab procedure. Be sure either to provide copies to students or enable them to print the guides themselves when they reach the instruction phase of the lab lesson.

## Background Information

In this set of experiments, students will examine the five major categories of reactions. Most chemical reactions can fall into at least one of these categories, which are summarized in the table below. Note that the law of conservation of matter applies to all types of reactions; since matter is neither created nor destroyed; the same number and type of atoms are found in both the reactants and the products of a chemical reaction, which is why the equations are balanced.

Reaction Type	Description	General Form	Example
<b>Synthesis</b>	Two or more reactants combine to form one product.	$A + B \rightarrow AB$	<b>Carbonation of Water:</b> $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$
<b>Decomposition</b>	A single reactant breaks down into two or more products.	$AB \rightarrow A + B$	<b>Reaction in Baking:</b> $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$
<b>Single Replacement</b>	An element replaces an ion in a compound.	$A + BC \rightarrow B + AC$	<b>Silver Tarnishing:</b> $2\text{Ag} + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + \text{H}_2$
<b>Double Replacement</b>	The metal ions of two substances replace each other.	$AB + CD \rightarrow AD + CB$	<b>Acid Rain and Marble:</b> $\text{CaCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{H}_2\text{CO}_3$
<b>Combustion</b>	A substance reacts with oxygen gas.	$A + \text{O}_2 \rightarrow \text{AO}$	<b>Rocket Combustion:</b> $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$

## Teacher Guide

It is not uncommon for a given reaction to be classified into more than one category. In this lab, one reaction (Reaction 3, Burn Copper Wire) represents both synthesis and combustion.

There are many clues that indicate a reaction has taken place, and in this experiment, students will observe at least one of each of the following: (a) change of the color of a substance, (b) release of a gas, (c) formation of a precipitate (solid, insoluble substance that separates from a solution), and (d) production or absorption of heat.

Chemical reactions have many applications and implications to the real world. Here are some examples, all revolving around baking a cake:

- A double replacement reaction occurs when you bake a cake and use baking soda in the batter. Baking soda, or  $\text{NaHCO}_3$ , reacts with any acids (unknown acids are  $\text{HX}$ ) in the batter in the following reaction:  $\text{NaHCO}_3 + \text{HX} \rightarrow \text{NaX} + \text{H}_2\text{CO}_3$ .
- Subsequently, the  $\text{H}_2\text{CO}_3$  (above) undergoes a decomposition reaction to produce water and carbon dioxide:  $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$ .
- The carbohydrates in the cake undergo combustion when the top of the cake burns. The variety of carbohydrates are represented by  $(\text{CH}_2\text{O})_n$ :  $(\text{CH}_2\text{O})_n + \text{O}_2(\text{g}) \rightarrow \text{CO}_2 + \text{H}_2\text{O}(\text{g})$ .

Many common combustion reactions are used to generate energy. Examples include cars that burn gasoline or the burning of wood in a fireplace.

A single replacement reaction is common when silver tarnishes. The silver reacts with hydrogen sulfide in the air to form silver sulfide in the equation:  $2\text{Ag}(\text{s}) + \text{H}_2\text{S}(\text{g}) \rightarrow \text{Ag}_2\text{S}(\text{s}) + \text{H}_2(\text{g})$

## Preparation / Alternatives

- You may wish to set up four pre-prepared stations, one for each reaction, as follows:
  - Reaction 1:** 1 M  $\text{CuSO}_4$  solution, zinc metal, 1 test tube, 1 test tube holder, transfer pipette
  - Reaction 2:** 0.1 M  $\text{KI}$  solution, 0.1 M  $\text{Pb}(\text{NO}_3)_2$  solution, 2 test tubes, 1 test tube holder, transfer pipettes
  - Reaction 3:** Bunsen burner, striker, 1 pair of tweezers, sandpaper, 3 in. copper wire
  - Reaction 4:** spatula,  $\text{Na}_2\text{CO}_3$ , 1 test tube, 1 test tube holder
- If sandpaper is not available, a scouring sponge can be used to clean the surface of the wire.
- If a transfer pipette is not available, an eye dropper can be used.

## Teacher Guide

- Prepare solutions ahead of time. To make each solution, dissolve each of the following in 1 L of water (students will not make measurements, so precision is unimportant here):
  - KI: 16.6 g will produce a 0.1 M solution.
  - $\text{Pb}(\text{NO}_3)_2$ : 33.1 g will produce a 0.1 M solution.
  - anhydrous  $\text{CuSO}_4$ : 160 g (or 250 g copper sulfate pentahydrate) will produce a 1 M solution.
- If an evaporating dish is not available, a glass dish or beaker can be used in its place.
- If a Bunsen burner is not available, an alcohol burner can be used.
- Follow your district and state chemical disposal policies when disposing of substances. You may need to provide a bulk disposal container for students to dispose of waste.

## Monitoring the Lab Procedure

- Ensure that safety procedures are followed at all times.
- Instruct students on proper use of a Bunsen burner. Make sure they understand how to ignite the burner and how to adjust the height of the flame.
- Instruct students that the magnesium ribbon burns with an extremely bright flame. Point out that they should not look directly at the flame.
- Make students aware that they should not leave the Bunsen burner unattended during use. Instruct students to turn the gas off immediately after completing the tests.

## Data

While students perform the procedure, they should record their data on the data sheet provided in the student guide. Sample data shown below matches the results of the virtual experiment. Student data may vary, but students should try to account for any deviations.

### Reaction 1: Add Zinc to Copper Sulfate

Observations of Reactants	$\text{CuSO}_4$ -light blue; Zn-silvery
Predicted Type(s) of Reaction	Students' answers will vary.
Observations of Products	Cu-brownish solid; $\text{ZnSO}_4$ -colorless
Balanced Chemical Equation	$\text{CuSO}_4(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{ZnSO}_4(\text{aq})$
Type(s) of Reaction	Single Replacement

## Teacher Guide

### Reaction 2: Mix Potassium Iodide and Lead (II) Nitrate

Observations of Reactants	KI-colorless; Pb(NO <sub>3</sub> ) <sub>2</sub> -colorless
Predicted Type(s) of Reaction	Students' answers will vary.
Observations of Products	KNO <sub>3</sub> -colorless; PbI <sub>2</sub> -yellow solid
Balanced Chemical Equation	$2\text{KI}(\text{aq}) + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbI}_2(\text{s}) + 2\text{KNO}_3(\text{aq})$
Type(s) of Reaction	Double Replacement

### Reaction 3: Burn Copper Wire

Observations of Reactants	Cu: brownish, metallic colored wire; O <sub>2</sub> from air
Predicted Type(s) of Reaction	Students' answers will vary.
Observations of Products	Black residue on the wire
Balanced Chemical Equation	$2\text{Cu}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CuO}(\text{s})$
Type(s) of Reaction	Synthesis/Combustion

### Reaction 4: Heat Sodium Carbonate

Observations of Reactants	Na <sub>2</sub> CO <sub>3</sub> -white powder
Predicted Type(s) of Reaction	Students' answers will vary.
Observations of Products	Solid white powder; gas released
Balanced Chemical Equation	$\text{Na}_2\text{CO}_3(\text{s}) \xrightarrow{\text{heat}} \text{Na}_2\text{O}(\text{s}) + \text{CO}_2(\text{g})$
Type(s) of Reaction	Decomposition

## Analysis

When students write their lab reports, they should provide a written explanation of their results comparing their observations of the initial reactants to the final products in each reaction. The student should also write about how the observations were used to identify the type of reaction that occurred at each station.

**Sample Analysis:** The results of the experiment show that the five reaction types could be identified based on the observations from the initial reactants and final products. A light blue

## Teacher Guide

copper sulfate solution and a silvery piece of metal combined in a single replacement reaction to form a brownish precipitate, and the solution turned clear. The reaction that describes this is:  $\text{CuSO}_4(\text{aq}) + 2\text{Zn}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Zn}_2\text{SO}_4(\text{aq})$ . Two colorless solutions, KI and  $\text{Pb}(\text{NO}_3)_2$ , combined to form a yellow precipitate in a double replacement reaction.  $\text{KI}(\text{aq}) + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbI}_2(\text{s}) + \text{KNO}_3(\text{aq})$  is the equation that describes this reaction. The brown copper wire changed to a black residue in the synthesis/combustion reaction. A chemical reaction can be written to describe the reaction:  $2\text{Cu}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CuO}(\text{s})$ . White powdery  $\text{Na}_2\text{CO}_3$  was heated, and the decomposition reaction gave off carbon dioxide gas in the following reaction:  $\text{Na}_2\text{CO}_3(\text{s}) + \text{heat} \rightarrow \text{Na}_2\text{O}(\text{s}) + \text{CO}_2(\text{g})$ . These four reaction types produced an observable result of a chemical reaction such as a precipitate, a gas was given off, or a color change was observed during the reaction.

## Conclusion

When students write their lab reports, they should restate their predictions for the products of each reaction, and explain whether their results were supported or refuted by the data. If the student's results vary from the actual results, they should provide an explanation. They may also revise the products and state what further experiment they would perform next. They should also identify any additional questions that arose from conducting the experiment.

### Sample Conclusion:

**Reaction 1:** The reaction of solid zinc and copper sulfate was a single replacement reaction that produced solid copper and zinc sulfate. This result was supported because a brown precipitate was observed as solid copper formed in the test tube. This observation could be used to confirm the type of reaction and the equation that describes the single replacement reaction of copper sulfate and zinc.

**Reaction 2:** The reaction of potassium iodide and lead (II) nitrate was a double replacement reaction that produced potassium nitrate and lead (II) iodide. This result was supported because a yellow precipitate, which is characteristic of lead (II) iodide, was observed in the test tube. This observation could be used to confirm the type of reaction and the equation that describes the double replacement reaction of potassium iodide and lead (II) nitrate.

**Reaction 3:** Burning copper is a synthesis/combustion reaction between copper and oxygen gas, where the product is solid copper oxide. This result was supported because burning the copper is a combustion reaction that requires oxygen gas as a reactant. Identifying the reactants and the balanced chemical equation were used to confirm the types of reaction.

**Reaction 4:** Heating sodium carbonate was a decomposition reaction that produced carbon dioxide and sodium oxide. This result was supported because the release of carbon dioxide gas was observed as a bubbling in the test tube and the mass of solid decreased during the reaction. This observation could be used to confirm the type of reaction and the equation that describes the decomposition reaction of sodium carbonate.

## Teacher Guide

To further explore the identification of the products of chemical reactions, this experiment could be expanded to identify the type of reactions in an additional group of reactions. Another experiment could investigate the results from one of the reactions in order to further characterize the material that is formed during the reaction. For example, the reactivity series could be used to further test zinc sulfate by adding solid aluminum to the solution and precipitating the zinc.

## Extension Activities

Here are some variations that may lead to an increased understanding of the five different types of chemical reactions.

- Have students research an everyday example of one type of chemical reaction. Encourage students to use an example they are very familiar with. Have the students prepare a demonstration or an experiment of the chemical reaction.
- Have students investigate a molecule that has been created via synthesis reaction(s). Have them describe the step(s) in the reaction to create the new molecule, indicating how the reaction occurs.
- Students may research different chemical reactions and then design a matching game to identify the five different reaction types. A chemical equation can be drawn on a card, and the student has to place the reaction into the proper category for reaction type.