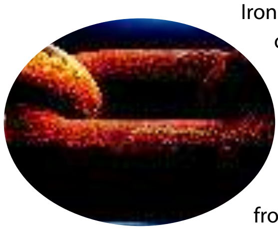
2.4 Chemical Reactions

Connecting to Your World

Iron is an element with many desirable properties. It is abundant, easy to shape when heated, and relatively strong, especially when mixed with carbon in steel. Iron has one main disadvantage. Over time, objects made of iron will rust if they are left exposed to air. The brittle layer of rust that forms on the surface of the object flakes off, exposing more iron to the air. In this section, you will learn to recognize chemical changes and to distinguish them from physical changes.



Guide for Reading

Key Concepts

- What always happens during a chemical change?
- What are four possible clues that a chemical change has taken place?
- How are the mass of the reactants and the mass of the products of a chemical reaction related?

Vocabulary

chemical property
chemical reaction
reactant
product
precipitate
law of conservation of mass

Reading Strategy

Predicting Before you read, predict what will happen to the mass of a sample of matter that burns. After you read, check the accuracy of your prediction and correct any misconceptions.

Chemical Changes

The compound formed when iron rusts is iron oxide (Fe_2O_3). Words such as *burn, rot, rust, decompose, ferment, explode,* and *corrode* usually signify a chemical change. The ability of a substance to undergo a specific chemical change is called a **chemical property.** Iron is able to combine with oxygen to form rust. So the ability to rust is a chemical property of iron. Chemical properties can be used to identify a substance. But chemical properties can be observed only when a substance undergoes a chemical change.

Figure 2.13 compares a physical change and a chemical change that can occur in a mixture of iron and sulfur. When a magnet is used to separate iron from sulfur, the change is a physical change. The substances present before the change are the same substances present after the change, although they are no longer physically blended. Recall that during a physical change, the composition of matter never changes. **During a chemical change, the composition of matter always changes.** When the mixture of iron and sulfur is heated, a chemical change occurs. The sulfur and iron react and form iron sulfide (FeS).

A chemical change is also called a chemical reaction. One or more substances change into one or more new substances during a **chemical reaction.** A substance present at the start of the reaction is a **reactant.** A substance produced in the reaction is a **product.** In the reaction of iron and sulfur, iron and sulfur are reactants and iron sulfide is a product.

Figure 2.13 A mixture of iron filings and sulfur can be changed. **a** A magnet separates the iron from the sulfur. **b** Heat combines iron and sulfur in a compound. **Classifying** ***Which change is a chemical change? Explain.***

Section Resources

Print

- **Guided Reading and Study Workbook,** Section 2.4
- **Core Teaching Resources,** Section 2.4 Review
- **Transparencies,** T18–T19
- **Laboratory Manual,** Labs 2–3
- **Laboratory Practicals,** 2-1
- **Small-Scale Chemistry Laboratory Manual,** Lab 2

Technology

- **Interactive Textbook with ChemASAP,** Assessment 2.4
- **Go Online,** Section 2.4

2.4

1 FOCUS

Objectives

2.4.1 **Describe** what happens during a chemical change.

2.4.2 **Identify** four possible clues that a chemical change has taken place.

2.4.3 **Apply** the law of conservation of mass to chemical reactions.

Guide for Reading

Build Vocabulary L2

Compare and Contrast Table Have students make a table to compare physical and chemical changes.

Reading Strategy L2

Predict Before students read the section, have them predict the meanings of *reactant* and *product*. Ask students what they are basing their predictions on.

2 INSTRUCT

Connecting to Your World

What evidence do you see in the photo that a chemical reaction has occurred? *(The metal has changed color.)*

Chemical Changes

Use Visuals L1

Figure 2.13 Discuss the difference between physical and chemical changes. Ask, **What substances are present before and after the change in photo a?** *(iron and sulfur)* **What substances are present before and after the change in photo b?** *(iron and sulfur before, iron sulfide after)*

FYI

The Roman numerals were omitted from iron(III) oxide and iron(II) sulfide to avoid having to explain the Stock system, which is explained on p. 254.

Answers to...

Figure 2.13 *b; A new substance is formed.*

Recognizing Chemical Changes

TEACHER Demo

Identifying a Chemical Change L2

Purpose Students will practice identifying chemical changes.

Materials Bunsen burner, match, tongs, magnesium ribbon, 4 test tubes, solutions of 0.1*M* $AgNO_3$, 0.1*M* NaCl, 0.1*M* K_2CrO_4, and 3*M* H_2SO_4, mossy zinc, marble chip, spatulas, cobalt blue glass filters

Safety For Step 3, wear gloves to avoid stains on your skin from silver nitrate. **CAUTION** *Students should not look at burning magnesium without the cobalt blue glass filters.*

Procedure As you do each step, have students identify the clue for chemical change. Emphasize that the clues point to a chemical change but do not confirm that a change has taken place.

a. Light a Bunsen burner. *(heat and light produced)*

b. Using tongs, hold a piece of magnesium ribbon in a burner flame until it ignites. Remove from heat and observe. *(The product is a white powder; heat and light are produced.)*

c. Put 5 mL of silver nitrate solution in each of two test tubes. Add a small amount of sodium chloride solution to one tube and potassium chromate solution to the other. *(color change, formation of a precipitate)*

d. Put 5 mL of the sulfuric acid in each of two test tubes. Add a piece of mossy zinc to one tube and a marble chip ($CaCO_3$) to the other. *(formation of a gas)*

Go Online NSTA SciLinks

Download a worksheet on **Chemical and Physical Changes** for students to complete, and find additional teacher support from NSTA SciLinks.

Recognizing Chemical Changes

How can you tell whether a chemical change has taken place? There are four clues that can serve as a guide. **Possible clues to chemical change include a transfer of energy, a change in color, the production of a gas, or the formation of a precipitate.**

Every chemical change involves a transfer of energy. For example, energy stored in natural gas is used to cook food. When the methane in natural gas combines with oxygen in the air, energy is given off in the form of heat and light. Some of this energy is transferred to and absorbed by food that is cooking over a lit gas burner. The energy causes chemical changes to take place in the food. The food may brown as it cooks, which is another clue that chemical changes are occurring.

You can observe two other clues to chemical change while cleaning a bathtub. The ring of soap scum that can form in a bathtub is an example of a precipitate. A **precipitate** is a solid that forms and settles out of a liquid mixture. Some bathroom cleaners that you can use to remove soap scum start to bubble when you spray them on the scum. The bubbles are a product of a chemical change that is taking place in the cleaner.

If you observe a clue to chemical change, you cannot be certain that a chemical change has taken place. The clue may be the result of a physical change. For example, energy is always transferred when matter changes from one state to another. Bubbles form when you boil water or open a carbonated drink. The only way to be sure that a chemical change has occurred is to test the composition of a sample before and after the change. Figure 2.14 shows examples of practical situations in which different clues to chemical change are visible.

Checkpoint ***What energy transfer takes place when food cooks?***

Go Online NSTA SciLinks

For: Links on Chemical and Physical Changes
Visit: www.SciLinks.org
Web Code: cdn-1024

Figure 2.14 Clues to chemical change often have practical applications. **a** Bubbles of carbon dioxide gas form when a geologist puts acid on a rock that contains compounds called carbonates. **b** When a test strip is dipped in urine, the color change is used to estimate the level of the sugar glucose in urine. **c** One step in the production of cheese is a reaction that causes milk to separate into solid curds and liquid whey.

Facts and Figures

Urinalysis Test Strips

A test-strip urinalysis is semi-quantitative, meaning that the test provides information about the level of a material present in the urine, but not a specific quantity. The strips can also be used to test for ketones, protein, blood, nitrite, bilirubin, urobilinogen, pH, white blood cells, and specific gravity. All the tests involve a color change.

In one glucose test, the hydrogen peroxide produced when glucose is oxidized reacts with potassium iodide. The oxygen produced in the second reaction binds with a dye to produce colors that range from blue to dark brown. You may want to relate what happens with test strips to what happens in the Small-Scale lab on p. 56.

Figure 2.15 When the liquids in photograph A are mixed, they react. None of the products are gases. **Analyzing Data** ***How do you know that a reaction took place and that mass was conserved during the reaction?***

Conservation of Mass

When wood burns, substances in the wood combine with oxygen from the air. As the wood burns, a sizable amount of matter is reduced to a small pile of ashes. The reaction seems to involve a reduction in the amount of matter. But appearances can be deceiving. **During any chemical reaction, the mass of the products is always equal to the mass of the reactants.** Two of the products of burning wood—carbon dioxide gas and water vapor—are released into the air. When the mass of these gases is considered, the amount of matter is unchanged. Careful measurements show that the total mass of the reactants (wood and the oxygen consumed) equals the total mass of the products (carbon dioxide, water vapor, and ash).

Mass also holds constant during physical changes. For example, when 10 grams of ice melt, 10 grams of liquid water are produced. Similar observations have been recorded for all chemical and physical changes studied. The scientific law that reflects these observations is the law of conservation of mass. The **law of conservation of mass** states that in any physical change or chemical reaction, mass is conserved. Mass is neither created nor destroyed. The conservation of mass is more easily observed when a change occurs in a closed container, as in Figure 2.15.

2.4 Section Assessment

28. **Key Concept** How does a chemical change affect the composition of matter?

29. **Key Concept** Name four possible clues that a chemical change has taken place.

30. **Key Concept** In a chemical reaction, how does the mass of the reactants compare with the mass of the products?

31. What is the main difference between physical changes and chemical changes?

32. Classify the following changes as physical or chemical changes.
- **a.** Water boils.
- **b.** Salt dissolves in water.
- **c.** Milk turns sour.
- **d.** A metal rusts.

33. According to the law of conservation of mass, when is mass conserved?

34. Hydrogen and oxygen react chemically to form water. How much water would form if 4.8 grams of hydrogen reacted with 38.4 grams of oxygen?

Connecting Concepts

The Scientific Method Lavoisier proposed the law of conservation of mass in 1789. Write a paragraph describing, in general, what Lavoisier must have done before he proposed this law. Use what you learned about the scientific method in Section 1.3.

Interactive Textbook

Assessment 2.4 Test yourself on the concepts in Section 2.4.

with ChemASAP

Conservation of Mass

Use Visuals L1

Figure 2.15 Explain that the photos are before and after views of a reaction. Ask, **Why are the containers covered?** *(The covers prevent evaporation of the solutions and loss of mass.)*

3 ASSESS

Evaluate Understanding L2

Write this word equation on the board.

methane + oxygen →
carbon dioxide + water + energy

Have students identify the reactants and products and one possible clue for a chemical change.

Reteach L1

Write a word equation on the board for the reaction of magnesium and oxygen to produce magnesium oxide. Ask students to explain how mass is conserved in this reaction. *(The difference between the mass of the magnesium and the mass of the magnesium oxide is the mass of the oxygen with which magnesium combines.)*

Connecting Concepts

Lavoisier would have done a series of experiments in which he measured the masses of reactants and products before he proposed the law of conservation of mass.

Interactive Textbook

If your class subscribes to the interactive Textbook, use it to review key concepts in Section 2.4.

with ChemASAP

Section 2.4 Assessment

28. The composition of matter always changes during a chemical change.

29. a transfer of energy, a change in color, the production of a gas, the formation of a precipitate

30. The mass of the products is always equal to the mass of the reactants.

31. In a physical change, the chemical composition of a substance does not change. In a chemical change, the chemical composition of the reactants changes as one or more products form.

32. **a.** physical **b.** physical **c.** chemical **d.** chemical

33. Mass is conserved in every physical change or chemical reaction.

34. 43.2 g

Answers to...

Figure 2.15 change of color and formation of a precipitate; The balance reading did not change.

Checkpoint The burning of methane produces heat that is transferred to the food.

Small-Scale LAB

1 + 2 + 3 = Black! L2

Objective In this activity, students will begin to:

- familiarize themselves with small-scale equipment and methodology.
- observe and analyze some chemical reactions.

Skills Focus Observing, Classifying

Prep Time 1 hour

Materials Paper, metric ruler, reaction surface, pipette, dropper, spatulas, KI, liquid starch, cereal, NaClO, H_2O_2, $CuSO_4$, foods, iodized and non-iodized salt, antacid tablets, color marker pens

Advance Prep

Solution	Preparation
0.1*M* KI	4.2 g KI in 250 mL water
0.2*M* $CuSO_4$	12.5 g $CuSO_4 \cdot 5H_2O$ in 250 mL water
1% NaClO	50 mL household bleach in 200 mL water
3% H_2O_2	Use undiluted household hydrogen peroxide
20% starch	50 mL liquid starch in 200 mL water

Class Time 40 minutes

Teaching Tips

- Demonstrate how to use a pipette as a stirrer. This information, as well as a discussion of reaction surfaces, can be found in the *Small-Scale Chemistry Laboratory Manual.*
- Explain that using a mixture of KI and NaClO to test for starch is an example of qualitative analysis.

Expected Outcome

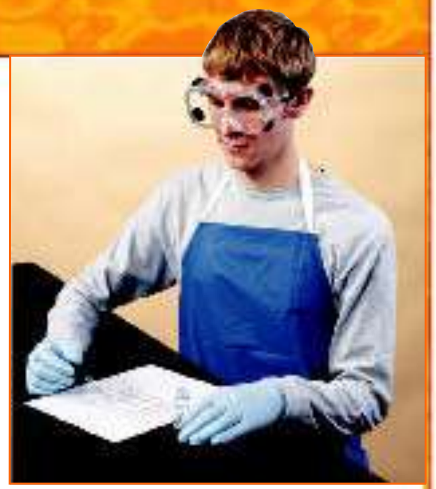
	NaClO	H_2O_2	$CuSO_4$
KI	yellow	yellow	brown ppt
KI + starch	black	black	black
KI + paper	black	black	black
KI + cereal	black	black	black

For Enrichment L3

Have students design and carry out an experiment to quantify the amount of KI in iodized salt.

Small-Scale LAB

1 + 2 + 3 = Black!



Purpose

To make macroscopic observations of chemical reactions and use them to solve problems.

Materials

- paper
- metric ruler
- reaction surface
- materials shown in grid
- pipette, medicine droppers, and spatulas

Procedure

1. Draw two copies of the grid on separate sheets of paper. Make each square in the grid 2 cm on each side.
2. Place a reaction surface over one of the grids. Use the second grid as a data table to record your observations.
3. Use the column and row labels to determine which materials belong in each square. Depending on the material, add one drop, one piece, or a few grains.
4. Stir each mixture by forcing air from an empty pipette as directed by your teacher.

	NaClO	H_2O_2	$CuSO_4$
KI			
KI + Starch			
KI + Paper			
KI + Cereal			

Analyze

Using your experimental data, record the answers to the following questions below your data table.

1. What color is a mixture of sodium hypochlorite (NaClO) and potassium iodide (KI)?
2. What happens when you mix NaClO, KI, and starch?
3. What do NaClO, H_2O_2, and $CuSO_4$ have in common?
4. What substance is found in both paper and cereal? How do you know?
5. If you used NaClO instead of $CuSO_4$ in reactions other than the reaction with KI and starch, would you expect the results to always be identical? Explain your answer.

You're The Chemist

The following small-scale activities allow you to develop your own procedures and analyze the results.

1. **Design It!** Design and carry out an experiment to see which foods contain starch.
2. **Design It!** Read the label on a package of iodized salt. How much KI does iodized salt contain? Design an experiment to demonstrate the presence of KI in iodized salt and its absence in salt that is not iodized.
3. **Design It!** Antacid tablets often contain starch as a binder to hold the ingredients in the tablet together. Design and carry out an experiment to explore various antacid tablets to see if they contain starch.
4. **Analyze It!** NaClO is a bleaching agent. Such agents are used to whiten clothes and remove stains. Use different color marker pens to draw several lines on a piece of white paper. Add one drop of NaClO to each line. What happens? Try inventing a technique that you can use to make "bleach art."

Analyze and Conclude

1. yellow
2. The mixture turns a blue-black color.
3. They all turn a mixture of KI and starch black.
4. Starch; both turn blue-black, which suggests the presence of starch.
5. The results may be the same in reactions that are similar to the one with KI and starch, but different in other reactions.

You're The Chemist

1. Add KI + NaClO to various foods. A black color indicates the presence of starch.
2. Most table salt contains 0.01% KI. Wet only a portion of a small pile of salt with starch. Add $CuSO_4$ or H_2O_2. A black color indicates the presence of KI.
3. If an antacid tablet contains starch, it will turn black when treated with KI + NaClO.
4. The color fades. A picture can be drawn with colored ink. Areas can be treated with NaClO to bleach parts of the picture.