Chemical Change

In a **chemical change***, the original substance is changed into one or more different substances that have different properties.*

As the wax in a candle melts and vaporizes, some of the wax particles join up with oxygen from the air. The result of this chemical change is the production of water vapour, carbon dioxide gas, heat, and light. The wax particles that seem to disappear are actually changing into something else.

Chemical changes always involve the production of new substances. Most chemical changes are difficult to reverse. Burning, cooking, and rusting are all examples of chemical changes, as is the change shown in **Figure 3**.

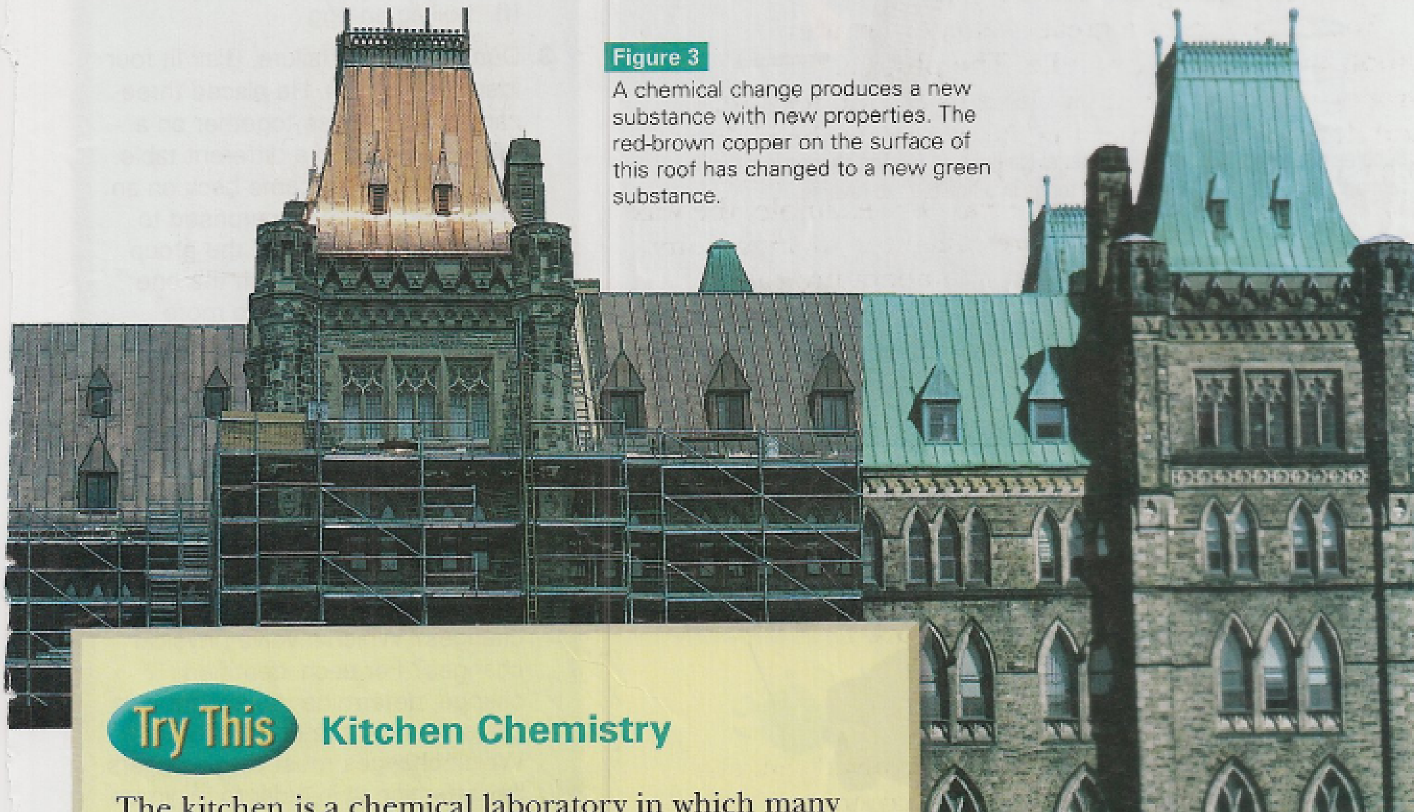


Figure 3

A chemical change produces a new substance with new properties. The red-brown copper on the surface of this roof has changed to a new green substance.

Try This — Kitchen Chemistry

The kitchen is a chemical laboratory in which many changes in matter occur. Obtain samples of the following substances: salt, water, baking soda, baking powder, and vinegar. Try mixing together small amounts of the substances in combinations of two. Create a table like **Table 1** to record your results.

Some household chemicals form dangerous products when mixed together. Check with your teacher before mixing any substances other than those listed.

Table 1 Mixing Kitchen Chemicals

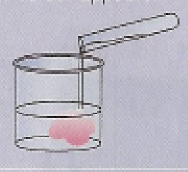
Substances Mixed	Observations	Evidence of a new substance?
salt and water	?	?
?	?	?

Chemical or Physical?

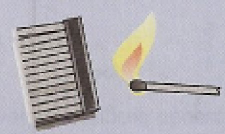
You can't see the chemical change in the wax just by looking at a burning candle. So how can you tell if a chemical change has occurred? The clues listed in **Table 2** can help you decide. But do not come to a conclusion too quickly. All of these clues *suggest* that a new substance has been produced, but any one of them could also accompany a physical change. You must consider several clues in order to determine what type of change has taken place.

Table 2 **Clues That a Chemical Change Has Happened**

A new colour appears.

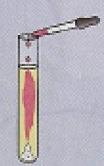


Heat or light is given off.



Bubbles of gas are formed.

A solid material (called a precipitate) forms in a liquid.



The change is difficult to reverse.

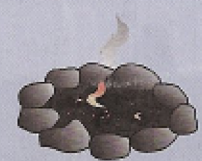
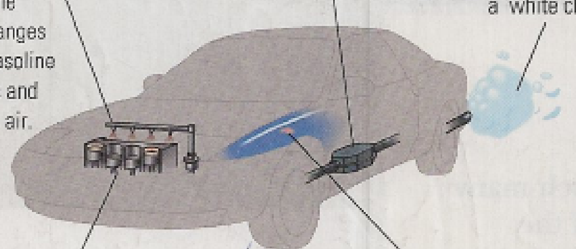


Figure 4

Operating a car involves many changes.



(a) In the fuel injector on top of the engine, changes occur as gasoline evaporates and mixes with air.

(b) Inside the engine cylinders, the explosion of the gasoline-air mixture produces hot exhaust gases, including water vapour, carbon dioxide, and nitrogen oxides.

(c) The exhaust gases pass through the catalytic converter, where some harmful gases are changed into safer new gases.

(d) The exhaust passes out the tailpipe. On a cold day, steam from the exhaust condenses into a white cloud.

(e) As the steel of the car is exposed to air and water, a crumbly reddish-brown substance forms: the steel has changed into rust.

Challenge

Identify physical and chemical changes that are useful to us. How would you display these examples?

In what ways can the substance you are marketing change physically or chemically? How does this make it useful?

Understanding Concepts

1. Explain how a physical change differs from a chemical change.
2. Classify each of the following as a physical or a chemical change. Explain why.
   - **(a)** garbage rotting
   - **(b)** cutting up carrots
   - **(c)** a silver spoon turning black
   - **(d)** making tea from tea leaves
   - **(e)** bleaching a stain
   - **(f)** boiling an egg
3. During a power failure, Blair lit four identical candles. He placed three candles very close together on a table, and one on a different table. When the power came back on an hour later, Blair was surprised to see that the candles in the group were much shorter than the one by itself. There was also more melted wax around the base of each of the three candles. Account for Blair's observation. What kind of candles should you keep on hand for emergencies?

Making Connections

4. Which of the changes described in **Figure 4** involve chemical changes? Which involve physical changes? For each identified change, determine the impact it could have on the environment. Which changes must car designers pay attention to in order to minimize damage to the environment?

Reflecting

5. Go back to the list you brainstormed for Getting Started (3) on page 13. Write beside each change on your list whether it is chemical or physical. If you are not sure of any, just leave a blank space. You can return to your list as you work through this chapter.

Career Profile

Hair Colourist

If you have the right personality and an *interest in the aesthetic side of* chemistry, then Helder Sousa recommends the job of colour technician. After studying for 10 months in a school for hair stylists, he soon gravitated to the technician side of the work.

While his high school chemistry helped give him an understanding of chemical processes, Sousa did most of his learning as an apprentice at a well-known Toronto salon. He started as an assistant, doing the shampooing and sweeping while he learned about colour theory. Gradually, by working with an experienced colourist, he learned how to achieve the effects the clients wanted. In many ways, learning how to colour hair is more complex than cutting. "Now, I have no nervousness about it. With the years comes more knowledge, like any job."

> "You have to love what you do—it's hard work to become good at it, and people are very picky about their hair."

The business begins and ends with the clients. "You may have an idea of what auburn means, but the client may mean something else—and you have to figure out just exactly what colour they want."

People tend to confide in their colourists, so psychological skills are in order too. "Good listening skills are a must. This is not the industry for someone who doesn't enjoy working with people." But if you do like working with people, and you're good at matching the right colours to the client, you can follow a range of careers—in film, television, or magazines. Sousa's advice: "Study long and hard and work in a good salon."

Exploring (3A)

1. There are two basic types of hair colour: temporary and permanent. Research how they differ chemically and how they affect the hair.
2. Find out if there are any courses for hair stylists in your area. What background is required? How long is the training?
3. What are the advantages of apprenticing, compared with college courses?
4. Create a pamphlet to inform others who may be interested in a career as a colour technician.

SKILLS HANDBOOK:
(3A) Research Skills

1.8 Investigation

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ○ Communicating

Observing Changes

Using their knowledge of physical and chemical properties and current technology, chemists cause many useful changes, including transforming crude oil into plastics, and changing minerals from the ground into copper and iron.

In this investigation, you will learn more about physical and chemical changes. Remember that a change is probably physical unless there is almost certain evidence that a new substance has been produced.

Materials

- safety goggles
- apron
- 4 test tubes
- test-tube rack
- distilled water
- 2-mL measuring spoon
- copper(II) sulfate powder
- test-tube stopper
- iron (a piece of steel wool about 1 cm × 1 cm × 2 cm)
- stirring rod
- dilute sodium carbonate (5% solution)
- dilute hydrochloric acid (3% solution)
- magnesium ribbon (2-cm strip)
- tongs

Copper(II) sulfate is poisonous. Report any spills to your teacher.

Hydrochloric acid is corrosive. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to your teacher.

Question

How can we recognize physical and chemical changes?

Hypothesis

1 Write a statement to answer the question.

4A

Procedure

Part 1: Copper(II) Sulfate and Water

2 Put on your apron and safety goggles.

3 Make a table similar to **Table 1** to record all your observations and inferences.

Table 1 Physical and Chemical Changes

Part	Starting Substances		Observations after Mixing	Inference Physical? Chemical?	Evidence
	Name	Properties			
1	water	?	?	?	?
	copper(II) sulfate	?	?	?	?
2	?	?	?	?	?

4 Obtain a small amount of copper(II) sulfate in a test tube. Put the test tube in the test-tube rack. Obtain some distilled water.

(a) In your table, describe the water and the copper(II) sulfate.

5 Pour distilled water into the test tube containing the copper(II) sulfate, to a depth of about 4 cm. Put a stopper in the test tube to seal it. Take the tube out of the rack and mix the contents by turning the tube upside down several times. Return the test tube to the rack.

Step 5

(a) Was there a change? Record your observations.

(b) Make an inference based on your observations: if there was a change, was it physical or chemical? How do you know? Record your inference and the evidence to support it.

Part 2: Copper(II) Sulfate and Iron

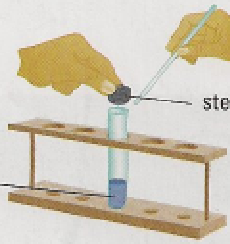
6 Into another clean, dry test tube in the rack, pour some of your mixture of copper(II) sulfate and water, to a depth of about 2 cm. (Save the remainder of your copper(II) sulfate mixture to use in Part 3.) Obtain a piece of steel wool (iron).

(a) Describe the steel wool and the solution before you continue.

SKILLS HANDBOOK: 4A Asking Questions and Hypothesizing

7 Using a stirring rod, push the steel wool into the copper(II) sulfate mixture.

Step 7



(a) Record your observations.

(b) Was there a physical or a chemical change? What is the evidence?

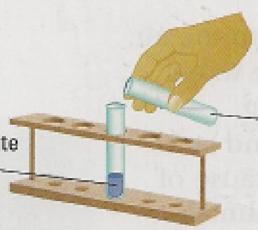
Part 3: Copper(II) Sulfate and Sodium Carbonate

8 Into another clean, dry test tube, pour sodium carbonate solution to a depth of about 1 cm.

(a) Describe the sodium carbonate solution and the remainder of your copper(II) sulfate mixture.

9 Pour one solution into the other.

Step 9



(a) Record your observations.

(b) Was there a physical or chemical change? What is the evidence?

10 Dispose of the mixtures in the test tubes as instructed by your teacher.

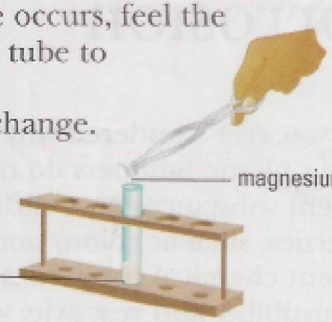
Part 4: Hydrochloric Acid and Magnesium

11 Into another clean, dry test tube, pour dilute hydrochloric acid to a depth of about 2 cm. Obtain a small piece of magnesium ribbon.

(a) Describe the dilute hydrochloric acid and the magnesium.

12 Using tongs, carefully add the magnesium ribbon to the test tube without splashing. As any change occurs, feel the bottom of the tube to check for any temperature change.

Step 12



(a) Record your observations.

(b) Was there a physical or chemical change? What is the evidence?

13 Dispose of the mixtures as instructed by your teacher. Wash your hands.

Analysis and Communication

14 Analyze your observations using your completed table by answering the following questions:

(a) What kind of change took place when you mixed the substances in each part of the investigation? What evidence do you have? Does this support the hypothesis?

(b) In each part of this investigation, identify what physical properties changed?

(c) Look at **Table 2** on page 30. Which of those clues did you observe?

(d) Which of the changes you observed might be reversed? Explain how.

Understanding Concepts

1. What are some examples of physical and chemical changes in the home? Give reasons for your classification.

Reflecting

2. If you wanted to test more properties of a new substance formed in Part 2, how could you separate it from other materials in the test tube?

Corrosion

Have you ever wondered why metal car bodies rust but plastic bumpers do not? As you know, different substances have different physical properties, such as colour and hardness, and different chemical properties, such as combustibility and reactivity with acid. One chemical property that has great economic importance is the tendency of a substance to undergo **corrosion**—the slow chemical change that occurs when a metal reacts with oxygen from the air to form a new substance called an oxide.

Figure 1
Rust damages many steel car bodies.

Kinds of Corrosion

The most dramatic example of corrosion is rusting—the reaction of iron with oxygen to form iron oxide. Iron is usually found in the form of steel, a mixture of iron, carbon, and other substances. This alloy or mixture of metals is much harder and tougher than the original iron.

Rusting is a chemical change that involves iron, oxygen from the air, and water, as well as the salts or other minerals dissolved in the water. Every year, millions of dollars of damage are caused to building structures, vehicles (like the car in **Figure 1**), and other iron and steel products due to this process. Rust is particularly damaging because of one of its physical properties: rust is porous, absorbing water almost like a sponge. As a result, it dissolves or flakes off, leaving another layer of fresh metal underneath to be attacked by oxygen. The process continues until the rust has eaten its way through the metal.

By contrast, aluminum has a similar chemical property in that it also reacts with oxygen, but the aluminum oxide that forms is strong and unaffected by water. The corrosion stops and the oxide acts as a protective coating. If you have aluminum cooking pans at home, you will be familiar with the grayish, dull coating of aluminum oxide.

Even silver develops a surface coating of tarnish if it comes into contact with sulfur-containing foods such as eggs or mustard. The black coating seen in **Figure 2** is silver sulfide. Silver tarnishes slowly if left out in the air; the more sulfur-containing pollutants in the air, the more quickly it tarnishes. The black layer can be removed by polishing the silver.

Figure 2
Silver slowly corrodes in air.

Preventing Corrosion

There are several ways to prevent corrosion. One method is to paint the surface of the metal (**Figure 3**). As long as the painted surface is not broken or cracked, oxygen in the air cannot get at the metal. For the same reason, cars are often sprayed with oil to coat the bottom and inner surfaces of the car body. Iron can also be protected by coating it with other metals.

Some metals have the chemical property of being easier to corrode than iron. This property is used to protect the hulls of ships and boat motors. For example, as seen in **Figure 4**, a plate of zinc is attached to steel boat motors. The steel motor parts remain untouched as the zinc is slowly used up. The zinc is replaced when it has completely corroded.

A special alloy of steel, made by mixing iron with nickel and copper, is now used in some building structures. The metals corrode quickly but the nickel and copper oxides form a protective layer that prevents further rusting.

Another way to prevent corrosion is to use materials that have different chemical properties. Plastics are being used increasingly in car bumpers and panels that get frequent bumps and scratches. Steel loses its strength if air and water penetrate through a scratch in the paint, but plastics never corrode and remain strong and flexible.

Figure 3

Some bridges are so large that painters take years to finish the whole structure. Then they have to begin again!

Figure 4

Another metal attached to a boat motor can protect it from corrosion in a process called cathodic protection.

Understanding Concepts

1. What is "corrosion"?
2. How is an oxide formed?
3. Describe two processes that form two different oxides.
4. Make a poster describing three ways to protect a metal from corrosion.

Making Connections

5. Corrosion of automobiles causes millions of dollars of damage every year. Which parts of the automobile corrode the most? Why? Describe how car owners and manufacturers can help to reduce the effect of corrosion.
6. Make a list of the products that you have in your home that can corrode. What decisions or steps can you take to protect these products from corrosion?

Reflecting

7. Engineers design pipelines to carry oil or natural gas over hundreds of kilometres. These pipelines are made of steel, but do not corrode. The engineers attach other metals to the pipelines every kilometre or so. How does this protect the steel?

1.10 Investigation

SKILLS MENU
- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

Preventing Corrosion

What kinds of decisions do designers and engineers make when they design products for people to buy? And what kinds of research do they do to help them with those decisions? You have learned that corrosion is a kind of chemical change that affects many everyday products. Being able to design and conduct experiments on corrosion is part of research and development for many companies. In this activity you will take on the role of someone in one of these industries and design an experiment to try to improve a product.

Part 1: Designing Engineering Team (2A)

You are part of the design engineering team for PDQ Automobile Corporation that has just designed a revolutionary commuter car (**Figure 1**). It is very lightweight and, therefore, fuel-efficient because it uses metals such as aluminum and magnesium instead of steel in the frame and body. However, critics have suggested that these metals are more likely to corrode, especially in Canadian winters when salt is used on the roads.

Materials

- sample strips of aluminum, magnesium, and steel
- a sheet of emery paper (to polish the metal)
- 6 beakers
- labels and marking pens
- salt
- water

Figure 1

Question

1. What question does your design team need to answer to support its choice of materials?

Hypothesis

2. Write a hypothesis for this experiment, based on the claims of PDQ's critics.

Experimental Design

3. Design an experiment, using the materials provided, to test your hypothesis.

Procedure

4. When you have your teacher's approval for your design, make a data table that you can use to record observations.
5. Assemble the necessary materials and conduct your experiment.

Analysis and Communication

6. Analyze your observations by answering the following questions:
   (a) Describe the appearance of the materials before you started.
   (b) Describe the appearance of the materials at various times during the testing period.
   (c) How did you design your experiment to make sure that the type of metal was the only variable?
7. (8C) Present your data and conclusions to the Board of Directors at PDQ. You may want to design a logo, motto, or mission statement for PDQ Corporation as part of your presentation.

SKILLS HANDBOOK: (2A) Controlled Experiments (8C) Science Projects

Part 2: Corrosion Laboratory Team (2A)

You are part of a small corrosion laboratory which has a contract with Ace Rust-Prevent Corporation. Your research team has been told to investigate the effectiveness of various methods of rust prevention, especially in Canadian winter conditions.

Materials

- steel nails
- a sheet of emery paper (to polish the metal)
- 6 beakers
- salt
- water
- rust-proofing chemicals (if available)
- motor oil
- paint
- paint brush

Question

1 What question does your laboratory need to answer for Ace Rust-Prevent Corp?

Hypothesis

2 Write a hypothesis for the experiment your laboratory will perform.

Experimental Design

3 Design an experiment, using the materials provided, to test your hypothesis.

(1B) Include safety precautions in your design.

Procedure

4 When you have your teacher's approval for your design, make a data table that you can use to record observations.

5 Assemble the necessary materials and conduct your experiment.

Analysis and Communication

6 Analyze your observations by answering the following questions:

(a) Describe the appearance of the materials before you started.

(b) Describe the appearance of the materials at various times over the testing period.

(c) How did you design your experiment to make sure that the different types of protection were tested fairly?

(d) Compare the effectiveness of the different methods of protection.

7 (8C) Discuss your data with your team and write a proposal for the most effective method. You may want to design a name and logo for your research laboratory as part of your presentation.

Reflecting

1. Review the scientific inquiry process outlined in section 2A of the Skills Handbook.
   - **(a)** Which steps did you follow in this investigation?
   - **(b)** Which steps were easiest, and which were most challenging. Explain why.
2. How did you organize your team? How successful were you?
3. What improvements would you make in your design or investigation if you were to do it again?

Challenge

What factors made the proposals effective? How can you use them to market your substance?

(1B) Safety in the Laboratory

Combustion

What chemical reaction occurs in the gas furnace that heats your home? What kind of chemical reaction occurs when you light a match? What caused the forest fire in **Figure 1**? What makes a car engine work? These, and the fires shown in **Figures 2** and **3**, are examples of an important type of chemical reaction called combustion. In **combustion**, a substance reacts rapidly with oxygen and releases energy. The energy is observed as heat and light. Many substances, such as wood, kerosene, and diesel oil, burn readily in air, which is only about 20% oxygen. This makes them useful as fuels.

The three necessary components of combustion are illustrated in **Figure 4**, called the fire triangle.

Fossil Fuels and Combustion

Coal, oil, natural gas, and gasoline are all fuels. They are called **fossil fuels** because they were formed from plants, animals, and microorganisms that lived millions of years ago. When these organisms died, they did not decompose completely. Instead, they were buried by sediments and the energy in their cells remained "locked up."

Human technology, developed over the centuries, depends on these long-buried organisms. Their stored energy powers homes, industries, and various means of transportation.

When any fossil fuel burns, the main products of the reaction are carbon dioxide and water vapour. The particles that make up fossil fuels are called **hydrocarbons**. To represent the combustion of a fossil fuel simply, the following word equation can be used:

hydrocarbon + oxygen → carbon dioxide + water

In a **word equation**, the substances you start with are written on the left and are called the **reactants**. The resulting substances, written on the right, are called **products**.

Figure 1
Some combustion reactions are destructive. Forest fires consume thousands of hectares of trees every year in Canada.

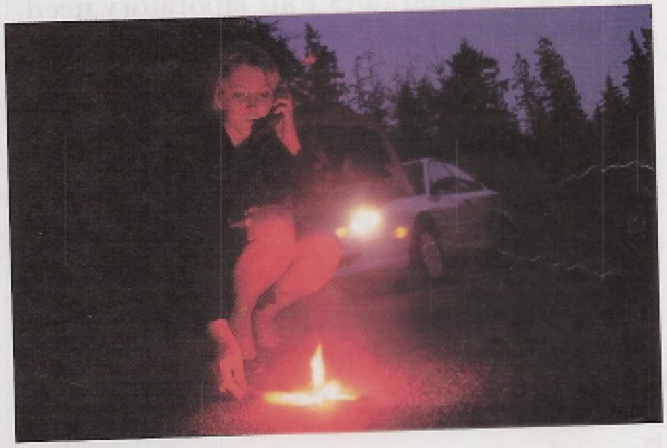


Figure 2
The quick reaction of magnesium with oxygen is combustion. Magnesium is often used as a component of emergency flares, which produce a bright light even in rain or snow.

Figure 3
Fires can rage for months when oil wells burn out of control. The fires can be extinguished using explosives and other methods that seal the leaking oil. Which component of the fire triangle is removed to stop the fire?