TOPIC 8 Reaction Rate

Chemical reactions can occur at different speeds (See Figures 2.58 A, B, and C). Why does one reaction take longer than another? Can you measure the speed of a chemical reaction? Can you slow down or speed up a chemical reaction?

The **reaction rate** is a measure of how fast a reaction occurs. To find the rate of reaction, you can measure either how quickly one of the reactants is disappearing or how quickly one of the products is appearing. Both measurements show how the amount of a substance changes per unit of time.

The rate of a chemical reaction can be speeded up or slowed down by changing the temperature. At higher temperatures the rate of most chemical reactions increases. Faster-moving molecules and atoms collide more frequently and therefore can form new substances more quickly. For example, the high temperature inside an oven speeds up the chemical reactions that change the liquid batter into a cake. Fresh fruit and vegetables are often kept in the refrigerator to slow down the chemical reactions.

Other ways of changing the rate of reactions include stirring and changing the size or the concentration of the reactants. Stirring a cake batter will speed up the reaction rate. If you grind up a chemical before mixing it, there will be more surface area for the chemical reaction. If you increase the concentration of a substance, you will increase the number of particles of a substance per unit of volume.

Figure 2.58A To speed up this reaction, ammonium nitrate has been ground into a powder and heated to a high temperature.

Figure 2.58B How could you speed up the reaction rate for a banana to ripen? How could you slow down the reaction rate?

Figure 2.58C How long do you think it has taken for carbonic acid to dissolve limestone and form this cave?

Find Out ACTIVITY

Changing with the Times

How can you speed up or slow down a chemical reaction?

Procedure

Do not perform the reactions shown in the table. Read the description of each trial. Think about the effect of the change in conditions on the rate of each reaction.

Chemical reaction	Trial 1	Trial 2
A. Calcite reacts with hydrochloric acid	The calcite is in large pieces	The calcite is in small pieces
B. Sulfuric acid reacts with the lead in a car battery	The acid is a 5% solution	The acid is a 10% solution
C. $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$	The reactants are stirred	The reactants are not stirred
D. An iron nail reacts with a solution of copper (II) sulfate	The reaction takes place at 65°C	The reaction takes place at 25°C

1. Predict which reactions would be faster in the second trial. Explain.
2. Predict which reactions would be slower in the second trial. Explain.
3. Write a word equation describing the chemical reaction in C.

What Did You Find Out? Analyzing and Interpreting

1. What additional changes could be made in chemical reaction A if you wanted to increase the speed of the reaction?
2. What could be done to slow down the chemical reaction in reaction B?

Extensions

4. What are two advantages to increasing the reaction rate for reactions? Give an example for each.
5. What are two advantages to decreasing the reaction rate for reactions? Give an example for each.

Career CONNECT

The Right Mix

Years ago, pharmacists ground up and mixed together the ingredients of many prescriptions themselves. Even though prescriptions these days come ready-mixed from pharmaceutical companies, pharmacists like Ginette Goulet still need to know about reaction rates.

Ginette has to know which combinations of prescription drugs and other factors can affect chemical reactions and cause problems for the patient. She lets her customers know, for example, if the prescription they receive should not be taken with milk, or if it should be taken on an empty stomach to be most effective. She also lets them know if certain "over-the-counter" drugs, such as antihistamines, should not be taken until they have finished the course of their prescription. Since some customers may be on more than one prescription at the same time, she needs to know which drugs can be taken safely together, so that there are no conflicts between the prescribed drugs.

Speeding Up a Reaction with Catalysts

Another way to change the rate of a reaction is to add or remove a substance called a catalyst. A **catalyst** is a substance that speeds up the rate of a reaction without being changed itself. A catalyst does not affect the amount of product produced in a chemical reaction. A catalyst increases only the *speed* of the reaction.

An **enzyme** is a natural catalyst made by living things. Almost all chemical reactions that take place in the body are catalyzed by enzymes. When you chew a piece of bread, glands in your mouth produce saliva, which contains an enzyme (see Figure 2.57). The enzyme in saliva acts as a catalyst to help break down starches into smaller molecules. When you get a foreign particle in your eye, an enzyme in your tears attacks the cell walls of bacteria, preventing them from infecting the eye.

Many other chemical reactions depend on catalysts to help them work faster. For example, the production of vegetable shortening, synthetic rubber, and high-octane gasoline are all chemical processes that succeed with the help of catalysts. Some laundry detergents contain enzymes that break down the proteins responsible for many stains in clothing.

You will examine the effects of a catalyst in the next investigation.

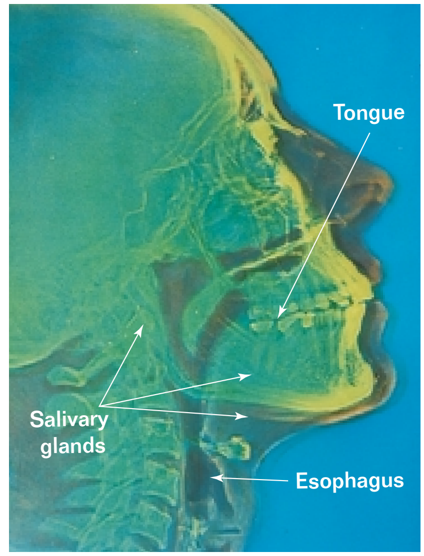


Figure 2.57 As you chew your food, the salivary glands in your mouth release an enzyme. The enzyme speeds up the breakdown of food.

Math CONNECT

A chemical reaction is proceeding at a rate of 4 g of product produced every 30 s. How many minutes will it take to obtain 80 g of the product from the reaction?

Slowing Down a Reaction with Inhibitors

Suppose you wanted to slow down the rate of a chemical reaction. What could you do? You could add an inhibitor. **Inhibitors** are substances that slow down chemical reactions. For example, some plants have natural inhibitors in their seeds to prevent germination until conditions are just right. Inhibitors are added to some foods and medicines to slow down their decomposition.

In the last investigation you observed that hydrogen peroxide decomposes to form oxygen and water (see Figure 2.58). An inhibitor is added to bottles of hydrogen peroxide to prevent its molecules from decomposing too quickly.

Figure 2.58 Hydrogen peroxide helps to disinfect wounds. Which gas is being produced in this picture?

DidYouKnow?

One of the most important groups of enzymes are the proteases. The proteases break down proteins. Proteases are used in many common products, such as meat tenderizers and contact lens cleaning solution. Proteins secreted by the cells around the eyes build up on contact lenses. Proteases in the cleaning solution help to remove the proteins. Sometimes people have deficiencies in certain enzymes. Research "lactose intolerance" on the Internet or at the library. Find out which enzyme is missing in people who have this condition.

INQUIRY

INVESTIGATION 2-H

SKILLCHECK
- Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- Communication and Teamwork

Reaction Time

The compound hydrogen peroxide will slowly decompose into water and oxygen if left in an open container.

$2H_2O_{2(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$

Question

What will happen to the decomposition time of hydrogen peroxide if a catalyst is added?

Hypothesis

Formulate a hypothesis about how the addition of a catalyst affects the decomposition of hydrogen peroxide.

Safety Precautions

- Hydrogen peroxide can irritate your eyes and skin. Be sure to wear protective equipment. Do not use more than 5 mL of 3% hydrogen peroxide in each test tube.
- If you accidentally spill hydrogen peroxide on your skin, wash it off with lots of cool water.
- Use caution with hot objects.
- Before striking matches, check that there are no flammable solvents nearby.

Apparatus

600 mL beaker
hot plate
2 test tubes
graduated cylinder (10 mL)
test tube rack
test tube tongs
metric measuring spoons

Materials

water
3% hydrogen peroxide
manganese dioxide
wooden splints
matches

Procedure

1. Make an observation chart like the one below.
2. Add 300 mL water to the beaker. Place the beaker on a hot plate. Turn the hot plate to medium power.
3. Put two test tubes in the test tube rack. Label the test tubes A and B.
4. Pour 5 mL 3% hydrogen peroxide into each of two test tubes.
5. Place 2 mL manganese dioxide in test tube A. **Record** your observations.
6. Light a wooden splint. Blow out the flame and quickly insert the glowing splint into each test tube. Do not let the splint touch the liquid. **Record** your observations.
7. Place both test tubes in the hot water bath. Heat the test tubes until all of the liquid in both test tubes has evaporated.
8. Remove the test tubes from the hot water bath. **Record** your observations.
9. Repeat step 6.
10. Turn off the hot plate. Return all equipment to the proper location. Wash your hands.

	Observations	
Test tube	**Before heating**	**After heating**
A		
B		

Analyze

1. Describe what happened when the manganese dioxide was added to test tube A.
2. What gas was produced in the test tube with manganese dioxide? How do you know?
3. In which test tube did the reaction occur more quickly? How do you know?
4. What remained in the test tubes at the end of the procedures?

Conclude and Apply

5. What is the function of the manganese dioxide? Give reasons for your answer.
6. How could you make this experiment more quantitative and make more accurate measurements?

Extensions

7. In the photograph below, sugar has been added to a carbonated beverage. Explain what has happened.

8. Construct a model that shows the decomposition of $2H_2O_{2(aq)}$ into $2H_2O_{(l)}$ and $O_{2(g)}$.

Pause& Reflect

Electronic equipment is usually packaged with small packets of silica gel. Silica gel is a desiccant. Desiccants absorb water vapour from the air. What chemical reaction is silica gel helping to prevent? What else will a dryer environment help prevent? Which other products are packaged with silica gel?

Figure 2.59 Iron combines with pure oxygen in the flask to form iron oxide. This is the same reaction as the rusting of iron, but happens much faster.

Corrosion

What happens to some metals when they are exposed to air and moisture? The metals undergo a chemical reaction and gradually corrode. **Corrosion** is the oxidation of metals or rocks in the presence of air and moisture. You may be familiar with one type of corrosion: **rust**. Rust is iron oxide, a product of the chemical reaction of iron, oxygen, and moisture. One equation for corrosion is shown below:

$$\underset{\text{(iron)}}{4Fe_{(s)}} + \underset{\text{(oxygen)}}{3O_{2(g)}} \rightarrow \underset{\text{(iron oxide)}}{2Fe_2O_{3(s)}}$$

Take a closer look at corrosion in the next activity.

Find Out ACTIVITY

Corrosion Collection

What role does a gas play in the process of corrosion?

Materials

gas collecting bottles	pie plate or dish
steel wool	grease pencils or tape
vinegar	water

Procedure Performing and Recording

1. Clean the steel wool by dipping it in the vinegar.
2. Pack the steel wool tightly in the bottom of the gas collecting bottle so it will not fall out when the bottle is inverted.
3. Fill the pie plate or dish two thirds full with water. Invert the gas collecting bottle containing the steel wool in the pie plate.
4. Mark the starting level of water in the gas collecting bottle with masking tape or a grease pencil.
5. Observe for at least two weeks. Every five days mark the level of water in the gas collecting bottle and add more water to the pie plate.

What Did You Find Out? Analyzing and Interpreting

1. What happened to the level of water in the gas collecting bottle when you first inverted it in the pie plate? Over a period of two weeks?
2. Why did you invert the bottle in the water?
3. Did a chemical or physical reaction take place? How do you know?
4. List the products and reactants of this reaction.
5. What gas is needed for corrosion to take place? What part of your experiment helped you make this inference?

Extensions

6. How could you have increased the reaction rate? How could you have decreased the reaction rate?
7. Make an inference as to how much of the atmosphere is composed of oxygen. Use the results of your experiment to make this inference.

Preventing Corrosion

Corroded materials lose their strength. Once the top layer of metal has corroded, more surface area is exposed. Oxygen from the air can then reach the inner layers. Corrosion also occurs at points of strain in the metal. Rust will eventually make its way through the metal, and the object will be completely corroded.

One way to protect a metal from corrosion is to apply a thin coating of paint. Another way to protect a metal is to coat it with zinc, which is more resistant to corrosion. The process of coating metals with a thin layer of zinc is called **galvanization**. What are some examples of galvanized products? Houses and buildings under construction are exposed to moisture and air, which could corrode the metal parts before the building is complete. If the nails and other metal parts are galvanized, then corrosion is not a serious problem.

Other metals can also be used as a covering to prevent rust. Some car bumpers are coated with a thin layer of chromium to protect the iron from corroding. The process of covering a metal with another metal by using electrolysis is called electroplating. Chromium is often electroplated onto a softer metal to improve its hardness, stability, and appearance.

Figure 2.60 The surface of a can that contains iron corrodes quickly outdoors. The rust formed on the surface of the can flakes off easily, so the can continues to corrode. The surface of an aluminum can oxidizes very quickly. The aluminum oxide formed makes a tough protective layer, which does not flake off easily. Therefore, aluminum cans will take over 400 years to degrade. How can you tell that most of the cans in this picture contain iron?

Combustion

Combustion is the highly exothermic combination of a substance with oxygen. Combustion requires heat, oxygen, and fuel. You may be familiar with the burning that takes place in a fireplace, a gas barbecue, or the furnace in your home. Did you know that combustion also takes place inside the internal combustion engine in a car? Gasoline combines with oxygen to release energy to make the car move. Every time something burns, it combines with oxygen from the air. Even the food you eat is converted to energy by combining with the oxygen that you breathe. You will investigate reactants and products of combustion in the next investigation.

Figure 2.61 How is enough heat produced to melt metal? The combustion reaction of acetylene and oxygen is

$$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)} + \text{energy}$$

DidYouKnow?

There are several forms of iron oxide, each with interesting, observable properties. Iron (II) oxide sometimes ignites spontaneously in air. Iron (III) oxide is called hematite, and is reddish brown in colour. Rouge is a specially purified form of iron (III) oxide, and Venetian red, which is largely iron (III) oxide, has been used to paint bridges, barns, and outdoor structures.

SKILLCHECK
- Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- Communication and Teamwork

An Illuminating Experience

In this investigation you will investigate the products of combustion. The investigation is divided into three parts. Be sure to keep accurate records of the results of each part of the experiment.

Question

What are the products of the combustion of a candle?

Hypothesis

Formulate a hypothesis about what the reactants and products are in the combustion of a candle.

Safety Precautions

- Before lighting candles, make sure there are no flammable solvents nearby.
- Use care with matches.

Apparatus

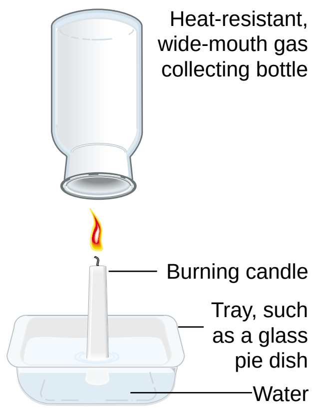
tray for water (15 cm x 20 cm)
gas-collecting bottle or glass jar
evaporating dish
all-purpose tongs

Materials

matches
candle (10 cm x 1 cm diameter)
ice cubes
aluminum foil
water

Procedure

1. Make an observation chart similar to the one shown below.



Part 1

2. Light the candle. Use a few drops of candle wax to secure the candle to the middle of the tray. Fill the tray two-thirds full of water.
3. While the candle is still burning, lower the inverted gas-collecting bottle or jar over the candle. Carefully **observe** what happens both to the candle and the level of water in the bottle.
4. **Record** observations on your chart and make inferences as to what happened.

Part 2

5. Light the candle.
6. Place an ice cube in the heat-resistant evaporating dish. Hold the evaporating dish with the all-purpose tongs over the burning candle for 10 s.
7. **Record** your observations. There should be at least two significant observations.

Investigation	Observations	Inferences
Part 1		
Part 2		
Part 3		

Part 3

8. Cut a piece of aluminum foil in a circle that has a diameter of approximately 22 cm. Fold the circle of foil in half, and in half again. Cut a small hole at the corner where all folds meet. Open the foil to make a large cone with a hole in the middle.

9. Hold the cone with the all-purpose tongs and place it over the burning candle with the hole near the top of the flame. Be careful not to extinguish the flame.

10. Light a match. Hold it over the hole in the aluminum foil that is being held over the burning candle. Be careful not to burn yourself.

11. **Observe** and **record** your observations.

Analyze

1. What are the products of the combustion of a candle? What evidence supports your answer?

2. Which product(s) of combustion are most important to your daily life? Why?

3. Which part of the experiment illustrates one of the reactants needed for combustion? What is the reactant?

4. Which safety precautions did you follow while working near an open flame? How could you improve your awareness of safety during investigations?

Conclude and Apply

5. What is the chemical name and formula for the black substance found on the bottom of the evaporating dish in Part 2? Where could the black substance have come from? Explain.

6. Research on the Internet or in the library and write the chemical equation for the combustion of gasoline in an automobile. (Hint: The organic compound octane is found in gasoline.)

Products of Combustion

You have just investigated the products in the combustion of a candle. Another chemical reaction involving combustion occurs when propane is burned in a barbecue. Burning propane is an exothermic reaction that produces heat to cook the food. When the heat becomes too intense, sometimes the organic compounds in the meat or vegetables are chemically changed to pure carbon as seen by the black coating. The equation for the combustion of propane is shown below:

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} + \text{energy (heat)}$$

propane + oxygen → carbon dioxide + water + energy (heat)

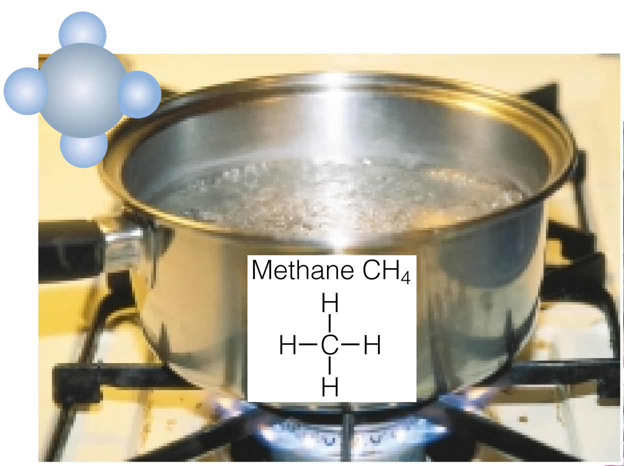
Compare the equation for the combustion of propane with the equation for the combustion of methane on page 149.

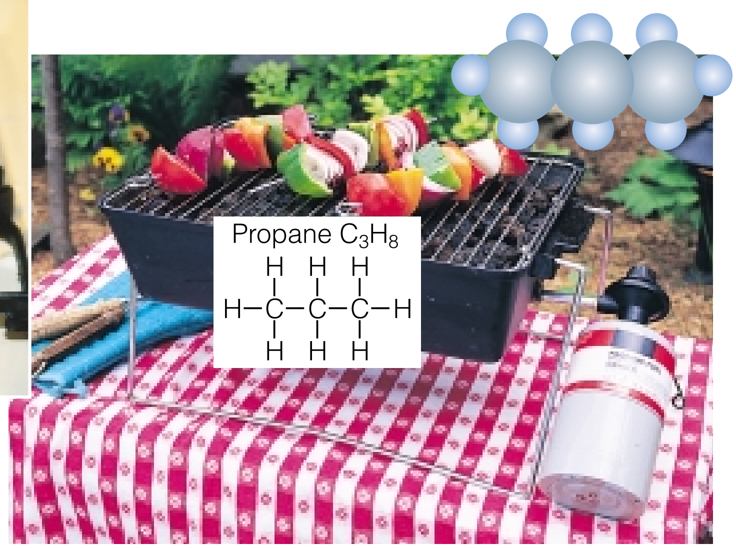
The products of combustion are not always beneficial. Burning wood or coal produces smoke and ash as well as heat. In addition, other substances are created by combustion. Soot, carbon monoxide, carbon dioxide, and oxides of sulfur and nitrogen can be created by the combustion of fuels such as coal, gas, and oil. Some products created when fuel is burned are pollutants. The brown haze that hangs over some cities is smog (see Figure 2.62). Smog is created when sunlight reacts with pollutant chemicals produced by burning fuels. You will learn more about pollution in Unit 3, Environmental Chemistry.

In the next activity you will observe several chemical reactions involving combustion.

Figure 2.62 Tiny particles of soot suspended in the air reduce visibility. These particles irritate the eyes and respiratory system.

Figure 2.63 Coal is a chemical mixture of carbon, sulfur, and other elements. Which element do you suppose is burning in this picture? Which chemical reaction is occurring while the coal is burning?





Figures 2.64A and B Burning methane and propane are examples of combustion reactions. Methane is the main component in natural gas and propane is sometimes used in barbecues.

Find Out ACTIVITY

Where's the Fire?

Combustion can be a simple or complex reaction. In this activity you are going to study a few simple reactions involving combustion. Be sure to place used matches, burned wood, and marshmallows in the appropriate waste container provided by the teacher.

Safety Precautions

- Before striking a match, make sure there are no flammable solvents nearby.
- Use care with matches and burning materials.

Materials

2 wooden splints
evaporating dish
wax
toothpick
miniature marshmallow
watch glass
matches
sugar cube

Procedure

Performing and Recording
Communication and Teamwork

1. Prepare an observation chart to collect your data and observations.
2. Light a wooden splint and observe the chemical reaction of the burning of the wood. Brainstorm with your group and see if you can write a word equation for the reaction you have just seen.
3. Break up a second wooden splint into small pieces and set them in an evaporating dish. Light the bits of broken splint. How does this reaction compare with the first splint you burned? Keep the ash for use later in this Find Out Activity.
4. Place a small piece of wax on a watch glass. Use a match to try to light the wax and make it burn. What happens?
5. Place a toothpick in a piece of wax to use as a wick. Light the toothpick and observe. Record your observations.
6. Place a marshmallow on a watch glass. Light the marshmallow with a match. Observe the reaction and record.
7. Place a cube of sugar on a watch glass. Try to light the sugar cube. Observe and record the results. Add a small amount of wood ash from your wooden splint fire to the sugar cube. Try to light the ash. Record your observations.

What Did You Find Out?

Analyzing and Interpreting

1. Write a word equation for the reaction you observed when you burned the wood.
2. Why were you not able to light the wax by itself or with the toothpick? (Hint: You are able to light candles made of wax.)
3. What are the products of combustion of a marshmallow?
4. What products are always made during combustion? How do you know?
5. What was the purpose of the ash you added to the sugar?
6. Describe the difference in burning times in steps 2 and 3. Explain why there was a difference.

Cool Tools

Virtual reality is the simulation of a real environment created by advanced technology. Headsets containing small screens can be used to view chemicals. Some chemists use cyberspace to build new compounds as shown in the picture to the right. The large purple ribbon-like molecule is an enzyme, while the blue is a DNA molecule. Chemists also use computers to predict the outcome of chemical reactions and the effect of catalysts. Computers provide a safe alternative starting point for the more dangerous experiments.

Stretch Your Mind

Articles on board the *Titanic* spent many years in seawater before they were brought to the surface. Many were covered with corroded metals, sand, and other chemicals. Chemistry helped to restore these items. Electrolysis and another process, called electrophoresis, were used to remove the corrosion from leather, bank notes, and these casserole dishes. Electrophoresis is a technique of separating ions. The artifact is placed in an electrolyte solution and a current is applied. The current breaks up the dirt, salts, and other corroded materials as the particles move to the electrodes.

TOPIC 8 Review

1. List five ways you could increase the rate of a chemical reaction.
2. List five ways you could decrease the rate of a chemical reaction.
3. Explain the differences between the terms in each of the following pairs of words:
   (a) reactant, product
   (b) catalyst, inhibitor
   (c) chemical reaction, rate of reaction
4. In your own words, describe the effects of the following factors on the rate of a chemical reaction.
   (a) concentration
   (b) surface area
   (c) temperature
5. State a word equation for corrosion.
6. Describe the process of galvanization. Why are some metal products, such as nails and bolts, galvanized?
7. Why does a candle burn longer in the open than under an inverted glass jar?
8. What are some of the beneficial and harmful effects of burning fuels?
9. **Thinking Critically** Describe the similarities and differences between combustion and corrosion.

Wrap-up TOPICS 7-8

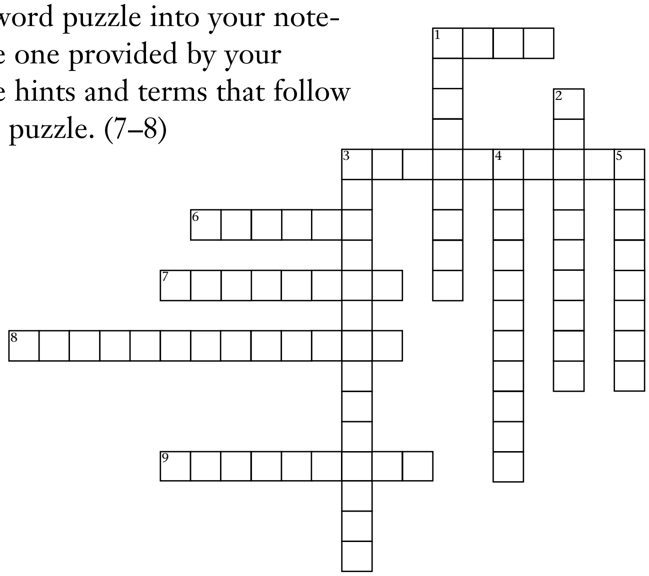
If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

chemical reaction
reactants
products
exothermic
endothermic
reaction rate
catalyst
enzyme
inhibitors
corrosion
rust
galvanization
combustion

Reviewing Key Terms

1. Copy the crossword puzzle into your notebook, or use the one provided by your teacher. Use the hints and terms that follow to complete the puzzle. (7–8)



Across
1. a type of corrosion
3. gives off energy
6. a type of catalyst
7. after the reaction
8. coat with zinc
9. slows down processes

Down
1. before the reaction
2. burning
3. deposit using currents
4. needs energy
5. speeding up, but not involved

Understanding Key Concepts

2. Is the following reaction endothermic or exothermic? How do you know? (7)

$$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)} + \text{energy}$$

3. If you wanted to slow down a chemical reaction, what could you add? Give several examples. (8)

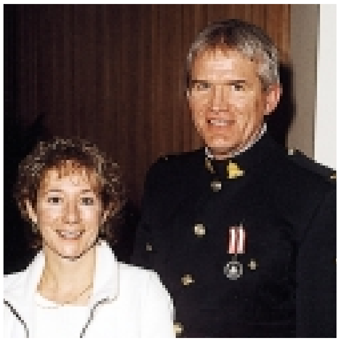
4. Give examples of three things that affect the rate of a chemical reaction. (8)

5. If you add a chemical to a test tube and the test tube becomes warmer, what can you infer? Give two different inferences. (7)

6. **Apply** Why are automobiles made with steel, which corrodes easily, instead of aluminum, which takes longer to completely corrode? (8)

7. **Thinking Critically** Give the word equation for photosynthesis and the word equation for respiration. Describe the similarities and differences between these two reactions. (7)

Ask an Expert



When Merle Fuller was a student, he loved to read mystery novels and watch mystery shows. He liked not knowing who the villain was and using his deductive reasoning to solve the mystery. Today he works in a job that he says is just like living in a mystery novel. Merle is a forensic technician with the Lethbridge Police Department.

Q What does a forensic technician do?

A Forensics means evidence worthy of presentation in court or other judicial proceedings. Our job is to attend crime scenes, identify potential evidence, photograph and sketch evidence, and collect and preserve evidence. In short, the Forensic Identification Unit is about matching physical evidence found at a crime scene to a perpetrator. It is like playing a "who done it" game, but for real. We apply scientific methodology to police work in recording and collecting of evidence.

Q What kind of evidence do you analyze?

A Evidence can include hair and fibres at the point of entry; footwear impressions in snow, in sand, or on linoleum floors; blood spatter on clothing, floors, or walls; or latent (hidden or undetected) fingerprint impressions on just about any surface type. In recent years our evidence collection has also included DNA (deoxyribonucleic acid) analysis. DNA is like a biological-chemical fingerprint. Except for identical twins, everyone has his or her own unique DNA signature. This is an exciting addition to police work. Just a drop of blood, a flake of skin, or a single hair is often enough to solve a crime and identify the perpetrator.

Q What tools do you use to analyze evidence?

A We always use our cameras to show what the scene or material looked like before we did any work to it. Our notebooks are just as important as our cameras. We can never remember all the details of something we saw or did, so we record it all in our notebooks. We use fine silica fibres and camel-hair brushes to apply powder to items we want to dust for fingerprints.

Q How do you use chemicals in your job?

A We have a laboratory full of chemicals to help us develop fingerprints on paper, plastics, cardboard, and other smooth surfaces. Some of the chemicals we use enhance the detection of the fingerprints. Other chemicals are used to help locate and identify blood, urine, and other bodily fluids. We also have a special light that is used to project a laser powered ultraviolet light. This is called a Luma-Lite and is very useful in detecting bodily fluids and blood even after someone has tried to clean them up.

Q **Have you ever seen a crime scene without evidence left by the perpetrator?**

A Every perpetrator leaves a mark at a crime scene because every perpetrator has a unique style or method of doing things. Even if the perpetrator wears gloves, he or she has to get into the room somehow. A perpetrator will likely leave tool marks, footwear impressions, fibres, and even blood or skin cells. No one can enter a room without leaving something behind. A forensic technician needs to be persistent and dedicated enough to find the evidence.

Figure 2.67 A forensic technician might test clothing with an indicator that reacts with light. This glowing spot indicates the presence of blood.

EXPLORING Further

Invisible Formulas

Invisible ink has been used for hundreds of years to send secret codes, messages, and formulas to family members, government officials, and spies. You can use invisible ink to send a secret formula to your classmate. All you need are toothpicks, lemon juice, index cards, and a source of heat such as a candle or hot plate.

Dip the toothpick into the lemon juice and use it like a paintbrush to write one of the chemical formulas you have learned in this unit. Allow the card to dry for a few minutes. The formula and message will become invisible.

Exchange cards with someone. Light a candle and hold the index card at least 4 cm above the flame. You only want the heat from the candle to react with the chemicals on the paper. You do not want to burn the paper. The hidden formula should appear written in brown-black letters.

If you want your message to disappear again, gently dab a cotton ball soaked in household bleach on the index card. The carbon will disappear. Is the disappearance of the carbon another chemical reaction or is it a physical reaction? How could you find out?

Other invisible inks can be made with a mild solution of baking soda in water, or ammonia in water and milk. Try these inks and test whether the chemical reaction involving oxidation is as noticeable as the one you have just witnessed with lemon juice. What other juices might work?

DESIGN YOUR OWN

INVESTIGATION

Tough as Nails

Think About It

Corrosion is a common chemical reaction. Every year many items made of steel, such as railway tracks, bridges, and automobiles are slowly eaten away. Steel can be protected from oxidation if it is coated with a more active metal such as zinc. Zinc loses electrons to oxygen more readily than iron does, forming a tough protective layer of zinc oxide. The coating of zinc and zinc oxide prevents the formation of rust by keeping oxygen from reaching the iron.

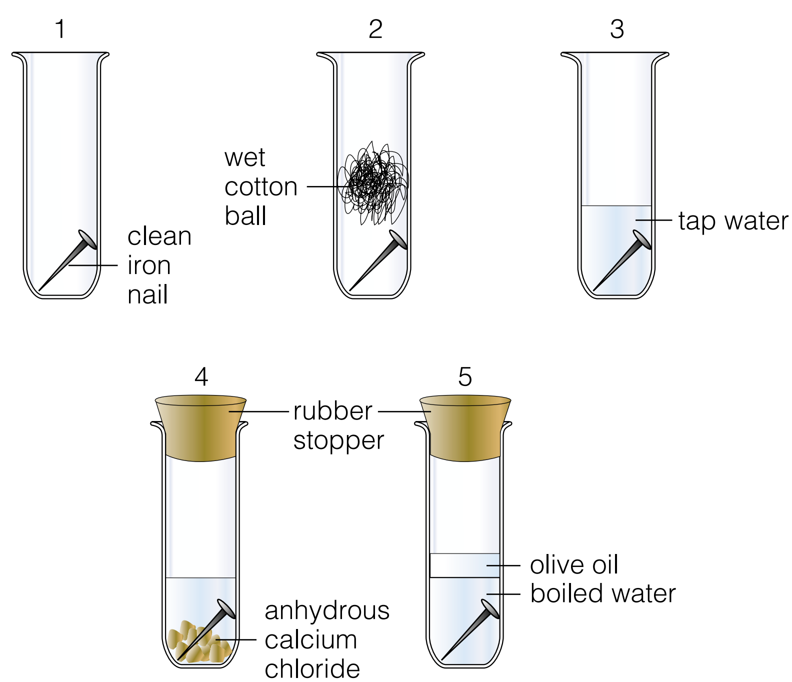
The amount of corrosion that occurs is dependent on factors such as amount of moisture, amount of oxygen, type of metal, and whether a protective coating covers the metal. In this investigation you and your team members will study corrosion in Alberta and think of a question about corrosion you would like to investigate. Formulate your question based on information you have studied in this unit and information you may find by researching on the Internet. (Hint: Use the key words Alberta+corrosion+metals when you do your search.)

Your task is to think of a question to investigate about corrosion. Be sure to have your materials and experimental steps approved by your teacher before you assemble any materials or begin your investigation. You may use other metals, but consider using nails, which can be easily purchased at a local hardware store. You might investigate the protection provided by galvanizing nails. Or you might want to investigate the factors necessary to cause corrosion. The diagram of test tubes on this page indicates one possible experiment you could perform.

Figure 2.68 The bucket on the left has been galvanized.

Skill FOCUS

For tips on how to set up a controlled experiment, turn to Skill Focus 6.



Materials

Brainstorm a list of the materials that will be most appropriate in answering your question. You may also need electronic resources, art materials, or construction materials.

Safety Precautions

- Do not mix chemicals without your teacher's knowledge and approval.
- List additional safety precautions as you design your experiment.

Initiate and Plan

1. With your group, decide on an experimental question to investigate. You might need to do some further research in order to decide on the question.
2. Formulate a hypothesis or a prediction that will answer your question. Base your hypothesis on previous knowledge and on inferences that you can make as a result of that knowledge.
3. Design an experiment to test your hypothesis or prediction. Use words and diagrams to explain your design. Think about the order in which you could carry out the steps in your procedure. Decide on the feature you will change (the manipulated variable) and the feature you will observe changing (the responding variable). Decide what your control will be. You might find it helpful to refer to the Experimental Design Checklist.

Perform and Record

(Test Your Hypothesis)

4. Set up and perform your experiment. If necessary, carry out second and third trials. Make any modification to your experiment, if necessary.
5. Gather and record data and observations as you conduct your experiment. Decide how to record and present your data in a clear format (table, graph, diagram, etc.).

Analyze and Interpret

(Draw Conclusions)

6. Draw conclusions based on the results of your experiment. Discuss your conclusions with your group.
7. Did your findings support your hypothesis? Explain.
8. Write up your findings in a laboratory report. Be sure to include the following:
   - Introduction
   - Hypothesis or Prediction
   - Procedure (step by step), including a diagram
   - Data/Observations in the form of words combined with graphs, tables, etc.
   - Conclusions

Experimental Design Checklist

1. Have you clearly stated the purpose of your experiment, the question you want to answer?
2. Have you written your best guess (hypothesis) about what you expect the answer will be?
3. Have you written a step-by-step procedure?
4. Have you obtained all the information you need from a variety of sources?
5. Did you make a complete list of all the materials you need?
6. Have you identified all of the variables in your experiment?
7. Identify all sources of error that you can think of in your design.
8. Did you repeat your experiment several times? How many?

UNIT

2 Review

Unit at a Glance

- All chemicals should be treated with respect. The WHMIS safety symbols have been adopted to safeguard the classroom, home, and workplace.
- All matter is made of atoms and can exist in three states. Matter can be divided into mixtures and pure substances.
- Physical changes cause a change in state, shape, or size of matter.
- Chemical changes create new substances.
- Pure substances can be divided into elements and compounds. A chemical formula is used to describe elements and compounds.
- Elements are organized into a periodic table according to similarities in their properties. Many scientists, including Mendeleev, Dalton, Thomson, Rutherford, and Bohr helped to develop the modern view of the elements, compounds, and atoms.
- The law of conservation of mass and the law of definite composition help explain the behaviour of elements and compounds in chemical reactions.
- Atoms are composed of small particles including electrons, protons, and neutrons. Electrons have a tendency to be found in pairs.
- Elements can be divided into metals, non-metals, and metalloids depending on their physical and chemical properties.
- Chemical symbols are used to represent elements and compounds. Chemical equations are used to represent chemical reactions.
- Chemical reactions are indicated by the creation of heat, light, the presence of a precipitate or gas, or a change in colour or odour.
- Compounds can be identified as molecular or ionic. Compounds are named according to rules established by IUPAC.
- Exothermic reactions produce heat. Endothermic reactions require heat.
- Catalysts speed up chemical reactions. Inhibitors slow down chemical reactions.
- Some metals corrode when they are exposed to air and moisture.
- Combustion is a highly exothermic combination of a substance with oxygen.

Understanding Key Concepts

1. Draw and label the symbols for the eight main categories in the WHMIS system.
2. List one physical and one chemical property for each of these elements: carbon, neon, and silicon.
3. Give four examples of pure substances, three examples of solutions, and three examples of mechanical mixtures that you might encounter during an average day.
4. What is the difference between a metal and a non-metal? Give three examples of each. Write their chemical formulas in parentheses after the names.
5. Here are some answers to questions about Unit 2. Make a question for each answer that could appear on a test for the unit.
   (a) conservation of mass
   (b) endothermic reaction
   (c) physical properties
   (d) chemical reaction
6. Describe an investigation in which you could contain and compare the quantity of reactants and products in a chemical reaction.
7. Give two examples of common reactions that involve chemical change. Write chemical equations for the reactions.

8. Identify four conditions that affect rates of chemical reactions.

9. Describe the effects of corrosion. What measures can be taken to prevent corrosion?

10. Explain the difference between observation and theory. Give one example of each.

11. How could you distinguish between a physical reaction and a chemical reaction?

12. Draw and label sketches of the atomic models of Dalton, Thomson, and Bohr.

13. Using chemical equations, write the chemical reactions for the following: photosynthesis, combustion, and corrosion of iron.

14. Which groups are divided by the "staircase" on the periodic table? How do their properties differ?

15. What could Dalton's atomic theory explain about matter that the particle model could not?

16. Describe a physical change that is not easily reversed.

17. Refer to the photograph of solid carbon dioxide (dry ice) in water on this page. Is the fog created an example of a physical or chemical change? How do you know?

Developing Skills

18. Refer to the photograph of lightning on this page. Use a dictionary to define chemilumenescence. How does this property connect with information you have learned in this unit? (Hint: Consider physical and chemical properties.)

19. Think of a common substance found at home. Write down three of its physical properties. Describe some chemical tests you could perform to identify its chemical properties.

20. Write the word and chemical equations for this reaction: sodium chloride is produced from the reaction of solid sodium with chlorine gas.

21. Using the table, answer the following questions:
   (a) Which of the substances are gases at 60°C? At −60°C?
   (b) Which of the substances are liquids at 60°C? At −60°C?
   (c) Which of the substances are solids at 60°C? At −60°C?

Substance	Boiling point °C	Freezing point °C
bromine	58	−7
propane	−42	−188
silver	2212	961
mercury	357	−39
radon	−62	−71

Problem Solving/Applying

22. Classify the following elements as metals, non-metals, or metalloids:
    (a) silicon
    (b) neon
    (c) lithium
    (d) hydrogen
    (e) boron
    (f) phosphorous

23. Name the compounds and state whether each is ionic or molecular:
    (a) CaS
    (b) NO
    (c) H_2O
    (d) AlN
    (e) SO_3
    (f) CO
    (g) AgI
    (f) Fe_2O_3
    (f) $CaCl_2$

24. Baking soda has the formula $NaHCO_3$. How are the properties of this compound different from the properties of the elements from which it was made?

25. During an experiment, two solid compounds burn in the presence of oxygen. Can you conclude that they are the same compound? Why or why not?

26. Describe an experiment you could perform to determine if a reaction is exothermic or endothermic.

27. What does the formula C_2H_6O tell you about the substance it represents? Be specific in your answer.

Critical Thinking

28. How are salt and a diamond similar? How are they different?

29. If you place a salty cracker in your mouth and start to chew it slowly, it will begin to taste sweet. Use your knowledge of chemical reactions to explain why this happens.

30. Sucrose breaks down slowly in water to form smaller sugar molecules like glucose. If a small amount of acid is added to the water, the reaction will happen much faster. The acid is not used up in the reaction. Explain the role of the acid in the reaction and give it a chemical name.

31. Propane is often used to cook food on an outdoor barbecue. Write a chemical equation for the reaction taking place when the propane is ignited. Write a word equation for what happens to food as it is cooked on the barbecue.

32. List one piece of evidence you would expect to see indicating a chemical reaction is taking place in each of the following situations:
    (a) A candle is burning.
    (b) Baking soda reacts with vinegar.
    (c) A glass of milk is left on the kitchen counter for a week.
    (d) A bagel is burned in the toaster.

33. Why might it be impossible to chemically change copper into gold as the alchemists tried to do?

34. Using a bag of microwave popcorn as an example, describe an experiment to illustrate the law of conservation of mass.

35. What difficulties would arise if materials were classified by appearance rather than composition?

36. Examine the photograph on this page. A pacemaker is a device inserted in the body to help regulate the rhythm of the heart. The battery that powers a pacemaker is often made with lithium. Which properties make lithium a good choice for the battery? Which properties of lithium could be a source of problems for this application?

37. A beaker containing a substance becomes cooler when you add another substance to it. What can you infer from this observation?

38. A beaker of coloured water becomes warm as it sits in the sunlight. Has a chemical reaction occurred? Explain.

39. How has understanding the atom changed the way scientists investigate chemistry?

40. List two elements and two compounds that can be dangerous to human health and/or the environment. Explain the danger of each, and identify the WHMIS symbols that should be labelled.

Pause & Reflect

Turn back to page 90 and reread the Focussing questions. For each question make a mind map (web) connecting the information you have learned in this unit. What other questions do you have about chemistry?