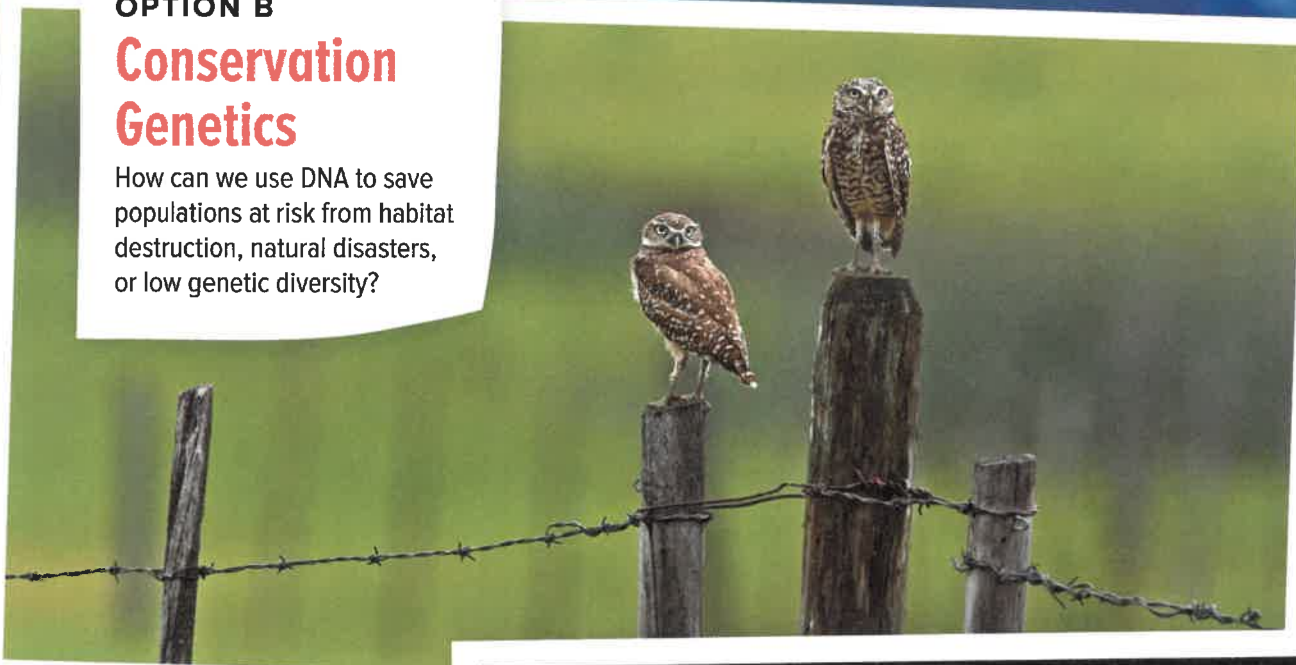
OPTION B

Conservation Genetics

How can we use DNA to save populations at risk from habitat destruction, natural disasters, or low genetic diversity?



OPTION C

XNA

Could other life in the universe have evolved without DNA or RNA?

Assessment Criteria

Did I and my group...

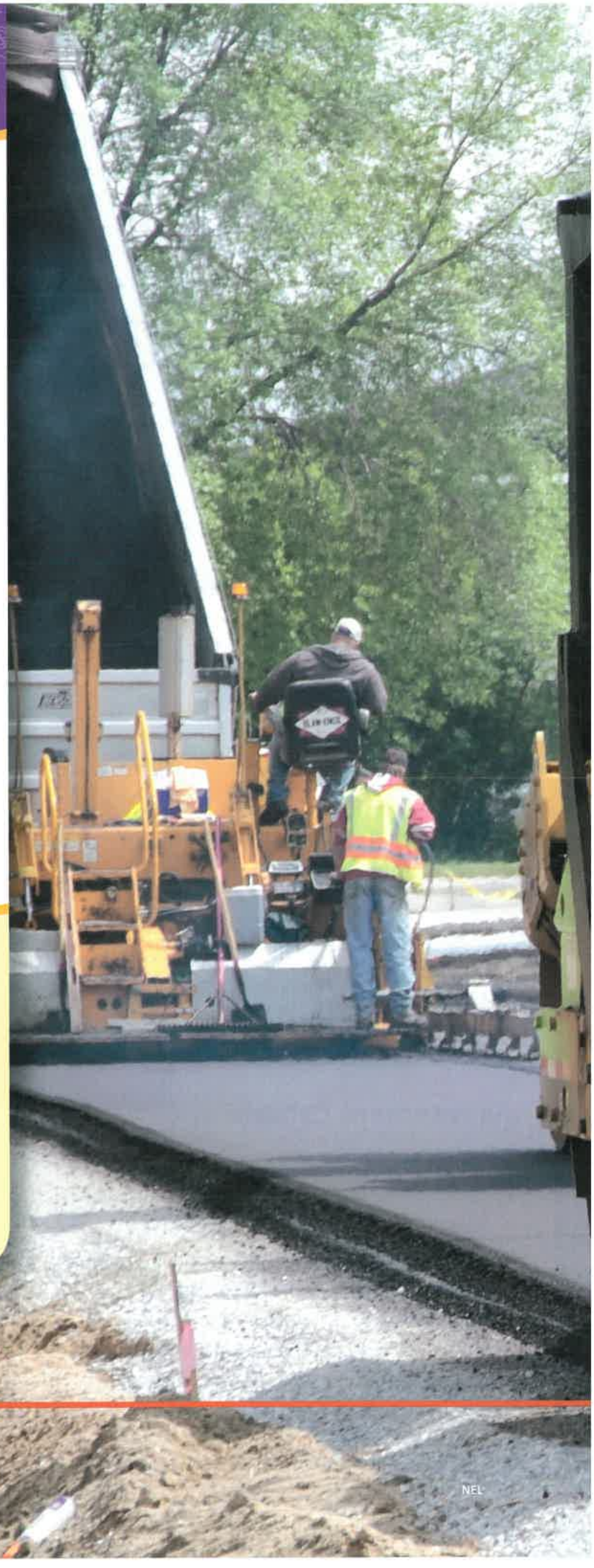
- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect on, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative course of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based argument using language, conventions, and representations appropriate for a specific purpose and audience? C

UNIT 2

Chemical processes require energy change as atoms are rearranged.

Many chemical compounds in the world around you are made by living things as part of their life processes. The sugars made by green plants are one example. People also isolate and make (synthesize) chemical compounds in laboratories and in industrial settings. Some synthetic compounds, such as the asphalt used to pave roads, are found in nature. Others, such as the plastics used to make traffic cones and hard hats, come from natural sources, but they do not exist in nature.

> **"Green chemistry is replacing our industrial chemistry with nature's recipe book. It's not easy, because life uses only a subset of the elements in the periodic table. And we use all of them, even the toxic ones."**
>
> *Janine Benyus*
> *Natural sciences author, innovation consultant*



- What role does energy play in the production of chemical substances in nature and those we synthesize?
- What are the benefits and the costs of the chemical substances and products that we synthesize?
- What questions do you have about—this photo? the title of this unit? ...?

UNIT 2

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations and use other investigative methods to explore properties and patterns involving elements and compounds
- Use scientific understandings to describe and explain the role of energy in chemical processes
- Seek patterns and connections to identify and describe types of chemical reactions
- Develop increasing facility to express ideas, attitudes, and actions in respectful and responsible ways

ESSENTIAL QUESTION

What happens to the energy and atoms of substances in chemical reactions?

TOPIC 2.1:
How are chemical processes part of our lives?

Some things you will do:

- demonstrate sustained intellectual curiosity about a topic or problem of personal interest
- ensure that safety and ethical guidelines are followed in investigations

Some things you will come to know:

- You live in a world filled with applications of chemistry.
- You have a responsibility to use chemicals and chemical knowledge safely.

TOPIC 2.2:
What happens to atoms in a chemical reaction?

Some things you will do:

- apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information
- construct, analyze, and interpret models and diagrams
- transfer and apply learning to new situations

Some things you will come to know:

- The making and breaking of chemical bonds involves changes in energy.
- Writing chemical equations depends on the law of conservation of mass.

TOPIC 2.3:
How is energy involved in chemical processes?

Some things you will do:

- collaboratively and individually plan, select, and use appropriate investigation methods
- analyze cause-and-effect relationships
- contribute to care for self, others, community and world through individual and collaborative approaches

Some things you will come to know:

- Chemical reactions involve a transfer of energy between systems and their surroundings.
- Some chemical reactions absorb energy, and others release energy.

TOPIC 2.4:
How do atoms rearrange in different types of chemical reactions?

Some things you will do:

- seek and analyze patterns, trends, and connections in data
- communicate scientific ideas, claims, information, and courses of action for a specific purpose and audience

Some things you will come to know:

- The many kinds of chemical reactions can be grouped into a few main types based on how their atoms are rearranged.
- Acids and bases are common chemical substances in daily life.

UNIT 2

Connect To What You Already Know

This feature helps you reflect on what you know about some foundational ideas that you have learned in previous grades. Work alone or quietly in small groups to answer the questions. Reach out to your classmates to ask about things that you are unsure about or to offer assistance. Your teacher also can provide additional reinforcement materials to help you prepare for this unit.

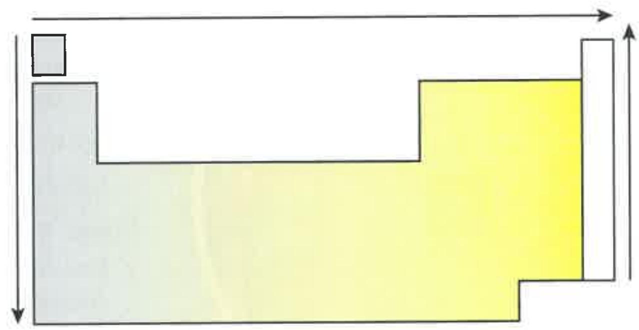
Refer to **Figure 1** on the next page as well as the periodic table on the inside back cover of this textbook as you answer the following questions.

1. Look at the symbols and atomic numbers of the elements.
   - **a)** What is the atomic number of helium?
   - **b)** What is the atomic number of gold?
   - **c)** What is the symbol of the element with atomic number 22?
   - **d)** What is the symbol of the element with atomic number 33?

2. Look at the atomic masses of the elements.
   - **a)** What is the atomic mass of aluminum?
   - **b)** What is the atomic mass of silver?
   - **c)** What is the symbol of the element with atomic mass 40.1?
   - **d)** What is the symbol of the element with atomic mass 83.8?

3. What is the difference between an element's atomic number and its atomic mass? What is the significance of the atomic number in terms of the periodic table?

Figure 1



4. Copy the diagram below into your notebook, and use it to answer the following.
   - **a)** What physical properties do the grey-shaded elements have in common?
   - **b)** What physical properties do the yellow-shaded elements have in common?
   - **c)** What physical properties do the elements in the white column have in common?
   - **d)** One element appears on its own in the upper left corner of the periodic table. What makes this element unique in terms of many of its physical properties?
   - **e)** Identify the trends in physical and chemical properties represented by the arrows that surround **Figure 1**.

5. Elements 1, 3, 11, and 19 are in the first column of the periodic table.
   - **a)** What are the two terms used to identify columns of the periodic table?
   - **b)** Draw Bohr diagrams for these elements.
   - **c)** How is the electron arrangement in these elements similar?
   - **d)** How many electrons would you expect there to be in the outer energy shell of the elements Rb and Cs? Explain.

6. Look at elements 3 to 10.
   - **a)** Draw Bohr diagrams for these elements
   - **b)** Compare your diagrams. How are they the same? How are they different?
   - **c)** What period do these elements belong to?
   - **d)** What is the relationship between period number and occupied energy shells?

7. An element's reactivity is associated with how close it is to having a full valence shell.
   a) What elements have full valence shells? Are they the most or least reactive elements? Explain.
   b) Why are elements of Group 1 and 17 the most reactive elements?
   c) What is an ion? Using Bohr diagrams of representative elements, show how a negatively charged and a positively charged ion forms. Explain the formation of ions for these elements.

8. Elements in the same column of the periodic table have similar properties. Think of two examples in everyday life where similar substances could be substituted for each other. What other factors would you consider before making the substitutions?

9. a) Which elements on the periodic table do not occur naturally on Earth?
   b) Of these, which ones are synthetic (made only in the laboratory)?
   c) In both cases, what is it about the nature of these elements that accounts for the fact that they are not naturally occurring on Earth?

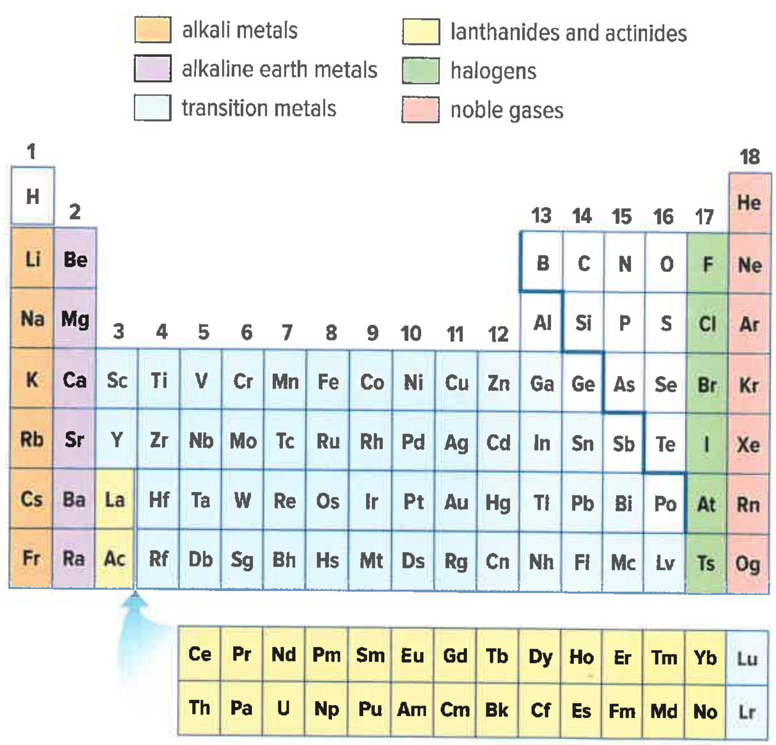
Figure 2

Elements are classified as metals, non-metals, and semi-metals based on their physical and chemical properties. The elements in groups 1, 2, and 13 to 18 are referred to as the main-group elements or representative elements. The elements in groups 3 to 12 are called the transition elements.

Most of the elements are metals. With the exception of mercury, metals are solid at room temperature. They are shiny when smooth and clean, and most are silver or grey in colour. They are good conductors of electric current and thermal energy. They are also malleable and ductile.

The non-metals, except for hydrogen, are found on the upper right side of the periodic table. Non-metals are general gases or brittle, dull-looking solids. They are poor conductors of electric current and thermal energy.

Semi-metals (also called metalloids) have physical and chemical properties of both metals and non-metals. For example, like metals, they are shiny solids at room temperature, but they are brittle and not ductile like non-metals. They also tend to be poor conductors of electric current and thermal energy.



TOPIC 2.1

How are chemical processes part of our lives?

Key Concepts

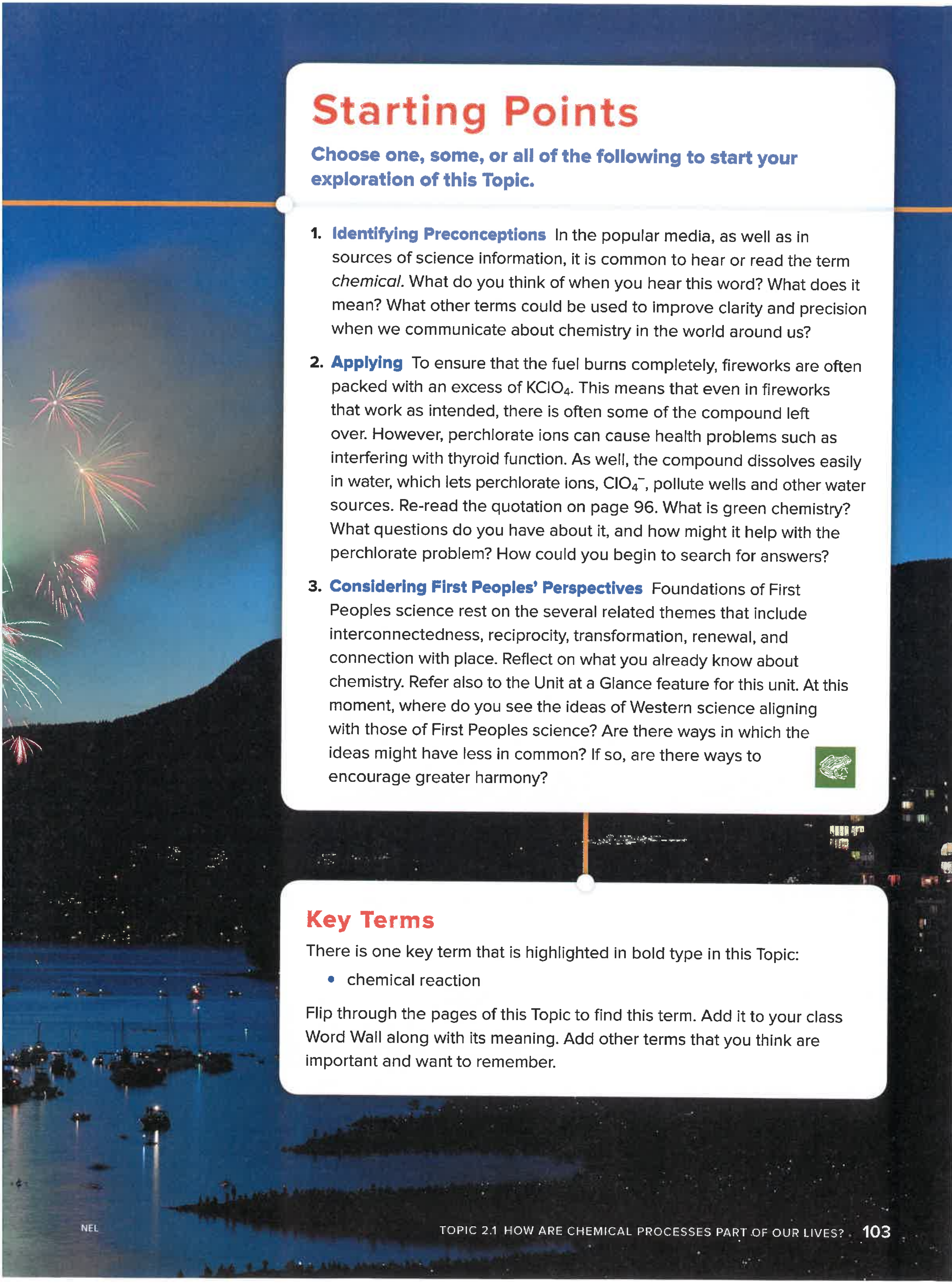
- Applications of chemistry are everywhere in the world around you.
- Knowing how to handle chemicals helps keep us and our environment safe.

Curricular Competencies

- Make observations aimed at identifying questions about the natural world.
- Ensure that safety and ethical guidelines are followed in investigations.
- Experience and interpret the local environment.
- Consider social, ethical, and environmental implications of findings.

The link between fireworks and celebration is more than 1000 years old. Its origins are in China, where the earliest fireworks had been invented centuries before. However, colourful displays like this one at Vancouver's annual Celebration of Light festival only became common less than 200 years ago. Before then, the only colours available were those you might see in a typical fire—orange, white, and yellow. Compounds of barium (which supply green hues) and strontium (which supply red) were not available until the elements themselves had been discovered. Strontium was discovered in 1790 and barium in 1808.

Many of today's fireworks use the ionic compound potassium perchlorate, $KClO_4$. When ignited by a lit fuse, this compound breaks apart and releases oxygen gas. Carbon and sulfur in the fireworks act as fuels. They react instantly with the oxygen, producing hot gases that provide some of the explosive force to propel the firework upward. The heat of the explosion causes metals and metal compounds in the firework to give off the coloured lights that we look forward to.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** In the popular media, as well as in sources of science information, it is common to hear or read the term *chemical*. What do you think of when you hear this word? What does it mean? What other terms could be used to improve clarity and precision when we communicate about chemistry in the world around us?

2. **Applying** To ensure that the fuel burns completely, fireworks are often packed with an excess of $KClO_4$. This means that even in fireworks that work as intended, there is often some of the compound left over. However, perchlorate ions can cause health problems such as interfering with thyroid function. As well, the compound dissolves easily in water, which lets perchlorate ions, ClO_4^-, pollute wells and other water sources. Re-read the quotation on page 96. What is green chemistry? What questions do you have about it, and how might it help with the perchlorate problem? How could you begin to search for answers?

3. **Considering First Peoples' Perspectives** Foundations of First Peoples science rest on the several related themes that include interconnectedness, reciprocity, transformation, renewal, and connection with place. Reflect on what you already know about chemistry. Refer also to the Unit at a Glance feature for this unit. At this moment, where do you see the ideas of Western science aligning with those of First Peoples science? Are there ways in which the ideas might have less in common? If so, are there ways to encourage greater harmony?

Key Terms

There is one key term that is highlighted in bold type in this Topic:

- chemical reaction

Flip through the pages of this Topic to find this term. Add it to your class Word Wall along with its meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Applications of chemistry are everywhere in the world around you.

Activity

Chem Chat

Take a few minutes to list and discuss all the ways you have relied on chemistry today, this week, and in the last month. As a class, compare your lists. What ideas appeared often? Which were less common? Which ideas surprised you?

Loud explosions, flashes of light, puffs of smoke—these are some of the things you might expect from chemical reactions. Many **chemical reactions** are explosive, colourful, and smoky, but many more take place in the world around you without your even noticing them. Whether they are obvious or not, chemical reactions maintain and sustain your health and the health of all life on Earth. This doesn't mean, however, that chemical reactions and other chemical processes come without hazards. Figure 2.1 shows just a few of the ways that chemistry affects our lives.

chemical reaction process in which atoms of one or more substances are rearranged to form different substances

Figure 2.1 Chemistry in modern life

Foods are sources of nutrients that require chemical reactions to break them down into forms that body cells can use. **Evaluating: How do the chemicals in fresh food, such as an apple, differ from those in prepackaged foods, such as a fruit-flavoured snack? How important are those differences?**

Personal care products have been specifically developed with certain properties. Many companies keep their procedures for making them top secret, especially if the product is highly profitable. **Questioning: What role does an understanding of chemistry play in the production and the use of personal care products?**

Chemistry allows doctors to use equipment such as MRI machines to visualize internal structures and processes in the body. **Applying: Describe a medical advance due to chemistry that has helped you or someone you know.**

Frog's Leaf (common plantain) is respected by First Peoples for the properties of its healing chemicals. **Communicating: What special relationships do First Peoples have with plants in their areas?**

Plastics are human-made (synthetic) products that have a wide range of uses. They were invented to be highly stable, so they do not break down easily as they are used. **Analyzing: How is the stability of plastic products both an advantage and a disadvantage?**

Natural sources for fabrics we wear are wool, cotton, silk, and linen. The chemical industry has expanded the range and properties of fabrics by inventing synthetic fibres such as nylon, acrylic, spandex, and polyester. **Applying: What are some advantages and disadvantages of synthetic clothing?**

The vehicles that move us from place to place on land, in the air, and on water also contribute to pollution of all three. Our homes and vehicles are safer thanks to chemistry. However, the increased number of them in society makes a significant contribution to air pollution. **Communicating: What role has chemistry played, both positive and negative, in the development of the transportation industry?**

Activity

Chemistry Career Fair

What comes to mind if you think of jobs or careers that involve chemistry? You might think of work that has the word *chemical* or *chemistry* in it, such as chemical technician or chemistry teacher. However, most jobs or careers that involve chemistry do not have the term in their name. Auto body technician, metallurgist, and dental hygienist are three examples.

What others are there? Brainstorm as many examples as you can think of. In each case, record any part or parts of the job that involves chemistry. Who can you talk to or where can you go to find out more about a job or career that might interest you?

Connect to Investigation 2-A on page 114

Before you leave this page . . .

1. Think of what you did before coming to school today. Name three things you did or used that involved chemistry.
2. Is it possible to live a life that is free of chemicals or chemistry? Explain your thinking.

TAKE Action

Make a Difference

Chemicals in Our Water

In nature, pure water doesn't exist. Water is called the universal solvent because many different substances can be dissolved in it. These substances can be naturally occurring, such as metals and ions found in the soil, or they can be the result of human activities. In some cases, these human activities are purposeful, such as adding fluoride to municipal drinking water to reduce tooth decay. In other cases, they are the result of household, mining, and industrial wastes, which cause water pollution. These can include human waste, solids such as plastics, potentially toxic chemicals, and pharmaceutical waste that includes prescription medications and personal care products that people flush down toilets or pour down drains.

Water Treatment Facilities Only Do So Much

In most municipalities, waste water that comes from homes, schools, and other buildings enters into a sewer system, which is a system of pipes that delivers the water to a treatment facility. Treatment of waste water varies from one town or city to another, depending on different factors, such as the size of the population and the economic cost of building, operating, and maintaining the facility. Even the most highly efficient municipal facilities cannot remove all polluting chemicals. That means they remain dissolved or suspended in the water that is delivered to people or flushed into local aquatic ecosystems.

British Columbia is home to numerous bodies of water, as well as a diverse and lengthy coastline.

Storm drains are openings covered by heavy metal grates along city streets that collect run-off and excess rainwater. However, storm water goes directly into local lakes and rivers with no treatment. This means any water that runs along the streets, driveways, and parking lots can pick up all types of pollutants and deliver it directly to our waterways. It also means that anything someone dumps into the storm drain will end up in a local lake or river.

Many First Nations in Canada do not have safe drinking water. Some have had to boil their water for many years. While most of these communities have some sort of treatment facilities, they are inadequate, so water supplies continue to be contaminated.

Developing a Plan

1. As a group, decide on how you wish to contribute to improving water quality. Consider the following questions to help you develop your plan:
   - Will it apply to your local community, or is it for a wider region such as the province or another country?
   - What aspect of water quality improvement do you want to address—improving public awareness? combating further pollution? cleaning up already polluted water resources?
   - What type of effort do you want to make? Do you want to provide information and awareness of a particular problem? Do you want to organize a volunteer group to work on a particular issue? Do you want to suggest how each individual can make a difference or how institutions or governments should make a difference?
   - Will you include information about different technologies that are available to help reduce water pollution?
   - How will you reach your target audience? How will you convince people that this is an important issue?
   - What information do you need to find out in order to decide on and develop your plan?
   - What criteria will you use to determine if your plan is a success or needs changes to adjust to unforeseen problems?
2. Develop your plan and have your teacher approve it. With your teacher's permission implement your plan or a part of it. This can be done using your suggested target audience or members of the class as a trial run.
3. Assess how well your plan worked.

Analyze and Evaluate

1. What were some of the challenges you experienced when developing your plan? What were some of the challenges in implementing the plan?
2. Based on what you have learned, how can you, personally, change some of your habits to help address water quality issues? How can community members change their habits? How likely is it that you and/or community members actually will make these changes?

Apply and Innovate

3. Some organizations have websites that include stories of successful projects and people who have made a difference. Compose a summary of how your plan made a difference that could be posted on such a website. If you could not implement your plan, develop a story that conveys the type of success you wished for.

CONCEPT 2

Knowing how to handle chemicals helps keep us and our environment safe.

Activity

Chemical Safety in Our Daily Lives

In a group, discuss possible ways people could be better informed about how to safely handle and dispose of potentially harmful materials such as those shown in the photos.

Chemical Safety in the Science Classroom

Many of the chemical compounds in products that people use at work or that you will use while performing investigations at school have properties that make them potentially dangerous. WHMIS (Workplace Hazardous Materials Information System) labels provide information about chemicals in science labs and at workplaces (Figure 2.2). Safety Data Sheets (SDS) provide further information, which by law must be available for every chemical. This information includes its chemical and physical properties and how it should be handled, stored, and disposed of. SDS also inform about hazards and first aid treatment in case of an accident.

 **Exploding bomb** (for explosion or reactivity hazards)	 **Flame** (for fire hazards)	 **Flame over circle** (for oxidizing hazards)
 **Gas cylinder** (for gases under pressure)	 **Corrosion** (for corrosive damage to metals, as well as skin, eyes)	 **Skull and Crossbones** (can cause death or toxicity with short exposure to small amounts)
 **Health hazard** (may cause or is suspected of causing serious health effects)	 **Exclamation mark** (may cause less serious health effects or damage the ozone layer)	 **Biohazardous infectious materials** (for organisms or toxins that can cause disease in people or animals)

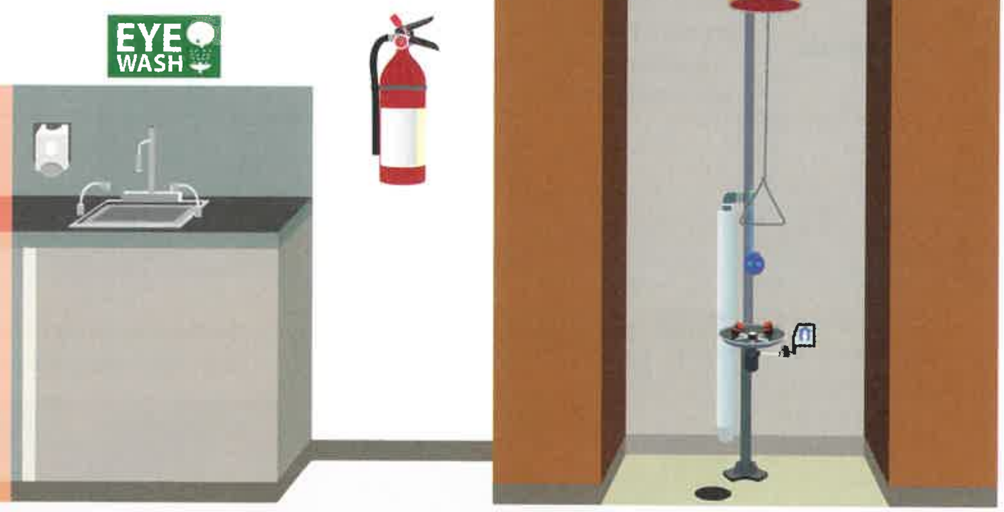
Figure 2.2 WHMIS symbols provide information about each chemical in the lab and workplace.

Safety Rules

You and your classmates are responsible for keeping yourself and others safe while handling chemicals. To do this, you need to know and respect the safety rules. Some important ones are represented in Figure 2.3. You must also read Safety in Your Science Classroom on pages xiv–xvii. Your teacher may provide you with further safety rules to follow.

Connect to Investigation 2-B on page 116

- Know the location and how to use all emergency equipment and emergency exits.
- If you come in contact with a solid, brush it off immediately. For liquid spills, wash the area with water.
- If you get anything in your eyes, rinse them with water at an eyewash station and have your lab partner notify your teacher immediately.



- Handle hot objects carefully. Never leave an open flame unattended. Make sure you know how to light a lab burner and use it properly.
- Point the end of a container that is being heated away from yourself and others. Never allow a container to boil dry.

- Always use protective equipment, such as a lab coat or apron and safety goggles. Tie back long hair and avoid wearing ties, scarves, and long necklaces. Do not wear sandals, or open-toes shoes.
- You should never put anything in your mouth, including food, gum, or any object. When working with chemicals, hold containers away from your face.

- If you are asked to smell a substance, hold the container in front of you and beneath your nose. Waft the fumes towards you.

Figure 2.3 Working in science classrooms requires you to know how to perform certain tasks safely.

Activity

Minimizing Risks

Working in small groups, choose a profession from the examples shown, or from ideas within your group. In discussion and through research, complete the table below.

Consult WHMIS, SDS, and HHPS information as needed. Combine your information with other groups to create a single summary table.

Profession	What chemicals and/or chemical reactions are used and why?	Risks associated	Ways to minimize risks to personal safety	Ways to minimize risks to the environment

The chemicals used in car restoration and painting can be hazardous to auto body repair technicians.

Welders rely on chemical reactions to perform their jobs—the same reactions that cause explosions.

Firefighters and other first responders not only fight fires but also may be exposed to hazardous chemicals.

Many professionals who do home renovations must work with potentially dangerous products, such as paint solvents, and be aware of possible exposure to harmful materials such as asbestos.

Before you leave this page . . .

1. Describe one action you can take to better handle a chemical so that any personal and environmental hazard can be minimized.

Check Your Understanding of Topic 2.1

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What do WHMIS and SDS stand for? What are their purposes and how are they associated with each other? PA E

2. Describe how to properly heat a test tube using a Bunsen burner. PC AI

3. Describe one precaution you should take when you see each of the following. E C

   a) 

   b) 

4. Name three things to do when preparing to carry out an investigation or activity that involves the use of chemicals. QP PC

Connecting Ideas

5. Make a sketch of your science classroom. Include the safety equipment and where it is located. C

6. Create a graphic organizer to summarize the positive and negative effects of chemicals introduced in the Topic. E C

7. Many farmers apply chemical fertilizers and other substances, such as insecticides, to help maintain their crops and improve the yields. Describe two things the farmer could do to reduce the risk of personal exposure and exposure to others of these chemicals. AI E

8. You have been asked to develop a safety plan for performing an investigation. PA AI

   a) How do WHMIS symbols help to do this?

   b) Describe how an SDS could be used.

   c) Why should chemical disposal be part of your plan?

Making New Connections

9. Iron-containing hemoglobin molecules in red blood cells carry oxygen to the cells of your body. Carbon monoxide binds to iron in hemoglobin molecules 200 times more strongly than oxygen does. When carbon monoxide molecules bind to hemoglobin, they tend to stay bound. Oxygen cannot bind to hemoglobin that is already bound to a carbon monoxide molecule. QP PA AI C

carbon monoxide

oxygen molecule

   a) Use the models of oxygen and carbon monoxide to infer why a hemoglobin molecule might accept a carbon monoxide molecule as well as an oxygen molecule.

   b) Carbon monoxide poisoning can lead to effects such as headaches, dizziness, nausea, loss of consciousness, and death. These effects increase with increased concentrations of the compound. Use your understanding of gas exchange to explain why carbon monoxide is toxic. Recall your previous studies about cellular respiration and gas exchange in the body, or aid your recall by consulting suitable information resources.

10. Use your experiences in answering question 9 to pose at least one other question that you could investigate about the cause or effect of toxic chemicals on the body. QP AI

AT ISSUE Fighting Fires with Chemistry

What's the Issue?

Fire extinguishers are mandatory in laboratories and many workplaces. Homeowners are also strongly encouraged to keep and maintain a fire extinguisher in locations where fires commonly occur, such as in or around kitchens, wood stoves, and garages.

Different Fires Need Different Extinguishers

There are different types of fire extinguishers, and the chemicals they contain have properties that are specific to certain types of fires. Using the right extinguisher will help to put out a fire. Using the wrong one could spread the fire and put lives in greater danger. As shown in the table on the next page, manufacturers put a letter and symbol on each fire extinguisher to show the type of fire it can be safely and effectively used to put out.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What type of fire extinguisher is present in your science lab? Why is this the correct one to use? Describe how to properly use it.
2. What type of fire extinguisher should you use if your school computer lab catches fire due to an overloaded electrical outlet? Explain your reasoning. (**Hint:** What does the lab contain other than computers?)
3. Why are kitchens and garages common places where fires occur in homes? How can the fires that occur in these places be different? It is recommended that every home have at least one fire extinguisher. Where should they be located? Explain your answers.
4. Halons are types of chemical compounds that have been used traditionally in fire extinguishers.
   a) Use a fact sheet provided by your teacher or other information resources to find out more about using halon to extinguish fires, as well as the health and environmental risks.
   b) Canada is currently phasing out the use of halon in fire extinguishers. What is the reason for this? How is halon to be disposed of safely? What will be used in its place?

Class of Fire (Letter and Symbol)	Fuel Source for Fire	Type of Extinguisher	Risks and Benefits
A	ordinary combustibles (wood, paper, cloth, and plastic)	• air-pressurized water • dry chemical • chemical foam	• Dry chemical extinguishers should be used with water, because they may not fully extinguish the fire on their own. • Carbon dioxide fire extinguishers should not be used on fires involving ordinary combustible materials; the fire may re-ignite.
B	flammable liquids (non-cooking) (gasoline, petroleum oil, paint), flammable gases	• carbon dioxide • dry chemical • chemical foam • halon (a liquefied, compressed gas)	• For liquid fires, never use air-pressurized water extinguishers. They can spread the fire and cause burns from splattered fuel.
C	electrical equipment (live electricity)	• carbon dioxide • dry chemical halon	• Use of water fire extinguishers on an electrical fire can cause life-threatening electrocution. • Dry chemical extinguishers leave a residue on surfaces that keeps them from igniting again. This residue is corrosive and often damages the items it protects from fire. • Carbon dioxide fire extinguishers do not leave a damaging residue.
D	combustible metals (magnesium, titanium)	• dry powder specific to the chemical that is burning	• It is unsafe to use any non-specific fire extinguisher on a combustible metal fire.
K	cooking media (vegetable and animal oils and fats)	• wet chemical	• These are classified as cooking fires. They are of greatest concern in the food industry and restaurants. • Air-pressurized water extinguishers should not be used for these fires. They can spread the fire and cause burns from splattered fuel.

PASS is an acronym to help people remember the four steps to take when using a fire extinguisher.

INVESTIGATION

2-A

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- computer with Internet access

Is It Worth It?

Understandings and innovations of chemistry have resulted in the development of many synthetic products that have changed societies around the world. However, some of these products have had unintended consequences, such as a negative impact on the environment. In this investigation, you will choose a product to investigate and use information about its life cycle to answer the question, "Is it worth it?"

Question

What is the environmental impact of the production, use, and disposal of a synthetic product?

Procedure

1. In a group, choose one common synthetic product. Some options could include
   - a plastic product (such as a plastic water bottle)
   - an electronics product (such as a smartphone)
   - a synthetic fabric (such as clothing)
2. Develop a research plan based on finding out the following information about the chosen product.
   - its uses and the positive and negative contributions it makes to society
   - the technology and materials used to design and create it and the effects of the manufacturing processes (Is the extraction of raw materials required? Is there an environmental impact of that? Does processing of raw materials require large amounts of energy or other resources, such as water? Is it manufactured in a manner and place that supports workplace safety, equality, and healthy conditions?)
   - its expected life time (Has it been designed to be replaced often? to last for years?)
   - how it is discarded and whether it is biodegradable (Does it go to landfill? Does toxic waste result from its disposal?)
   - what recycling programs or "green" alternative products are available
   - answers to two questions about it that your group decides to investigate

Your plan should include deciding what sources of information you will use and how to share the work among group members so it is distributed equitably.

3. Have your teacher approve your plan before you proceed.

4. Carry out your research plan. As a group, combine your research findings to form a complete analysis.

Process and Analyze

1. Describe the positive contributions that the product makes.

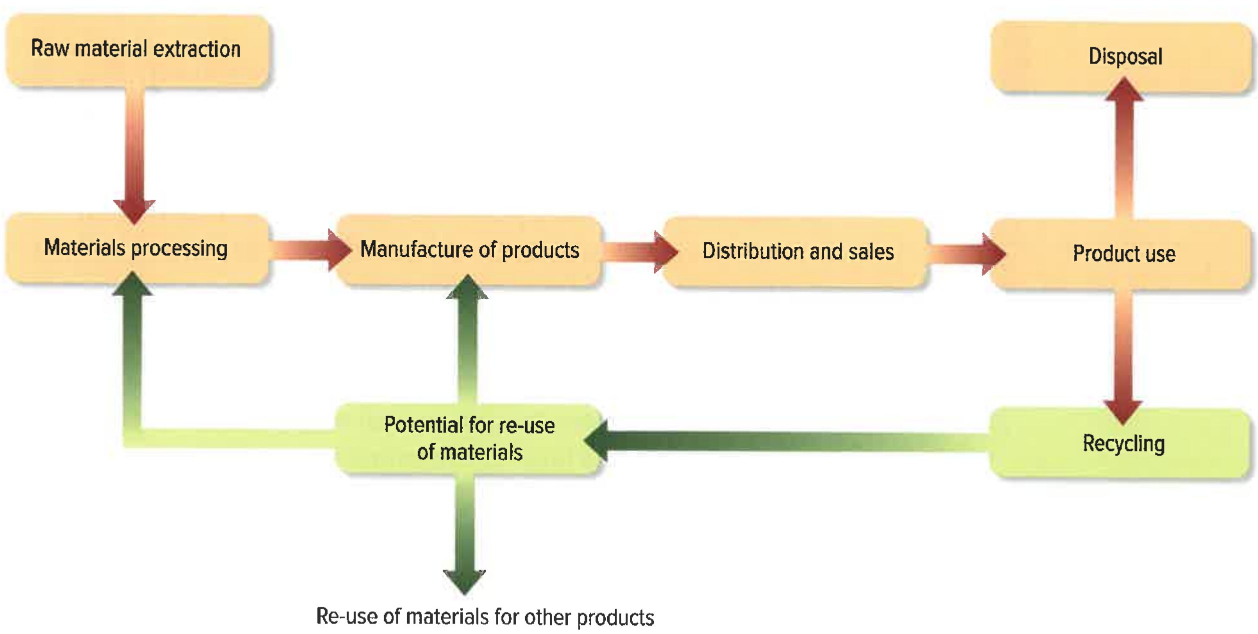
2. Describe the negative effects that the product has on the environment.

3. What are some ways that the negative consequences can be minimized by such things as "green" alternatives or recycling programs?

Conclude and Communicate

4. Share your findings and analysis with the class, using a format of your choice. Possibilities include a video documentary, social media website, or blog. Your presentation should include an answer to the question, "Is it worth it?"

A product's life cycle includes all aspects involved in making, distributing, selling, using, and disposing of the product. The environmental and social impact at each stage of a product's life cycle may be questioned and evaluated.



INVESTIGATION

2-B

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- computer with Internet access

Prepare an Emergency Response Plan

Chemicals are part of our everyday lives but accidents can threaten the well-being of people and the environment. Being prepared for possible emergencies helps to reduce the effects of accidents. In this investigation, you will develop an emergency response plan for a hypothetical situation.

Question

What features make an effective emergency response plan for a school or community?

Procedure

1. Working in small groups, decide on the type of emergency response plan you want to develop. For example, is it for a school? a small community? a large city? a workplace?
2. Choose one scenario for your emergency plan. Some examples are provided below.
   - An earthquake causes a gas leak in the school while school is in session.
   - An earthquake causes a gas leak in your community.
   - A transportation accident causes a dangerous chemical spill on a busy highway near a large city.
   - A fire breaks out in the school and the fire alarm goes off.
   - A fire breaks out in your home during the night.
3. Include the following considerations in your plan:
   - The preparation and planning required to be ready for an emergency. This includes the people who should be involved in organizing and executing the plan.
   - What the evacuation procedure will be and under what conditions it is to be followed
   - How the emergency response plan will be communicated to people; what the lines of communication will be among people involved in organizing and executing the plan
   - How any contamination is to be dealt with and cleaned up; how affected material is to be disposed of

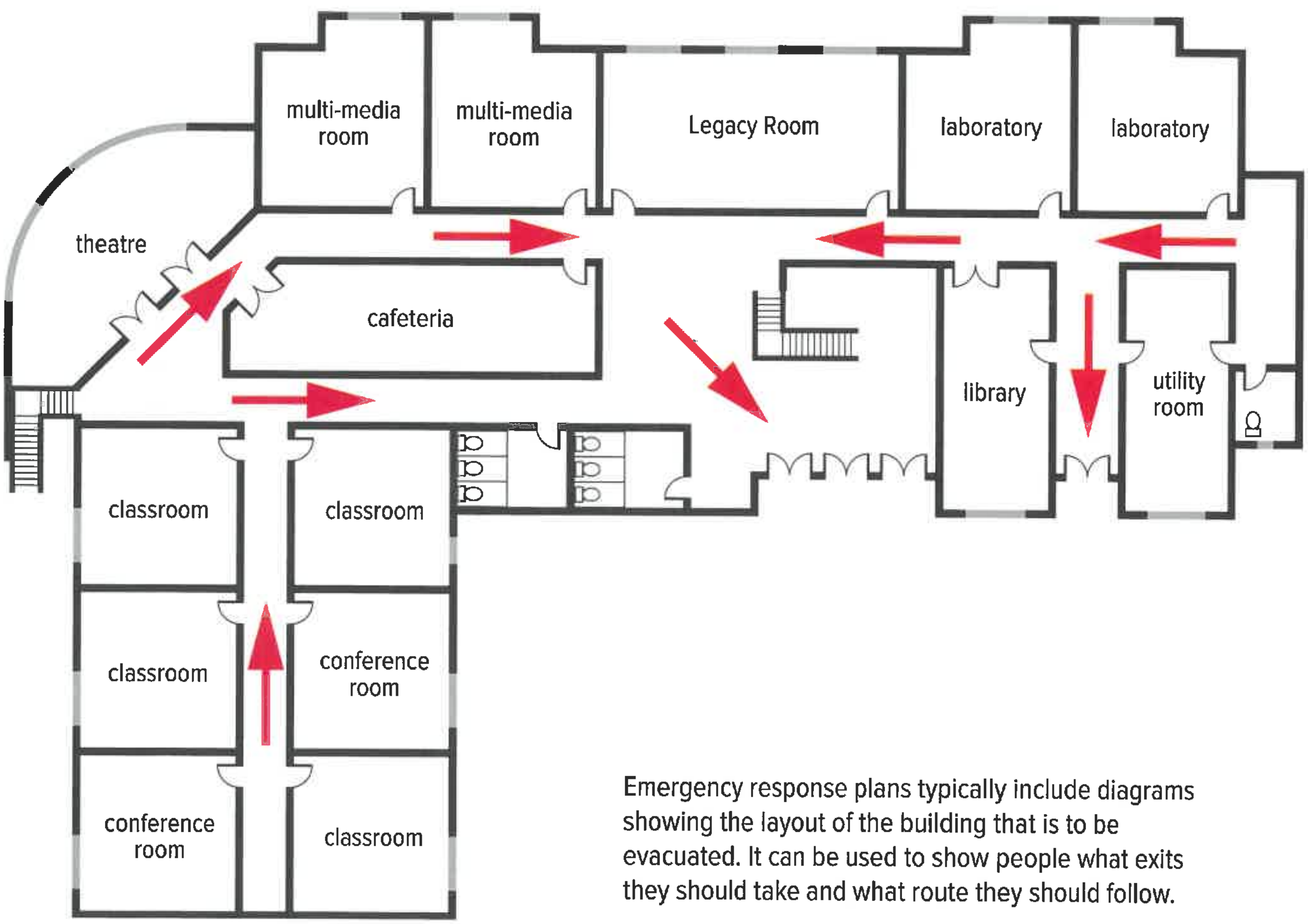
4. With your teacher's permission, contact local first responders. Find out some things they consider when developing an emergency response plan.
5. Develop your emergency response plan.

Process and Analyze

1. Find out what emergency response plan and protocols your school's Health and Safety Committee has developed. In terms of the different factors that were considered, how does it compare with your group's plan?

Conclude and Communicate

2. Share your emergency response plan with the class. Then develop a presentation, using the format of your choice, that could be used to convey this information to the school, town, or city involved. Keep your audience in mind when designing your presentation.



Emergency response plans typically include diagrams showing the layout of the building that is to be evacuated. It can be used to show people what exits they should take and what route they should follow.

TOPIC 2.2

What happens to atoms in a chemical reaction?

Key Concepts

- Atoms bond together to form ionic and covalent compounds.
- Bonds are broken, atoms are rearranged, and new bonds are formed.
- Mass cannot be created or destroyed in a chemical reaction.
- A chemical equation represents what happens to the atoms in a reaction.

Curricular Competencies

- Seek and analyze patterns, trends, and connections in data.
- Generate and introduce new or refined ideas when problem solving.
- Consider the role of scientists in innovation.

Touchscreens like this one and those used for smartphones and tablets are the result of chemical ingenuity that involves arranging atoms in a particular way to produce new material with desirable properties. These screens have been designed to withstand not only the force of objects being dropped on them, but also the impact of being dropped from a height. The toughened glass that makes up these screens is a synthetic glass-ceramic material. It shares the properties of both glass and ceramics, but is harder and stronger than each material on its own. Heating glass at very high temperatures provides some of the desired crystalline structure of ceramics, and replacing sodium ions with potassium ions chemically strengthens the glass.

Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What is a chemical bond? What are the different ways that atoms can chemically bond together? Give an example of each. Then describe how atoms of elements chemically combine.
2. **Evaluating** In making the synthetic glass described in the opening paragraph, potassium ions replace sodium ions in the spaces they occupy in the glass. As a result, the glass becomes compressed, which makes it much stronger. Why does switching from sodium ions to potassium ions cause the glass to become compressed?
3. **Considering First Peoples Perspectives** Balsamroot is a food of great importance to First Nations of the interior of BC. Balsamroot contains inulin, which is a carbohydrate people cannot digest, so raw balsamroot has little nutritional value. However, First Nations long ago understood how chemical changes could be applied to make the nutritional value of this energy-rich food source available to people. Find out what this understanding is.

Key Terms

There are 10 key terms that are highlighted in bold type in this topic:

- ionic compound
- covalent compound
- molecule
- chemical equation
- product
- ionic bond
- covalent bond
- law of conservation of mass
- reactant
- coefficient

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Atoms bond together to form ionic and covalent compounds.

Activity

Finding Compounds

Your teacher will provide your group with cards that have a chemical name or formula of an ionic or covalent compound and its properties. Look around the classroom, and identify where each compound is. The compound may be part of a material or exist on its own. State which compounds are ionic and which are covalent. Explain how you decided.

Chemical reactions involve one or more pure substances interacting to form a different substance or substances. These pure substances can be elements or compounds. Compounds are made of atoms of different elements that chemically combine in specific proportions. They are classified into one of two categories, ionic or covalent, based on the type of chemical bond that forms between the atoms.

Ionic Compounds

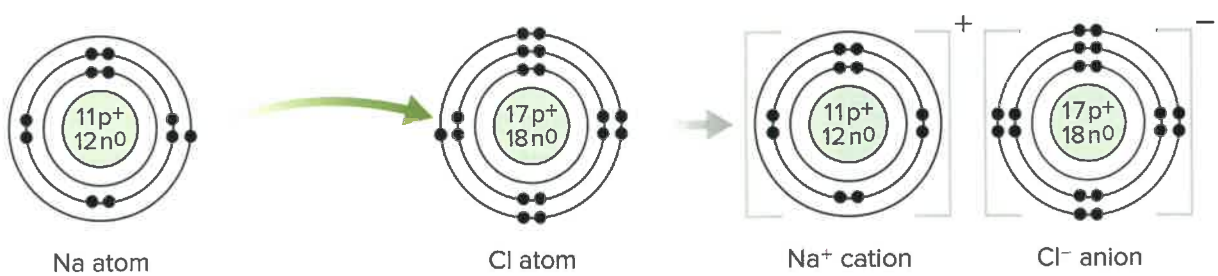
ionic compound a compound made of oppositely charged ions

ionic bond a strong attraction that forms between oppositely charged ions

Ionic compounds consist of positively charged ions, called *cations*, and negatively charged ions, called *anions*. These ions are held together by **ionic bonds**. In binary ionic compounds, atoms of a metal element lose one or more electrons to atoms of a non-metal element (**Figure 2.4**). There is an *electrostatic attraction* between the cations and anions, resulting in the ionic bond. The strength of that attraction, and the resulting ionic bond, depend on the types of ions involved.

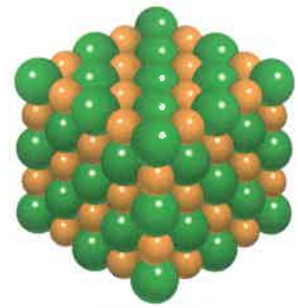
In the formation of ionic compounds, the electron transfer results in ions that have full valence shells and, therefore, greater stability.

Figure 2.4 In binary ionic compounds such as sodium chloride, the transfer of electrons from metal atoms to non-metal atoms produces ions that are strongly attracted to each other. **Processing: What is the chemical formula for sodium chloride? Explain why sodium ions and chloride ions have the charges that they do.**



Activity

Predicting and Visualizing Ionic Compounds



1. Sodium chloride exists as a cubic crystal lattice.

   Describe how ions in sodium chloride are arranged in the crystal lattice. The chemical formula for an ionic compound represents the *formula unit*, which is the smallest whole number ratio of positive and negative ions to form a neutral compound. What is the formula unit of sodium chloride?

2. Give the names and chemical formulas for the ionic compounds that will form from the following pairs of elements. Why does each element form the ion it does? How many bonds form in each formula unit?

   a) calcium and oxygen
   b) sodium and fluorine
   c) aluminum and sulfur
   d) potassium and bromine

3. Choose one of the above compounds. Find out how its ions are arranged in a crystal lattice, and build a three-dimensional model using materials supplied by your teacher. Work with other students to evaluate the models.

Covalent Compounds

Covalent compounds consist of atoms of two or more non-metal elements joined together by **covalent bonds**. A covalent bond is a strong attraction between atoms that forms when the two atoms share electrons. The sharing of electrons results in electrostatic attractions between the positive nucleus of each atom and the negative electrons of the atoms.

As with ionic compounds, the formation of a covalent compound results in an increase in stability of the atoms due to the filling of valance shells. However, non-metals in covalent compounds achieve a full valence shell by sharing electrons.

In water, the single valence electron of each hydrogen atom is paired with one of the valence electrons of oxygen. The sharing of this electron pair forms a single covalent bond. Covalent compounds can also contain double bonds, which form when atoms share two pairs of electrons, and triple bonds, which form when atoms share three pairs of electrons (Figure 2.5).

covalent compound a compound that results when atoms of two or more elements bond covalently

covalent bond a strong attraction between atoms that forms when atoms share valence electrons

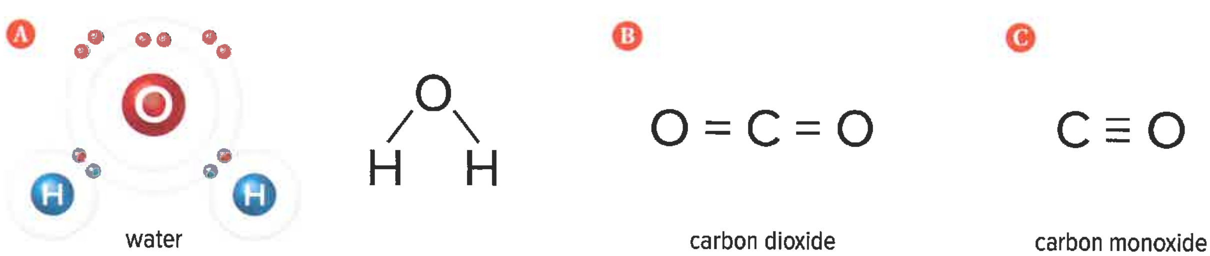


Figure 2.5 (A) In water, oxygen forms a covalent bond with each hydrogen atom. Single bonds may be represented with a single line. (B) Double bonds are shown using two parallel lines. (C) Triple bonds are shown using three parallel lines.

molecule a particle made up of two or more atoms bonded by covalent bonds

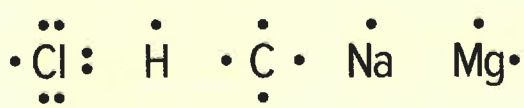
Most covalent compounds exist as molecules. A **molecule** is the smallest independent unit of a covalent compound. In a glass of water, individual molecules of water exist. In contrast, sodium chloride exists as a continuous arrangement of ions, not as separate molecules.

Two or more atoms of the same element that are joined by a covalent bond are also molecules. These elements include H_2, N_2, O_2, Cl_2, Br_2, I_2, F_2, S_8, and P_4. However, these molecules are not compounds, because they contain only one element.

Extending the Connections

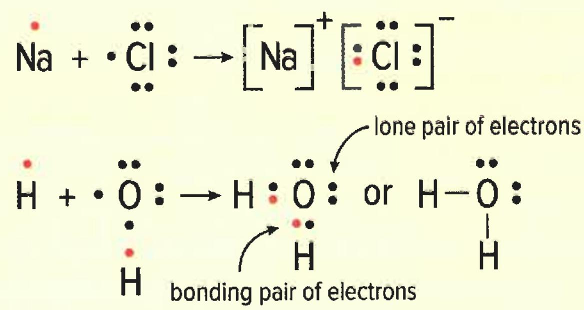
Lewis Diagrams

A common way to model electrons in an atom and the arrangement of atoms in a molecule or formula unit is with Lewis diagrams. They show only the valence electrons. Lewis diagrams consist of an element's chemical symbol surrounded by dots that represent its valence electrons. For helium, the dots are paired. Starting with second-period elements, dots are placed singly around the symbol at the points of a compass until the fifth one.



Then they are paired. In Lewis diagrams for molecules, each bonding pair of electrons is represented with a single line. Lewis diagrams that represent bonding in sodium chloride and water are shown below.

Draw the Lewis diagram for Cl_2. What is an advantage to using Lewis diagrams instead of Bohr diagrams? What is a limitation?



Activity

Showing the Bonds

1. Name each of the following substances. Which is different from the others? Which should be classified as molecules? Which should not?

   $MgBr_2$, CCl_4, KI, F_2

2. Use Bohr diagrams or Lewis diagrams to show how ionic or covalent bonds form in each substance. How many bonds does each molecule or formula unit have?
3. Use materials provided by your teacher to build a three-dimensional model of CCl_4. What type of compound is it? How does it compare with the model of NaCl you made?

Before you leave this page . . .

1. What type of bond is formed between two non-metal atoms? Describe how it forms.
2. Describe how a binary compound composed of sodium and bromine forms.

CONCEPT 2

Bonds are broken, atoms are rearranged, and new bonds are formed.

Activity

Rearranging the Atoms

CAUTION: Avoid touching the burner directly while hot. Following your teacher's instructions, light a Bunsen burner. Methane, CH_4, is the covalent compound in natural gas that burns in the presence of oxygen, O_2, to produce the flame that you see. In this reaction, carbon dioxide gas and water vapour form.

1. Where does the oxygen come from? Where are the products that form?
2. Using the materials provided by your teacher, build models of the four chemicals that show individual atoms and bonds between the atoms.
3. Describe how the atoms in molecules of methane and oxygen are rearranged to form the products. (Keep your models to use in other activities.)

When thinking about chemical reactions, imagine the atoms of each substance and how they might need to move for the reaction to take place. Some examples are shown in **Figure 2.6**.

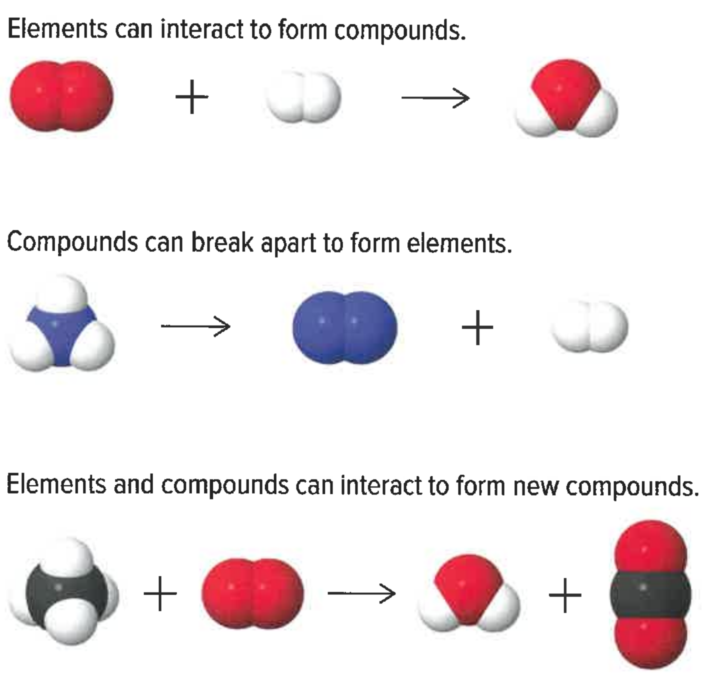


Figure 2.6 Examples of ways that elements and compounds can form new substances in chemical reactions. **Analyzing: What is happening to the atoms and bonds?**

Chemical Bonds and Energy

In order for atoms to be rearranged in a chemical reaction, the chemical bonds that hold them together must first be broken. Then new bonds can form between different atoms to produce different substances. For all chemical reactions, changes in energy are involved in these processes.

Chemical bonds are electrostatic attractions that hold atoms or ions together (Figure 2.7). In order to break those bonds (attractions), energy must be added until the atoms or ions are no longer held together. The amount of energy that is needed to break a chemical bond depends on the atoms or ions involved.

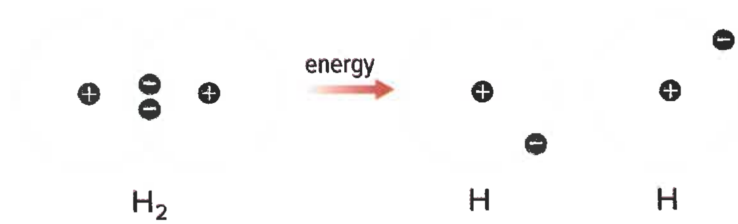


Figure 2.7 Energy must be added to break a chemical bond. **Applying: Is the bond shown here covalent or ionic? How do you know?**

When a chemical bond forms, energy is released. When chemical bonds form and the atoms achieve full valence shells of electrons, the atoms gain stability. Thus, atoms go from low stability (high energy state) to greater stability (lower energy state), and the "extra" energy is released (Figure 2.8).

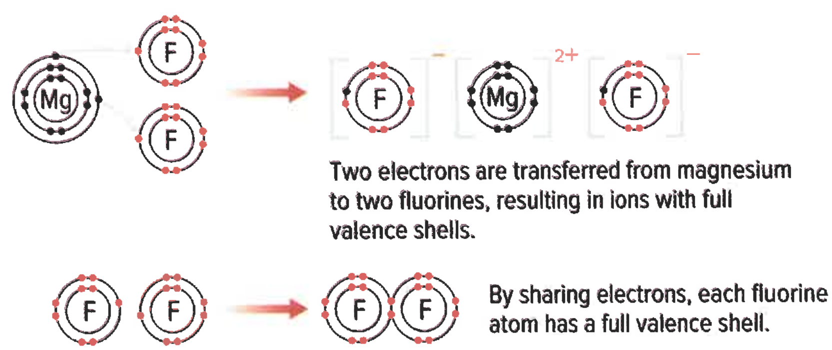


Figure 2.8 When a bond forms, energy is released.

Activity

Making and Breaking the Bonds

Look at your models for the reaction of methane with oxygen to produce carbon dioxide and water. What happens in the reaction in terms of the bonds that are broken and new bonds that must form? Which would require energy and which would release energy? (Keep your models to use in other activities.)

Before you leave this page . . .

1. Is it possible for a chemical reaction to occur without new chemical bonds forming? Explain.
2. Describe how energy is involved in making and breaking chemical bonds.

CONCEPT 3

Mass cannot be created or destroyed in a chemical reaction.

In the late 1700s, a French chemist named Antoine Lavoisier, shown in **Figure 2.9**, greatly advanced the understanding of chemical reactions. He recognized that accurate inferences could be made about what happens to substances in a chemical reaction by studying the masses of those substances. Many experiments were performed that involved measuring the mass of the substances before the reaction, performing the reaction in a sealed container, called a *closed system* (**Figure 2.10**), and then carefully measuring the mass of the substances after the reaction.

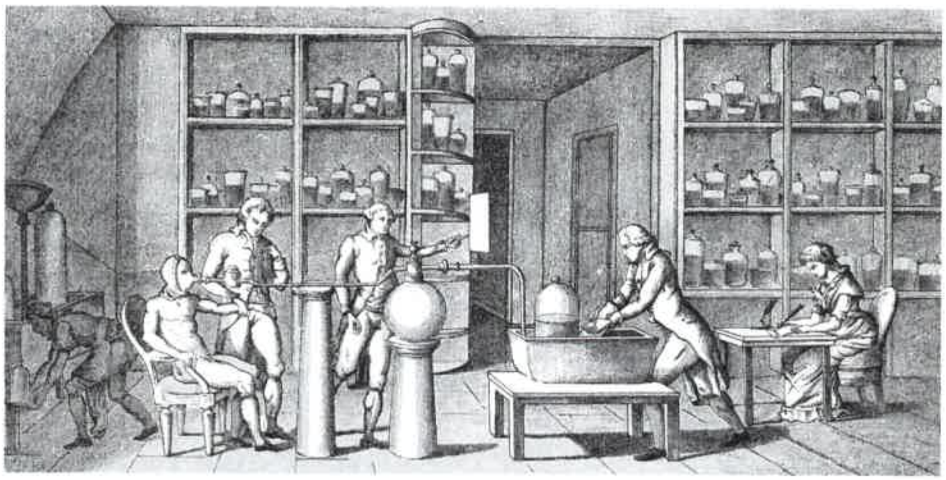


Figure 2.9 Antoine and Marie-Anne Lavoisier were a successful scientific team. Marie-Anne translated scientific papers from English into French for her husband and drew diagrams of the equipment he used for his experiments. **Analyzing: What is going on in this image? What equipment do you recognize? What kind of experiment do you think is taking place?**

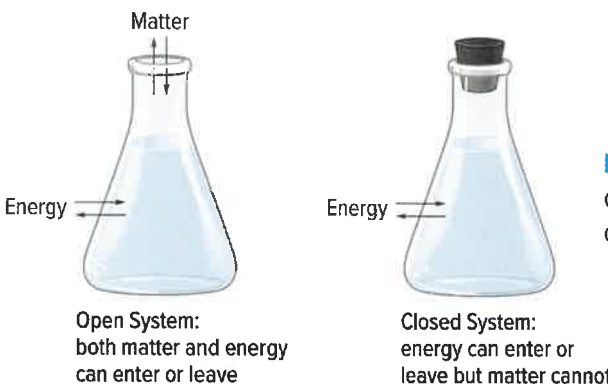


Figure 2.10 Reactions can occur in open or closed systems.

Extending the Connections

Women in Chemistry and Other Sciences

Margaret Cavendish published ideas about atoms and energy in the late 1600s. Elizabeth Fulhame was a chemist reknowned for her meticulous experimental methods during the late 1700s. You likely have never heard of either. Why do we know so much less, and often so little, about women in science until more recent times? Who should we know more about?

Showing the Conservation of Mass

One experiment that Lavoisier studied extensively involved mercury(II) oxide, HgO. This compound is a red solid that breaks down to form silver-coloured liquid mercury, Hg, and colourless oxygen gas, O_2, when it is heated. Figure 2.11 shows the kind of apparatus Lavoisier used in his experiments with mercury(II) oxide.

He repeated this reaction many times, and each time the results were the same: the total mass of the mercury(II) oxide was the same as the total mass of the mercury and oxygen that were produced. Therefore, whatever atoms are present in the substances undergoing a chemical reaction must also be present in the new substances that form. This observation is summarized in the **law of conservation of mass**.

law of conservation of mass in a chemical reaction, the total mass of the substances used is equal to the total mass of the substances produced

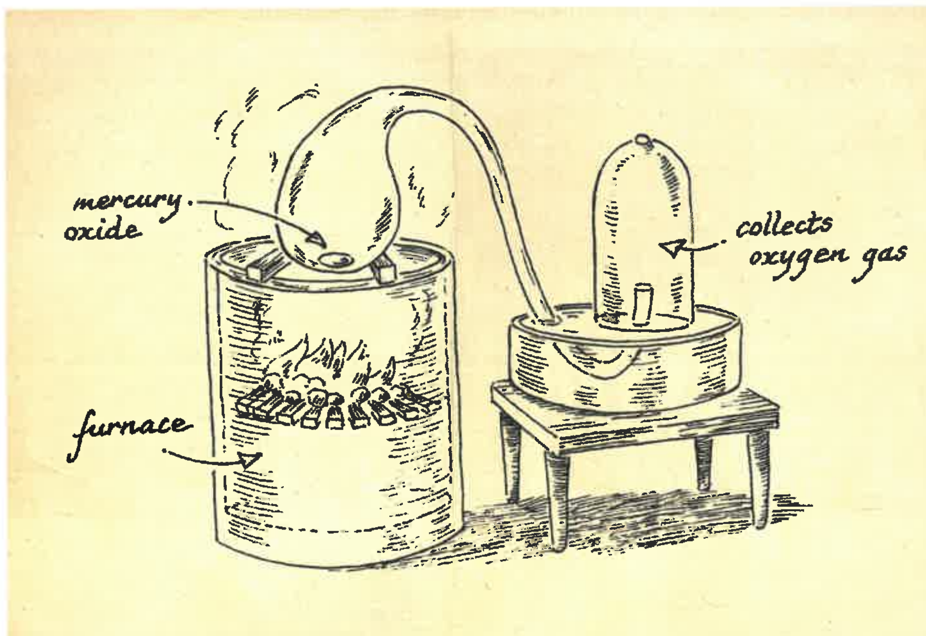


Figure 2.11 This sketch shows the apparatus that Lavoisier used for his experiment with HgO. **Communicating: Is this setup a closed or open system? How can you tell?**

Connect to Investigation 2-C on page 136

Activity

Modelling Conservation of Mass

Working with a partner, use your models of methane, oxygen, carbon dioxide, and water to show what must happen in order for the reaction to obey the law of conservation of mass. How many models of each type of molecule did you need to use in order to demonstrate the law of conservation of mass? Explain your answer.

Before you leave this page . . .

1. What is the law of conservation of mass?
2. What is the difference between an open and closed system?
3. What would you expect Lavoisier's results to be if he had used an open system? Explain your answer.

Make a Difference

TAKE a Stand

What does the law of conservation of mass tell us about waste?

The law of conservation of mass has important implications for society and the environment. New air, water, chemicals, and other material natural resources cannot be produced or removed by any use of science or technology. All the matter that exists on Earth, now, is all the matter that ever existed and ever will exist since the universe formed. We can extract substances from the environment and change them into other useful substances, but we cannot make matter where it did not already exist. In the same way, we can bury our waste materials in the ground, dump them in waterways, or send them into the air as incineration smoke, but the matter of which those materials were made is still here. In nature, matter can only be endlessly recycled.

Analyze and Evaluate

1. Wastes may be classified in terms of their potential danger (hazardous vs. non-hazardous) as well as their source (residential, municipal, agricultural, industrial). In what ways is it useful to classify wastes in these or other ways? Is it possible that the act of classifying wastes creates a false sense of security? Discuss your ideas.
2. How is reducing waste different from recycling it? Why is this distinction important?

Apply and Innovate

3. Take a stand about a chemical waste you are aware of. What can be done to reduce it and its impact on the environment? How can you inform the public and what can you do to encourage changes in thinking and behaviour? Develop a strategy using the conservation of mass as a basis for your argument.

CONCEPT 4

A chemical equation represents what happens to the atoms in a reaction.

Activity

Paper Clip Equation

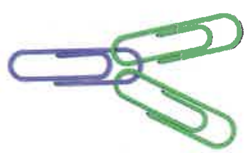
A chemical reaction is represented below. The compounds to the left of the arrow represent substances that react and undergo a change. The compounds to the right of the arrow are the new substances that form.

$$Na_3P + CaF_2 \longrightarrow Ca_3P_2 + NaF$$

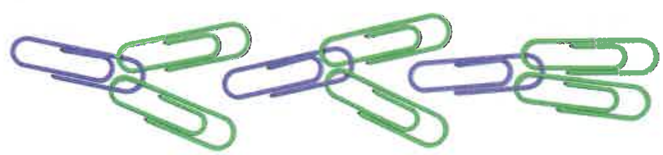
How many atoms of each element are on the left-hand side of the equation? How many atoms of each element are on the right-hand side of the arrow?

Does this chemical equation reflect the conservation of mass? Explain.

Use paper clips to model this reaction. One paper clip of a given colour should represent one atom of a given element. Work with the paper clip models to represent a reaction that has the same number of each colour of paper clip in the reacting substances as the substances formed. How could you change the chemical equation to reflect your models?



CaF_2



$3 \times CaF_2$

chemical equation the representation of a chemical reaction using words or chemical formulas

reactant a substance that undergoes a chemical change

product a substance formed in a chemical change

A **chemical equation** is a statement that uses words or symbols to describe a chemical reaction. Figure 2.12 shows how information is represented in a chemical equation. A **reactant** is any substance that undergoes a chemical change in the reaction. A **product** is any new substance that is formed from the reaction. An arrow is used to point towards the end result, which is product formation.

A plus sign on the left side means "reacts with"

A plus sign on the right side means "and"

reactant A + reactant B ⟶ product C + product D

The arrow means "to produce" or "yields"

Figure 2.12 Reactants undergo chemical change to form products.

Using Chemical Equations

Figure 2.13 Magnesium and oxygen react to produce magnesium oxide. **Analyzing: Is there an overall release or absorption of energy in this reaction? What evidence supports this?**

Figure 2.13 shows the chemical reaction between magnesium metal and oxygen gas, which produces magnesium oxide. One way to represent this reaction is with a word equation:

$$\text{magnesium} + \text{oxygen} \longrightarrow \text{magnesium oxide}$$

A *word equation* uses words to describe what happens to reactants and products in a chemical reaction. However, the information it provides is limited.

Skeleton Equation (Unbalanced chemical equation)

A *skeleton equation* provides the chemical formulas for the reactants and products. However, it does not necessarily reflect the law of conservation of mass. The correct proportions of reactants and products may not be shown. In the example below, there are different numbers of atoms of oxygen on each side of the equation.

$$Mg + O_2 \longrightarrow MgO$$

Balanced Chemical Equation

According to the law of conservation of mass, atoms are never destroyed or created in a chemical reaction—they are just rearranged. So, in a *balanced chemical equation*, the same number of atoms of each element must appear on both sides of the arrow. This is achieved using **coefficients**.

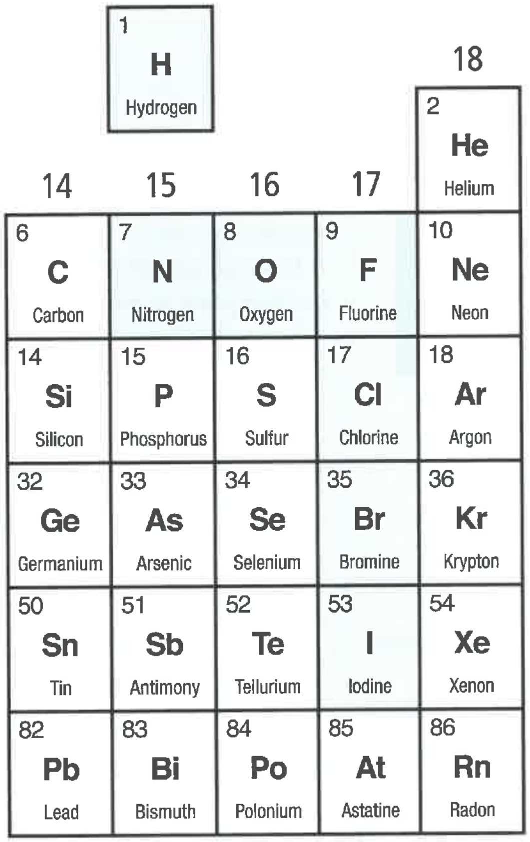
Balanced chemical equations are always written using the smallest whole number ratio of coefficients. The example below tells you that two atoms of magnesium combine with one molecule of oxygen to produce two formula units of magnesium oxide. A chemical equation may also provide information about the physical states of the reactants and products.

coefficient number placed in front of a chemical formula in a balanced chemical equation to show the ratios of substances in a reaction

A substance can be a gas (g), liquid (ℓ), or solid (s). Substances that are dissolved in water are aqueous solutions (aq).

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$

The number placed in front of a chemical formula is called a coefficient. The coefficient applies to the whole formula that it is placed in front of. Coefficients not shown are assumed to be 1.



Diatomic and Polyatomic Elements in Chemical Equations

Notice in the chemical equation on the previous page that oxygen is represented as $O_2(g)$. Recall that oxygen naturally exists as a diatomic ("two-atom") element. Other diatomic elements are hydrogen, $H_2(g)$, nitrogen, $N_2(g)$, fluorine, $F_2(g)$, chlorine, $Cl_2(g)$, bromine, $Br_2(\ell)$, and iodine, $I_2(s)$. Sulfur and phosphorus exist as the polyatomic elements $S_8(s)$ and $P_4(s)$.

A common way to remember the diatomic elements is to "visualize" them on the periodic table forming the number "7," with the exception of hydrogen (**Figure 2.14**).

Figure 2.14 Except for hydrogen, diatomic elements are positioned in the periodic table in the shape of a "7." **Innovating: Develop an abbreviation or other memory aid to help you remember the diatomic and polyatomic elements.**

Coefficients versus Subscripts

It is important to be clear about how subscripts in chemical formulas differ from coefficients in chemical equations. As shown in **Figure 2.15**, the subscripts in a chemical formula indicate how many atoms of each element are present in a molecule or formula unit. The coefficient indicates how many molecules or formula units are present.

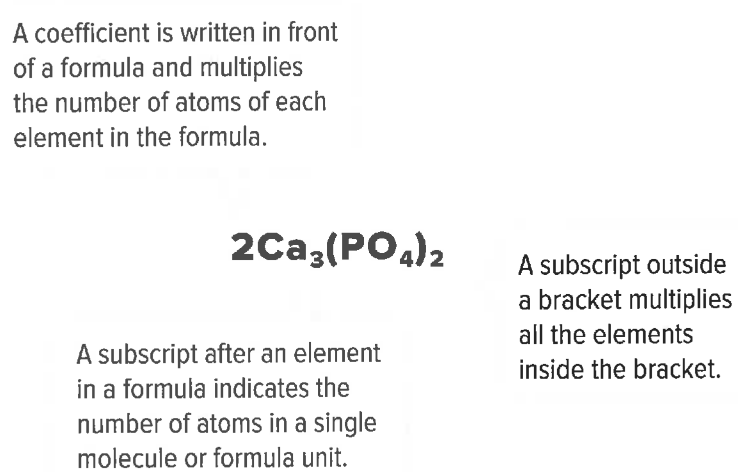


Figure 2.15 Coefficients indicate the number of molecules or formula units. **Analyzing: How many atoms of each element are represented?**

Balancing Chemical Equations

Balancing chemical equations involves applying the law of conservation of mass. The number of atoms of each element on the reactant side of the equation must equal the number of atoms of the same elements on the product side of the equation. Remember that equations are balanced using coefficients, never by changing the subscripts in chemical formulas. Changing a subscript in a chemical formula changes the identity of the compound.

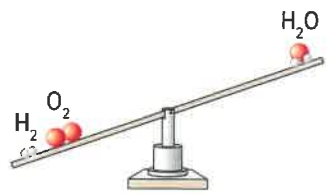
How to Balance a Chemical Equation

1. $H_2(g) + O_2(g) \longrightarrow H_2O(\ell)$

   In the skeleton equation, there is the same number of hydrogen atoms on both sides of the equation. There are more oxygen atoms in the reactants, however, than in the product.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	2	2	yes
O	2	1	no

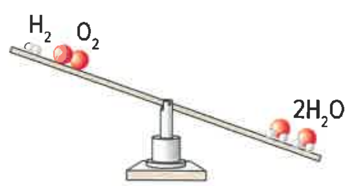


2. $H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$

   Balance equations by adjusting coefficients. Placing the coefficient 2 in front of $H_2O(\ell)$ balances the oxygen atoms on each side of the equation. But now there are 4 hydrogen atoms on the product side and only 2 on the reactant side.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	2	4	no
O	2	2	yes

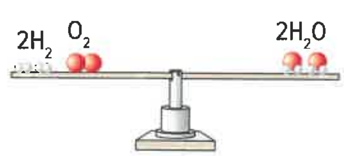


3. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$

   Placing the coefficient 2 in front of $H_2(g)$ brings the total number of hydrogen atoms to 4 on each side of the equation. The equation is now balanced. Once you think the chemical equation is balanced, do a final check by counting the atoms of each element one more time.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	4	4	yes
O	2	2	yes



Tips for Balancing Chemical Equations

When balancing a chemical equation, it is important to remember that each equation is different and the identical approach does not work for every equation. However, there are some general guidelines you can follow.

- Begin by checking that all chemical formulas are correct so that you do not waste time trying to balance an equation that is not possible.
- Balance compounds first and elements last.
- When you have placed a coefficient for a compound, balance the rest of the atoms in that compound before moving on to the next substance.
- Balance atoms that appear only once on the reactant side and product side first. Elements such as hydrogen and oxygen often appear in more than one reactant or more than one product, so it is easier to balance them after the other elements are balanced.
- If a polyatomic ion appears in both a reactant and a product, treat it as a single unit.
- Once you think the chemical equation is balanced, do a final check by counting the atoms of each element on both sides of the equation.

Sample Problem 1:

Writing a Balanced Chemical Equation

In the industrial production of gaseous ammonia, gaseous nitrogen and gaseous hydrogen are the reactants. Write the balanced chemical equation for this reaction, including the states of reactants and products.

Solution

1. Begin by writing a word equation.

   nitrogen + hydrogen ⟶ ammonia

2. Write a skeleton equation. Remember that nitrogen and hydrogen are diatomic elements. Include the states.

   $N_2(g) + H_2(g) \longrightarrow NH_3(g)$

3. Use coefficients to balance the equation. First consider the compound in the equation. You need to have 2 nitrogen atoms in the product to balance the nitrogen in the reactants. Therefore, place a coefficient of 2 in front of $NH_3(g)$.

   $N_2(g) + H_2(g) \longrightarrow 2NH_3(g)$

   Now the nitrogen atoms are balanced. The hydrogen atoms are not balanced, because there are 2 hydrogen atoms on the reactant side and 6 hydrogen atoms on the product side. Therefore, place a coefficient of 3 in front of $H_2(g)$.

   $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

4. Do a final check to make sure there are the same number of atoms of each element on both sides of the equation. There are 2 nitrogens and 6 hydrogens on both sides.

Sample Problem 2:

Writing a Balanced Chemical Equation Containing a Polyatomic Ion

Balance the following skeleton equation.

$CaCl_2(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + Ca(NO_3)_2(aq)$

Solution

1. Write out the equation. Make sure that you have copied each chemical formula correctly.
2. Use coefficients to balance the equation. When a polyatomic ion appears in both a reactant and a product, treat it as a single unit. There is one NO_3^- in the reactants and two NO_3^- in the products. Since you need to have two NO_3^- in the reactants, place a coefficient of 2 in front of $AgNO_3(aq)$.

   $CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow AgCl(s) + Ca(NO_3)_2(aq)$
3. There are now two silver ions in the reactants. You know you need to have two silver ions in the products to balance these in the equation. Therefore, place a coefficient of 2 in front of $AgCl(s)$.

   $CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$

   Notice that adding the coefficient has also balanced the number of chloride ions. The number of calcium ions also remains balanced.
4. As a final check, count the number of each type of atom on the left side of the equation and on the right side of the equation. Make sure they are the same.

Ion	Reactant	Product
Ca^{2+}	1	1
Ag^+	2	2
Cl^-	2	2
NO_3^-	2	2

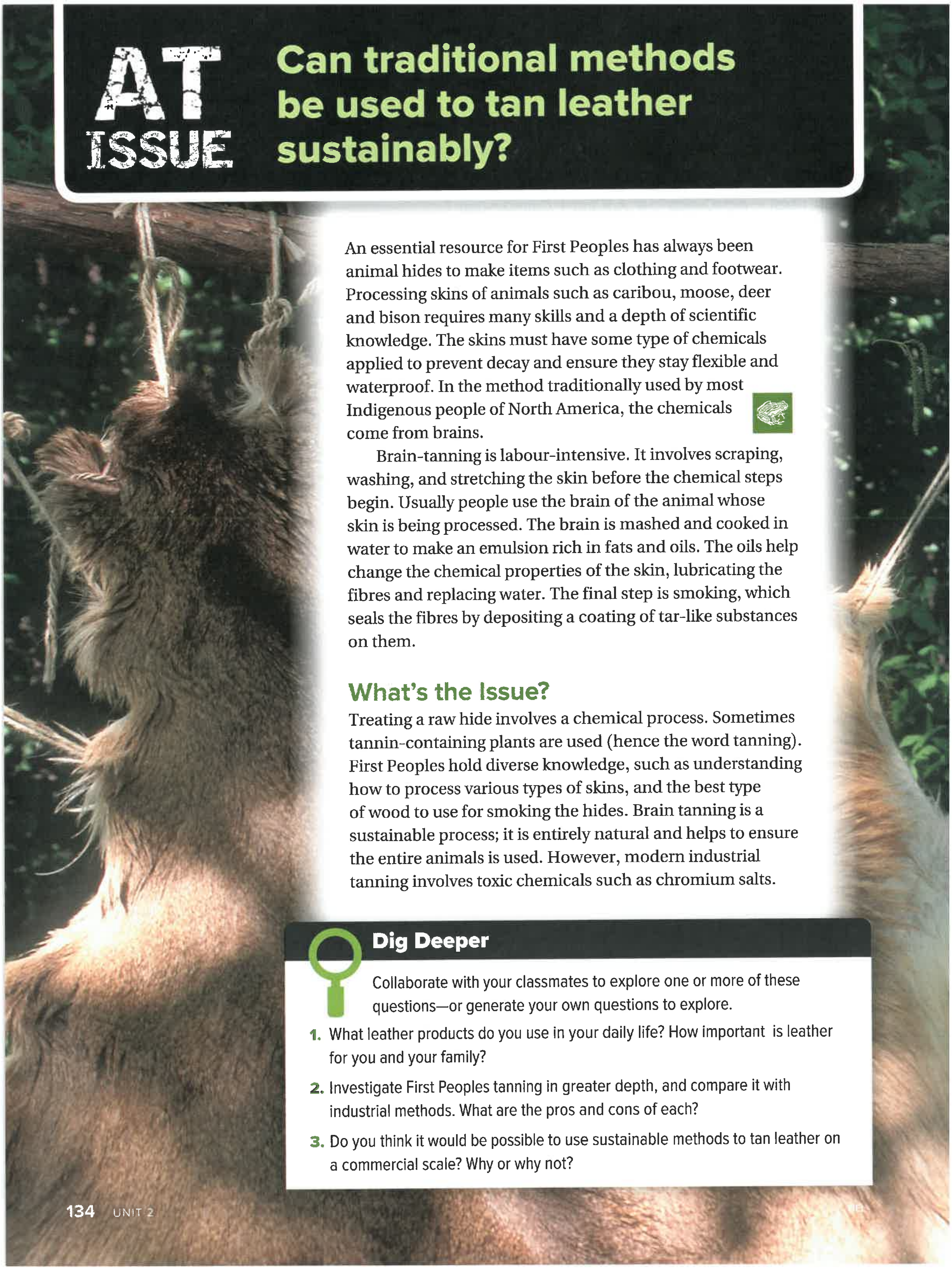
Practice Problems

Balance each of the following skeleton equations.

1. $Li(s) + Br_2(g) \longrightarrow LiBr(s)$
2. $Al(s) + CuO(s) \longrightarrow Al_2O_3(s) + Cu(s)$
3. $Pb(NO_3)_2(aq) + K_3PO_4(aq) \longrightarrow KNO_3(aq) + Pb_3(PO_4)_2(s)$

For each of the following reactions, write a word equation, a skeleton equation, and a balanced chemical equation. Include the states of matter.

4. Nitrogen monoxide gas reacts with oxygen gas to form nitrogen dioxide gas.
5. Solid copper reacts with aqueous silver nitrate to form solid silver and aqueous copper(II) nitrate.
6. Potassium sulfate and silver nitrate, both dissolved in water, react to form solid silver sulfate and dissolved potassium nitrate.



AT ISSUE Can traditional methods be used to tan leather sustainably?

An essential resource for First Peoples has always been animal hides to make items such as clothing and footwear. Processing skins of animals such as caribou, moose, deer and bison requires many skills and a depth of scientific knowledge. The skins must have some type of chemicals applied to prevent decay and ensure they stay flexible and waterproof. In the method traditionally used by most Indigenous people of North America, the chemicals come from brains.

Brain-tanning is labour-intensive. It involves scraping, washing, and stretching the skin before the chemical steps begin. Usually people use the brain of the animal whose skin is being processed. The brain is mashed and cooked in water to make an emulsion rich in fats and oils. The oils help change the chemical properties of the skin, lubricating the fibres and replacing water. The final step is smoking, which seals the fibres by depositing a coating of tar-like substances on them.

What's the Issue?

Treating a raw hide involves a chemical process. Sometimes tannin-containing plants are used (hence the word tanning). First Peoples hold diverse knowledge, such as understanding how to process various types of skins, and the best type of wood to use for smoking the hides. Brain tanning is a sustainable process; it is entirely natural and helps to ensure the entire animals is used. However, modern industrial tanning involves toxic chemicals such as chromium salts.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What leather products do you use in your daily life? How important is leather for you and your family?
2. Investigate First Peoples tanning in greater depth, and compare it with industrial methods. What are the pros and cons of each?
3. Do you think it would be possible to use sustainable methods to tan leather on a commercial scale? Why or why not?

Check Your Understanding of Topic 2.2

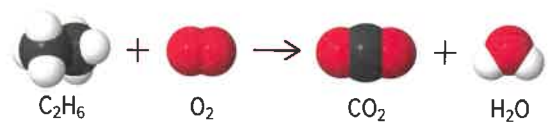
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What is the difference between a coefficient and a subscript of a chemical formula? PA
2. Give an example of an anion and an example of a cation. Describe how each forms. When an ionic compound forms, is it possible for a cation to form but not an anion? Justify your answer. C
3. Using a graphic organizer, such as a T-chart, compare and contrast the bonds in covalent compounds and ionic compounds. PA C
4. Iron metal reacts with oxygen gas to form solid iron(III) oxide. Write a word equation, a skeleton equation, and a balanced chemical equation for this reaction. PA E C
5. Write balanced chemical equations for each of the following. You do not need to include states for parts a) and b). PA E C
   a) potassium + iodine $\rightarrow$ potassium iodide
   b) lead(II) nitrate + sodium chloride $\rightarrow$ lead(II) chloride + sodium nitrate
   c) $H_2O_2(aq) \rightarrow H_2O(\ell) + O_2(g)$
   d) $MgO(s) \rightarrow Mg(s) + O_2(g)$
   e) $Fe(s) + H_2SO_4(aq) \rightarrow H_2(g) + Fe_2(SO_4)_3(aq)$

Connecting Ideas

6. Explain why energy is required to break chemical bonds. Why do some bonds require more energy to break than others? PA E
7. Choose a Group 2 metal element and a halogen element that could combine to form a compound. QP PA
   a) Provide the name and chemical formula for the compound that is predicted to form.
   b) Explain why this compound would form. As part of your answer, use Bohr diagrams or Lewis diagrams to show how bond formation occurs.
8. a) Consider the definition of the term matter. The law of conservation of mass is sometimes referred to as the law of conservation of matter. Do you think this is an appropriate alternative? Justify your opinion. QP E
   b) Using the image below, describe how a balanced chemical equation represents the law of conservation of mass. Redraw the image so it represents a balanced chemical equation. C



   c) Using a table format, list the bonds that are broken and formed during the reaction. Also include whether energy is absorbed or released in each process. C

Making New Connections

9. Identify the open and closed systems that are represented below. Explain why each represents that type of system. Then give as many examples of each type of system as you can, with a minimum of five examples each. Describe what each example is used for and why it is necessary for it to be that type of system. E AI

INVESTIGATION

2-C

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Wear safety eyewear and lab coat or apron throughout this investigation.
- Wear gloves throughout this investigation.
- Rinse any spills with plenty of water, and report them to your teacher immediately.
- Dispose of materials as directed by your teacher.

What You Need

Part 1:

- 25 mL graduated cylinder
- dilute sodium hydroxide solution, 0.1 mol/L NaOH(aq)
- 250 mL Erlenmeyer flask
- dilute iron(III) nitrate solution, 0.1 mol/L $Fe(NO_3)_3(aq)$
- small test tube, 8 mm × 100 mm
- rubber stopper (to fit the Erlenmeyer flask)
- electronic balance (minimum readability 0.01 g)

Part 2:

- 100 mL water
- 250 mL beaker
- electronic balance
- Alka-Seltzer™ tablet
- timer or stopwatch

The Law of Conservation of Mass

According to the law of conservation of mass, matter cannot be created or destroyed. This means that in a chemical reaction, the number of atoms of each element are the same before and after the reaction. Using open and closed systems, you will investigate the law of conservation of mass by analyzing the masses of substances in a chemical reaction.

Question

Does the total mass of substances change in a chemical reaction?

Procedure

Part 1:

1. Read Procedure steps 2 to 7. Design a table to record your results.
2. Use a graduated cylinder to measure 20 mL of dilute sodium hydroxide solution, NaOH(aq). Pour the solution into the Erlenmeyer flask.
3. Add about 5 mL of the iron(III) nitrate solution, $Fe(NO_3)_3(aq)$, into the small test tube. This should be enough to fill the small test tube about half full.
4. Tilt the Erlenmeyer flask carefully and let the small test tube slide down inside, as shown in the photograph. Do not let the solutions mix. Seal the flask with the stopper.

5. Measure the mass of the flask and its contents. Record your measurement. Also record your observations about the appearance of the contents of the flask.
6. Tip the flask so that the solutions mix. Observe what happens and record your observations.
7. When the reaction is complete, measure the mass of the flask and its contents. Record your measurement.
8. Clean up your work area and dispose of any materials according to your teacher's instructions.

Part 2:

1. Read Procedure steps 2 to 4. Design a table to record your results.
2. Pour 100 mL of water into a 250 mL beaker.
3. Determine the masses of the beaker with water and an Alka Seltzer™ tablet. Place the tablet next to the beaker on the balance. Do not add the tablet into the water. Record the mass and any other observations.
4. Leaving the beaker of water on the balance, place the tablet in the water. Observe what happens and record the mass every 30 seconds, using a stopwatch or timer to monitor the time. Continue until most of the bubbling has stopped (about 10 minutes). Record your observations of the final solution.
5. Clean up your work area, and dispose of any materials according to your teacher's instructions.

Process and Analyze

1. What did you observe that tells you a chemical reaction took place in Part 1? in Part 2?
2. Graph the data you collected in Part 2. What labels will you use for the *x*-axis and *y*-axis?

Conclude and Communicate

3. Identify the closed system and the open system in this investigation. Provide an explanation for your answer.
4. For Part 1, how did the initial mass of the chemicals, flask, test tube, and stopper compare with their mass after the reaction? Do you think you would see similar results if you carried out an investigation like this with different reacting chemicals? Explain your answer.
5. What did you observe during the reaction in Part 2? Provide an explanation for this. What do you think the results would have been if you had sealed the opening of the beaker? Explain why.

TOPIC 2.3

How is energy involved in chemical processes?

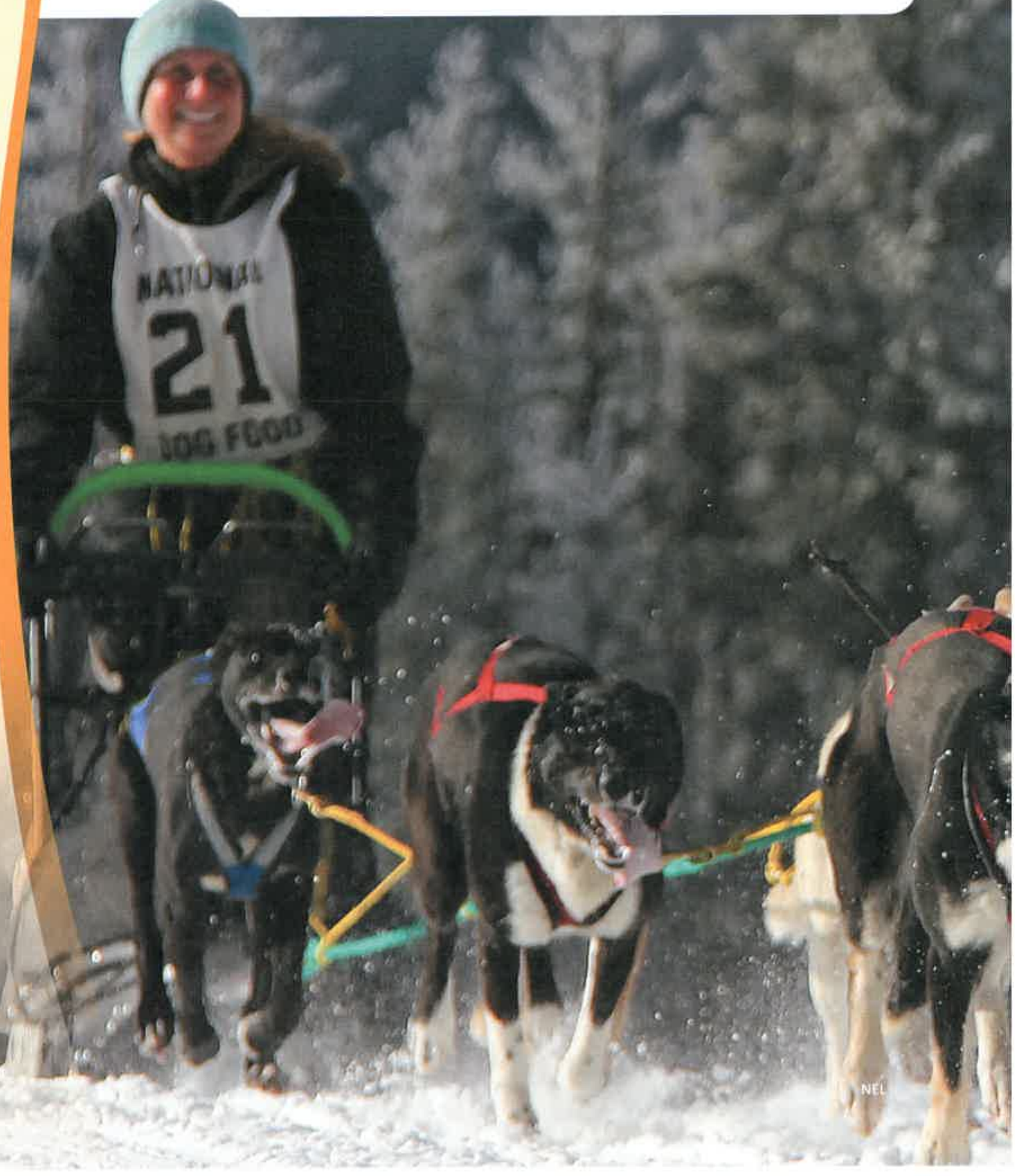
Key Concepts

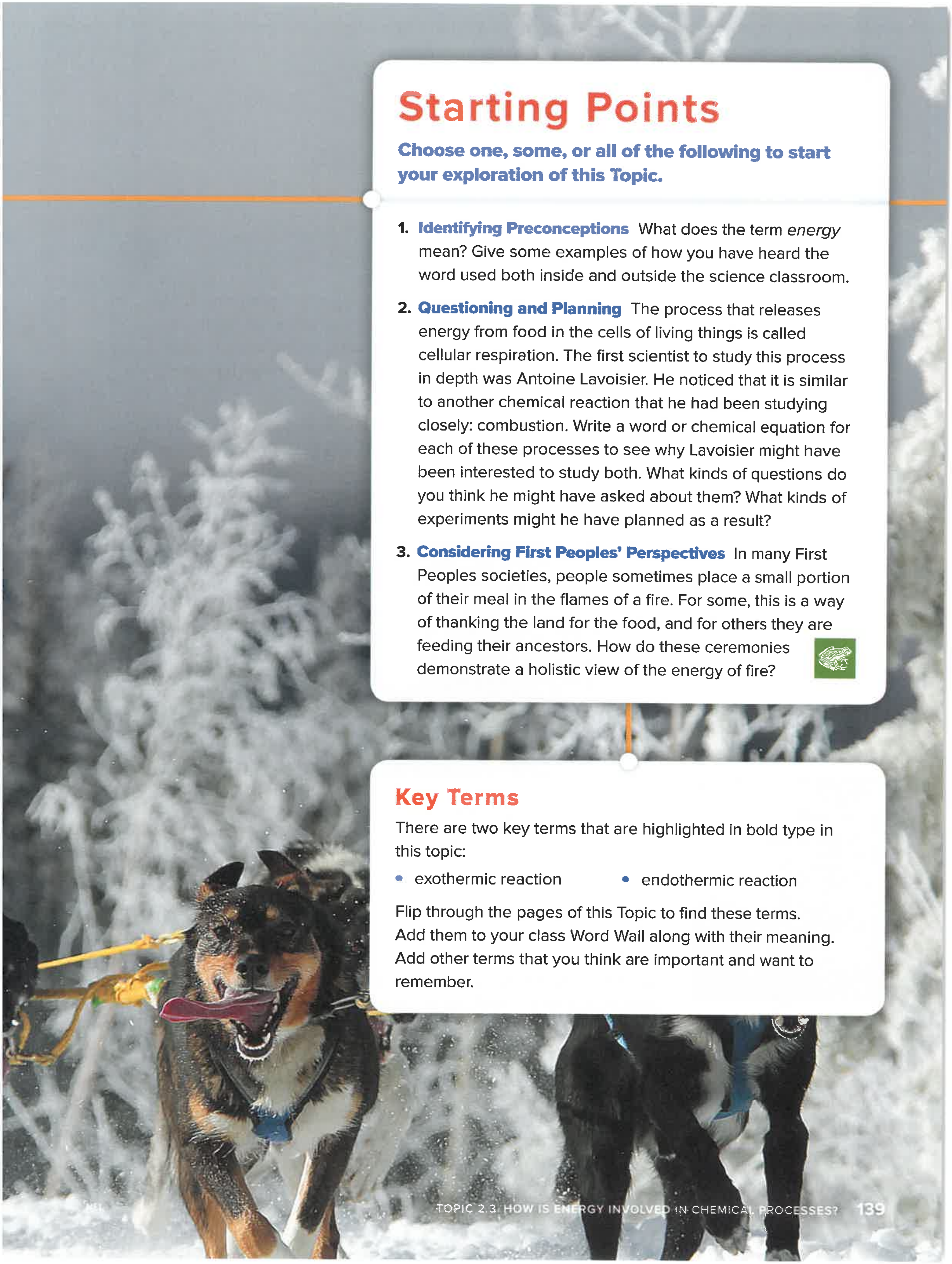
- Matter and energy interact in physical and chemical changes.
- There is a transfer of energy between chemical reactions and the surroundings.

Curricular Competencies

- Collaboratively and individually plan, select, and use appropriate investigation methods.
- Use knowledge of scientific concepts to draw conclusions consistent with evidence.
- Evaluate methods and experimental conditions.
- Formulate physical or mental theoretical models to describe a phenomenon.

British Columbia's Gold Rush Trail Sled Dog Mail Run takes place for three days every January. Mushers are sworn in as official mail carriers and carry Canada Post mail in their dog sleds to post offices along the route, in Quesnel, Wells, and Barkerville. Although once a race, this event is now about community participation. In addition to the dogs, skiers, snowshoers, runners, and kick-sledders are welcome. All participants (dogs and humans) depend on chemical reactions in their body cells for the energy they need. This energy is released as chemical bonds holding together nutrient compounds are broken and then reformed to produce new compounds.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What does the term *energy* mean? Give some examples of how you have heard the word used both inside and outside the science classroom.
2. **Questioning and Planning** The process that releases energy from food in the cells of living things is called cellular respiration. The first scientist to study this process in depth was Antoine Lavoisier. He noticed that it is similar to another chemical reaction that he had been studying closely: combustion. Write a word or chemical equation for each of these processes to see why Lavoisier might have been interested to study both. What kinds of questions do you think he might have asked about them? What kinds of experiments might he have planned as a result?
3. **Considering First Peoples' Perspectives** In many First Peoples societies, people sometimes place a small portion of their meal in the flames of a fire. For some, this is a way of thanking the land for the food, and for others they are feeding their ancestors. How do these ceremonies demonstrate a holistic view of the energy of fire?

Key Terms

There are two key terms that are highlighted in bold type in this topic:

- exothermic reaction
- endothermic reaction

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Matter and energy interact in physical and chemical changes.

Activity

Changes and Energy

Your teacher will provide you and a partner with a piece of ice. What happens to the ice as it sits at room temperature? How is energy involved in this process? What happens if the ice is in your hand? Is the amount of energy in your hand increasing or decreasing? Support your answers with evidence from the activity.

Matter and energy are continually interacting in the world around us. Cooking food is just one common example. To boil the water and make the toast in Figure 2.16, energy is needed. The temperature of the water increases as energy is transferred from the stove burner, and the changes to the bread rely on the addition of energy from a toaster.

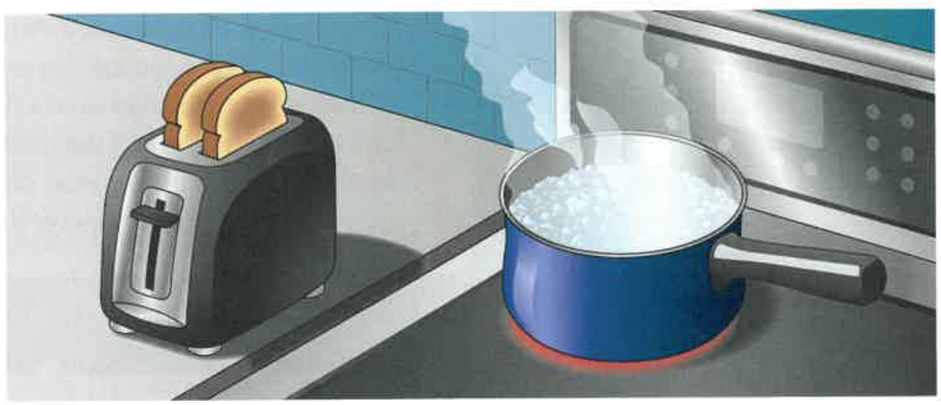


Figure 2.16 Many common events at home require an input of energy.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

propane + oxygen → carbon dioxide + water

Figure 2.17 A lighter provides energy to start the reaction between oxygen and propane. **Predicting: If energy input was not needed to light this torch, what would happen when propane was released from the tank?**

Getting Things Started

For any chemical change to occur, the reactants must collide with enough energy to begin to break the bonds in the reactants. This minimum amount of energy needed for a reaction to occur is called the *activation energy*. It is often useful to think of the activation energy as a barrier or "hill" that needs to be overcome for a reaction to happen.

Many chemical reactions require an initial input of energy—the reactants will not react by simply mixing them together. For example, lighting a propane torch requires a spark or lighter (Figure 2.17). This is the energy input needed for the chemical reaction between oxygen (in the air) and the propane gas. The lighter provides a few molecules of oxygen and propane with enough energy to overcome the energy barrier. In the case of this reaction, a large amount of energy is released—that's what the flame and heat to weld material are. Once the propane is ignited, it will continue to burn because the energy released during the reaction provides the energy for other molecules to overcome the energy barrier to react.

AT ISSUE How does energy change help to solve crimes?

What's the Issue?

A forensics investigator is testing a pair of garage coveralls to find out if the red staining on the fabric is blood. After spraying the coveralls with a solution containing a compound called luminol, a glowing blue-green light shows up—suggesting foul play.

Energy Helps to Solve Crimes

Luminol is a solid that is typically dissolved in a solution of hydrogen peroxide that contains a source of hydroxide ions, such as KOH(aq). The solution can be sprayed onto an object or an area to test for blood.

Luminol reacts with iron from hemoglobin molecules in blood to form a compound that is in an excited state. This means that an electron in each luminol molecule has absorbed energy and has been excited to a higher energy level. When the electron drops back to its original energy level, energy is released as light. This light can be seen easily in a darkened room and lasts for about 30 seconds. Luminol is so sensitive to the iron in blood that blood can be detected even when it cannot be seen.

A positive test does not always mean blood is present. Luminol reacts with other compounds that contain iron, as well as with copper and nickel. Bleach also reacts with luminol. Saliva and even horseradish can also cause luminol to emit light.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What happens when luminol interacts with blood?
2. Does a positive luminol test provide conclusive evidence that a stain is blood? Explain.
3. What is DNA? Why do you think DNA testing of the blood is the next step in the investigation? Why would investigators do the test with luminol first?

CONCEPT 2

Energy is transferred between chemical reactions and the surroundings.

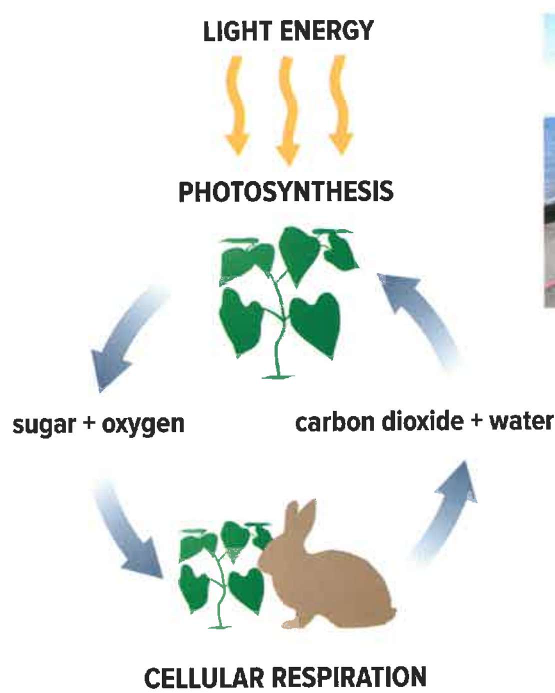
Activity

Where Did the Energy Go?

1. Read the procedure and make a table to record your observations.
2. Place 5 mL of vinegar into a large test tube that is in a test tube rack. Using a thermometer, record the temperature of the vinegar. Leave the thermometer in the test tube.
3. Add a small scoop (about 0.5 g) of baking soda to the test tube. Record the temperature every 5 seconds, until it no longer changes. Record any other observations. Draw a temperature versus time graph of your data. What is the overall temperature change? How would you describe the reaction in terms of energy changes? Was more energy involved in breaking bonds in this reaction or in forming bonds?

All chemical reactions are accompanied by changes in energy. These energy changes are crucial to life on Earth. For example, through photosynthesis green plants absorb energy from sunlight and store it in the chemical bonds of the sugar molecules they produce. Animals that eat the plants use the stored energy through the process of cellular respiration to fuel things such as growth and movement (Figure 2.18).

Figure 2.18 Energy stored in the chemical bonds of molecules used to fuel our bodies is released through the chemical reactions of cellular respiration.



Plants, animals, and other organisms use the sugar and oxygen produced by photosynthesis as part of cellular respiration.

Plants and other organisms use the carbon dioxide and water produced by cellular respiration as part of photosynthesis.

The System and the Surroundings

Chemists think of energy changes in chemical reactions in terms of energy transfers between the *system* and the *surroundings*. The system is the materials involved in the chemical reaction and everything else in the universe is the surroundings. The *law of conservation of energy* states that the total energy of the universe is constant—energy cannot be created or destroyed. In terms of a chemical reaction, it means energy that leaves the system must enter the surroundings, and energy that enters the system must come from the surroundings (Figure 2.19).

Figure 2.19 The chemical reaction occurring in the flask is the system. The flask, the student, and the laboratory are part of the surroundings.

Exothermic and Endothermic Reactions

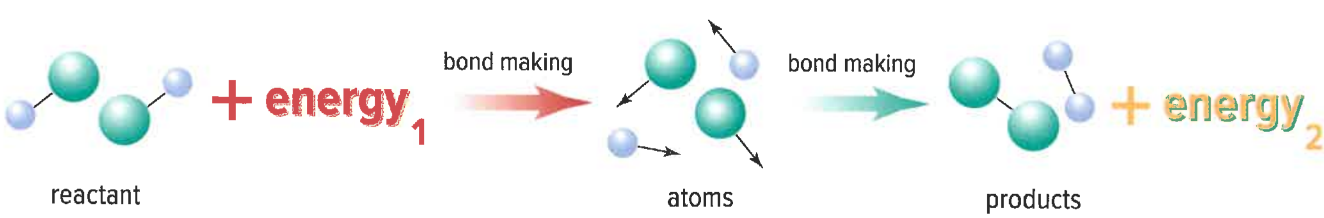
Recall that energy must be absorbed to break bonds and energy is released when bonds form. By comparing the total energy used when bonds in the reactants are broken with the total energy released when bonds in the products are formed, you can determine whether there is an overall release of energy or absorption of energy in a chemical reaction.

When, overall, more energy is released into the surroundings than absorbed by the system, the reaction is called an **exothermic reaction.** (The prefix *exo* means "external" and *thermic* refers to heat.) In exothermic reactions, there is more energy released from the formation of bonds than energy required to break the bonds. When there is an overall greater amount of energy absorbed by the system than released to the surroundings, the reaction is called an **endothermic reaction** (*endo* means "internal"). In endothermic reactions, there is more energy required to break the bonds than energy released from the formation of bonds (Figure 2.20).

exothermic reaction a chemical reaction in which there is net release of energy to the surroundings

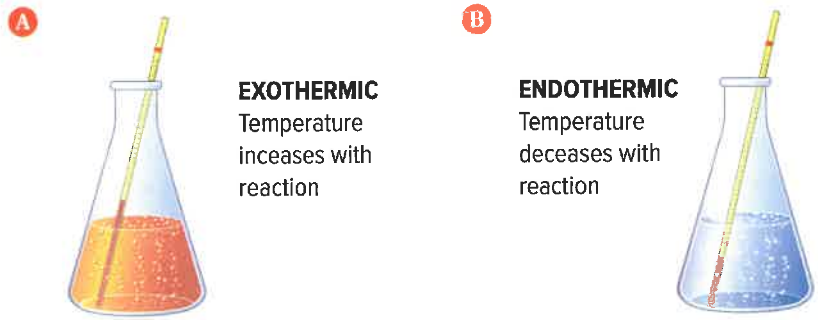
endothermic reaction a chemical reaction in which there is net absorption of energy from the surroundings

Figure 2.20 When the $energy_2$ term is greater than the $energy_1$ term, the overall process is exothermic. When $energy_1$ is greater than $energy_2$, the overall process is endothermic.



Connect to Investigation 2-D on page 150

Figure 2.21 Comparing the temperature of reactions occuring in solution. **Analyzing: How do the relative amounts of energy absorbed and released by the reactions compare?**



Measuring Energy Changes

Connect to Investigation 2-E on page 152

Energy changes in a reaction can be monitored by measuring change in temperature. For example, many chemical reactions occur in a solvent such as water. In Figure 2.21A, the temperature of the solution increases as energy released from the reaction (system) is transferred to the surroundings. In Figure 2.21B, the temperature of the solution decreases as energy is absorbed by the reaction from the surroundings. Sometimes, though, as in Figure 2.22, you don't need a thermometer to tell if a reaction is exothermic or endothermic.

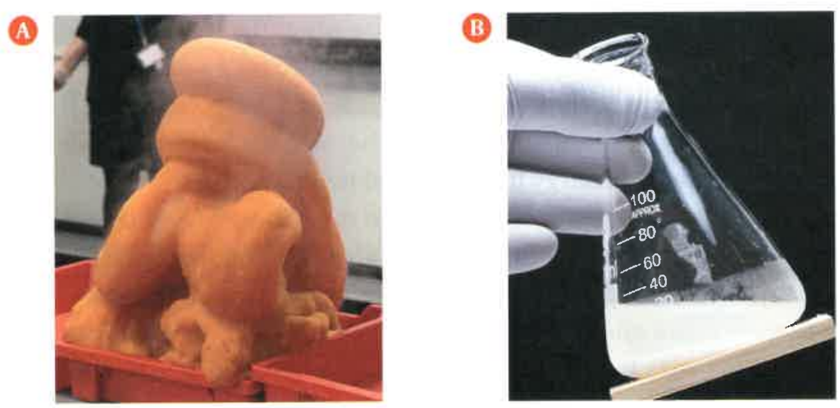


Figure 2.22 Steamy foam in A results from a reaction of yeast, dish soap, and hydrogen peroxide. In B, the reaction of ammonium thiocyanate and barium hydroxide freezes the flask to the wooden base. **Analyzing: Which reaction is absorbing energy?**

Activity

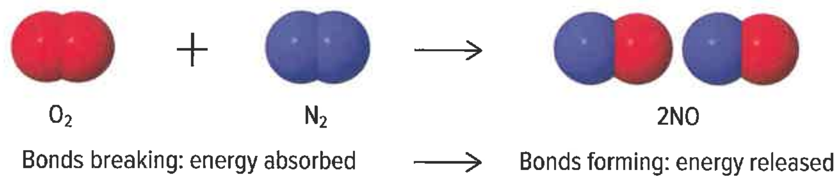
Warming Up

The reaction you will perform is $2NaHCO_3 + CaCl_2 \longrightarrow CaCO_3 + CO_2 + 2NaCl + H_2O$

1. Read the procedure and make an appropriate table to record your observations.
2. Add 0.3 g of baking soda to 5 mL of water in a large test tube in a test tube rack. Record the temperature of the solution. Leave the thermometer in the test tube.
3. Add 0.5 g of $CaCl_2$ to the test tube. Record the temperature every 5 s until it stops changing. Also record other observations. Draw a temperature-time graph of your data. Is the reaction exothermic or endothermic? What is your evidence?

Representing Energy Changes

Consider the reaction below. For every molecule of nitrogen that reacts with a molecule of oxygen, two molecules of nitrogen monoxide are produced.



Connect to Investigation 2-F on page 153

In this reaction, nitrogen-nitrogen bonds and oxygen-oxygen bonds are broken. The breaking of these bonds in each case absorbs energy. Nitrogen-oxygen bonds form, and the formation of these bonds releases energy. The total energy absorbed to break each nitrogen-nitrogen bond and oxygen-oxygen bond is more than the total energy released when nitrogen-oxygen bonds form. Therefore, there is an overall absorption of energy, and the reaction is endothermic.

Figure 2.23 shows how energy changes of a reaction can be represented. These are called energy-level diagrams, and they show the relative energy levels of the reactants and products in a reaction. For endothermic reactions, there is more energy required to break bonds than energy that is released when new bonds form. Therefore, there is an overall absorption of energy. This means that the energy of the products is greater than the energy of the reactants. For exothermic reactions, there is an overall release of energy, and the products are at a lower energy than the reactants.

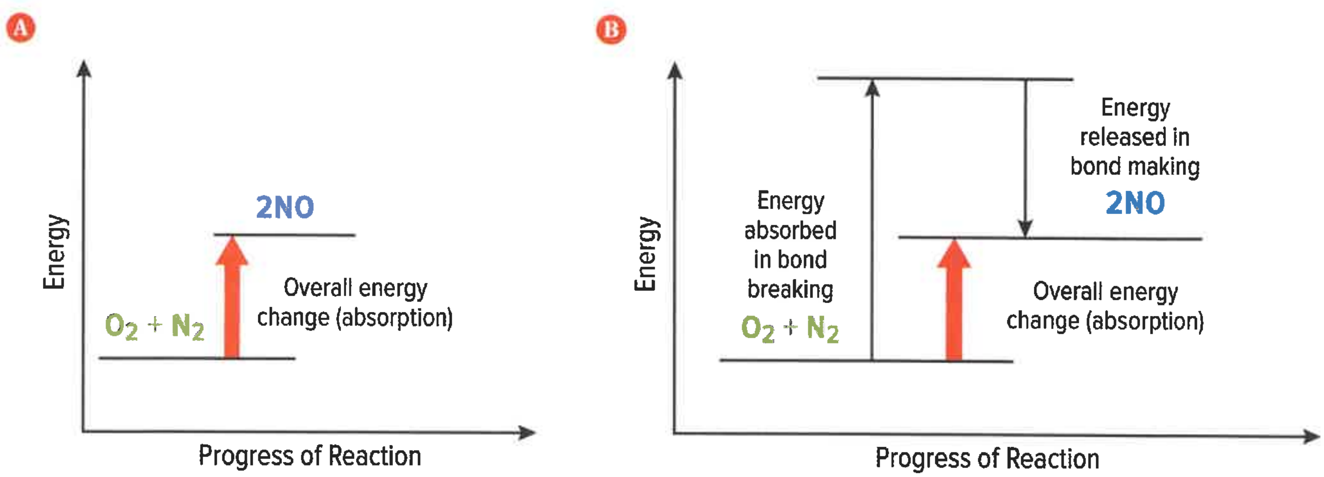


Figure 2.23 (A) This diagram shows the overall absorption of energy. Notice that the products have more energy than the reactants. (B) This diagram shows how the overall energy change is the net result of energy absorbed to break bonds and energy released in the forming of bonds.

Before you leave this page . . .

1. What is an endothermic reaction?
2. Describe the relative energies of reactants and products in an endothermic reaction.
3. If there is a decrease in energy of the system, what happens to the energy of the surroundings?

AT ISSUE Why does it matter how quickly a reaction occurs?

What's the Issue?

Every chemical reaction happens at a certain rate under specific conditions. You can speed up or slow down the reaction by changing the conditions. For example, an increase in temperature, surface area, or concentration of a reactant will each cause a reaction to happen faster. So does the presence of a catalyst. (A catalyst makes a reaction happen faster without being used up in the reaction. For example, catalytic converters on vehicles contain metals that act as catalysts in reactions that convert harmful gases in exhaust to less harmful substances.)

An automobile catalytic converter (full view and cross-section)

Runaway Reactions

When a chemical reaction is "scaled up" from the laboratory to industry, extra caution is needed. A great deal of heat can be released during exothermic reactions. Inside a large reaction vessel, the safe removal of heat is essential, because it can cause a "runaway" reaction. Since an increase in temperature increases the rate of a reaction, heat released from a reaction can cause it to self-accelerate and become uncontrolled.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. How fast or slow a reaction occurs is important. For example, the process of rusting is a chemical reaction that occurs very slowly, which is desirable. Give three examples of chemical reactions that demonstrate the importance of how fast a reaction occurs.
2. Chemical reactions depend on collisions between reactant atoms and molecules. Changing the number of collisions that happen in a certain amount of time will alter how quickly a reaction happens. Use this as a basis for developing an explanation for the effect of temperature, surface area, and amount of reactant on the speed of a reaction.
3. Your body cells contain many different catalysts called enzymes. What can you infer about the reactions in your body and the link between enzyme activity in the body and health?
4. In a group discuss the issue of industrial chemical reactions and possible safety concerns. What could be done to prevent runaway reactions? How can the surrounding environment be protected?

Check Your Understanding of Topic 2.3

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

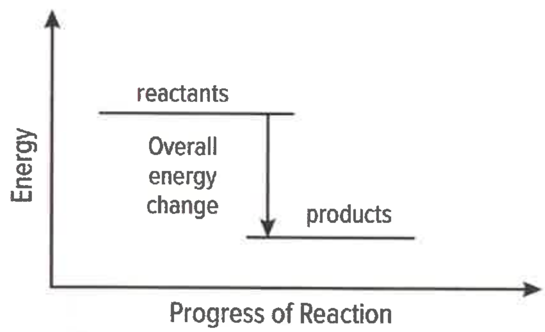
Understanding Key Ideas

1. Describe an example of a physical change or chemical change that is endothermic and a physical or chemical change that is exothermic. PA

2. Compare the overall energy changes that occur in endothermic reactions with those that occur in exothermic reactions. How are the energies of bond formation and bond breaking involved? PA E

3. Draw a sketch of the overall transfer of energy between the system and surroundings for an endothermic reaction. C

4. An energy-level diagram is shown below.



   a) Does the diagram represent an exothermic or endothermic reaction? Explain. PA

   b) Draw a diagram that would represent a greater overall energy change. C

Connecting Ideas

5. Students perform a chemical reaction in a glass test tube. They notice that the test tube feels cooler than it did before the reactants were added. PC PA

   a) Did the students most likely perform an exothermic or endothermic reaction?

   b) What data could the students collect to confirm the type of reaction?

   c) Identify the system and the surroundings in this investigation.

6. Is melting an ice cube an endothermic or exothermic process? Explain. QP AI

7. Although many individual reactions are part of photosynthesis and cellular respiration, the following chemical equations can be used to represent the overall processes.

   Photosynthesis:

   $6H_2O + 6CO_2 + \text{energy} \longrightarrow 6O_2 + C_6H_{12}O_6$

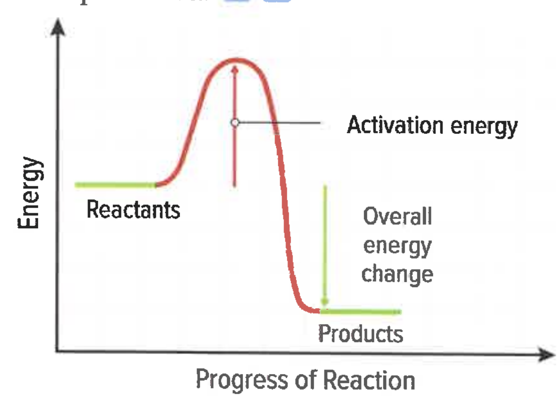
   Cellular respiration:

   $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$

   Is photosynthesis an endothermic process or an exothermic process? What about cellular respiration? Explain your answers. QP PA E

Making New Connections

8. The image below shows another way that energy changes in a chemical reaction can be represented. E AI



   a) What is activation energy? Why do you think it is represented as a "hill"?

   b) Describe the relative energy levels of the reactants and products.

   c) Does this diagram represent an exothermic or endothermic reaction? Explain your answer.

   d) Infer which are the most stable particles in the reaction. Which are the least stable? Justify your responses based on the energies of the particles.

BE Inspired

Make a Difference

Ata Sina and the Shape-Shifting Paper

What do the Japanese art of origami and plastic polymer chemistry have in common? Ata Sina has an unusual answer to this question. As a graduate student at the University of British Columbia, he created a paper that folds, on its own, into intricate three-dimensional shapes like origami.

The paper is manufactured in several stages. First, a computer program is used to create carefully placed cuts and folds in the paper. Next, thermoplastic polymers are attached to the paper in certain locations. Then the paper spends 10 to 20 seconds in a 110°C oven. The thermoplastic polymers have been forced into the shape of long, stretched-out polymer chains. In the oven, the elongated polymers absorb energy, which increases the motion of their molecules. This increased motion allows the molecules to break out of their forced, elongated shape, which causes the thermoplastic to shrink. As it does so, it lifts the paper to form the three-dimensional shape.

When the thermoplastic shrinks, its strength increases as well. As a result, the structures formed by the shape-shifting paper are strong, in addition to being light-weight and affordable. If also takes less energy to produce structures made of this material compared to plastic.

Evaluate and Communicate

1. Ata Sina's shape-shifting paper has multiple uses, such as an artistic material, sustainable packaging, or a children's toy. Create a marketing proposal for one of the above applications of shape-shifting paper or come up with your own. The proposal should also explain the chemistry behind the paper.
2. Ata Sina's shape-shifting paper allowed him to combine his interest in both art and science. What personal interests do you have that could be combined with science, and in what ways? Share your ideas with a partner or in a group. You might find that notions from various sources can be combined in unusual ways that inspire even more intriguing ideas.

Chemistry Connections

Forensic Scientist

Environmental Assesor

Materials Technician

Food Scientist

Laboratory Analyst

What kinds of jobs are there for people interested in chemical processes?

Mudlogger

Ready for some rugged adventure? Mudloggers apply their knowledge of chemistry and geology as they collect and analyze rock samples from deep underground in search of oil and natural gas deposits.

Fuel Researcher

Interested in sustainability and a desire to reduce the effects of climate change? Fuel researchers assess the performance and emissions impact of fuels as well as investigate renewables and alternatives.

Fire Protection Engineer

How many hats do you like to wear at once—scientist, engineer, emergency response planner, lawyer, architect, security system designer? A fire protection engineer calls on skills from all these fields to help safeguard life and property.

Questions

1. What other jobs and careers do you know or can you think of that involve working with chemicals or studying chemical reactions?
2. Research a job or career related to Unit 2 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

INVESTIGATION

2-D

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Wear safety goggles, gloves, and a lab coat.
- The materials can become quite hot. Avoid touching the hot liquid or glass. Use a thermal glove or tongs.

What You Need

Part 1:

- 35 mL of copper(II) chloride solution, 0.5 mol/L $CuCl_2(aq)$
- two 250 mL beakers
- thermometer
- aluminum foil, 6 cm by 6 cm
- fluted filter paper for gravity filtration
- funnel
- ring clamp, retort stand, beaker, and stirring rod
- wash bottle, with tap water

Part 2:

- 40 mL tap water
- 250 mL Erlenmeyer flask
- thermometer
- 5 g sodium hydrogen carbonate (baking soda), $NaHCO_3$
- 5 g citric acid, $C_6H_8O_7$
- timer or stopwatch

Exothermic and Endothermic Reactions

Evidence that suggests a chemical change has occurred includes a change in temperature of the chemical reaction mixture. This temperature change is associated with energy changes that accompany chemical reactions. The overall energy change is the net result of energy that is absorbed to break chemical bonds and energy that is released when new chemical bonds form.

In this investigation, you will measure changes in temperature during a chemical reaction to determine if there is an overall release or absorption of energy. Based on your results, you will classify the reaction as endothermic or exothermic.

Question

How can exothermic and endothermic reactions be identified?

Procedure

Part 1:

1. Read Steps 2 to 7, and then design a table to record your observations.
2. Add 35 mL of copper(II) chloride solution to a beaker. Insert the thermometer. Loosely crumple the aluminum foil into a 1.5 cm diameter ball. Record the temperature of the solution to the nearest tenth of a degree and any other observations.

3. Place the foil ball in the solution and monitor the chemical reaction that is occurring in the beaker. Record the temperature every 30 seconds and any other changes you observe as the reaction proceeds.
4. Allow the reaction to cool. While you are doing that, watch as your teacher demonstrates how to use the filter paper and funnel to perform a gravity filtration so that you can separate the solid from the reaction mixture.
5. Secure the funnel, with filter paper, to the retort stand by using a ring clamp. Make sure to place the beaker under the funnel to collect the liquid.
6. Pour the reaction mixture through the filter paper. Pour slowly so it does not flow over the top of the funnel. Rinse the residue out of the first beaker with cold water using a wash bottle. Pour the rinse into the funnel.
7. When all the fluid has passed through, carefully remove the filter with the solid you collected. Record your observations.
8. Clean your work area, and dispose of materials according to your teacher's instructions.

Part 2:

1. Read Steps 2 to 4, and then design a table to record your observations.
2. Add 40 mL of water to an Erlenmeyer flask. Place the thermometer in the flask and record the temperature.
3. Place 5 g baking soda in the Erlenmeyer flask. Swirl to dissolve the solid and record the temperature.
4. Add 5 g citric acid to the flask, mix the contents, then record the temperature. Record the temperature every 15 seconds, using a stopwatch or timer to monitor the time. Also record any changes you observe as the reaction proceeds.
5. Clean your work area and dispose of materials according to your teacher's instructions.

Process and Analyze

1. Did a chemical reaction occur in Part 1? in Part 2? What observations support your answer?
2. Graph the data you collected in Parts 1 and 2.
3. What is the overall change in temperature for the reaction you performed in Part 1? What is the overall change in temperature for the reaction you performed in Part 2?

Conclude and Communicate

4. Describe the reactions you performed in terms of the overall energy changes that occurred. How do the data you collected support these conclusions?
5. Identify each reaction you performed as endothermic or exothermic. Describe evidence that supports your answer.
6. The skeleton equation for the reaction between aluminum and copper(II) chloride is below.

   $Al(s) + CuCl_2(aq) \longrightarrow AlCl_3(aq) + Cu(s)$

   a) Write the balanced chemical equation for this reaction.
   b) What did you notice about the colour of the solution during the reaction? Propose an explanation.
   c) What happened to the aluminum? Propose an explanation.
   d) Based on your observations and explanations, describe what you think is happening to the atoms and ions in the reaction between aluminum and a solution of copper ions and chloride ions. What bonds are broken? What new bonds form?

INVESTIGATION

2-E

GUIDED INQUIRY

What Makes the Best Hand Warmer?

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Wear safety goggles, gloves, and a lab coat or apron.
- Handle chemicals safely. Avoid touching all reactants and products.
- Wash your hands thoroughly after completing this investigation.

What You Need

- test tubes or beakers
- thermometer
- water
- calcium chloride
- ammonium chloride
- sodium chloride
- other compounds your teacher may provide

Hand warmers can be slipped inside mitts to help combat cold conditions. One design has water on one side and on another side a substance that dissolves in the water when the packet is squeezed. In this investigation, the class will determine which chemical, when dissolved in water, would make the most effective component of a hand warmer.

Question

Which chemical makes the best component for a hand warmer?

Procedure

1. Your teacher will assign your group the chemicals to test. Design a procedure that identifies which of them, when dissolved in water, will make the most effective hand warmer. Your design should include the following considerations:
   - How quickly does the temperature change?
   - What is the maximum temperature that should be reached to ensure that skin is not harmed?
   - What volume is needed?
   - How expensive is it?
   - How safe is it for the person as well as the environment?
2. Write out the procedure for how you will test the chemicals. Include all safety precautions you will take, as well as clean-up and disposal instructions.
3. Have your teacher approve your procedure before proceeding.

Process and Analyze

1. What criteria did you use to assess which chemical was best? Explain why you chose them.
2. Summarize your data in a table.

Conclude and Communicate

3. As a class, share your results. Which chemical was identified as the most suitable for a hand warmer, and what was the rationale?
4. Identify each process you studied as exothermic or endothermic. Explain your answer.
5. Find out more about why the dissolving of ionic compounds in water can be exothermic or endothermic processes.

INVESTIGATION
2-F

OPEN INQUIRY

Skills and Strategies

- Questioning and Predicting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

What You Need

- computer with Internet access

Chemical Reactions as Energy Sources

One way that society relies on chemical reactions is as a source of energy. Many of us use natural gas to heat our homes, gasoline to power vehicles, as well as more environmentally friendly alternatives such as hydrogen fuel cells and battery-powered cars. In this investigation, you will develop questions you have about one way our society produces energy by chemical reactions.

Procedure

1. Working in small groups, decide on what type of energy production from chemical reactions you want to investigate. This can include use of fossil fuels such as gasoline and propane at the individual level for heating, transportation, or cooking, as well as alternative energy sources such as hydrogen fuel cells.
2. Write out any questions your group has about the energy source and how chemistry is involved.
3. Decide which question or questions you will investigate and plan how you will answer them. Your investigation should include addressing the following:
   - What is the energy used for?
   - What is the chemical reaction and balanced chemical equation that represents it? Include a description of what is occurring to the atoms involved and what bonds are broken and formed.
   - What are the pros and cons (including environmental and socio-economic impacts) of using this chemistry to generate the energy?

Process and Analyze

1. What is the source of and use for the energy you chose?
2. Were you able to determine the answers to all of your questions? If so, what are they? If not, why were you not able to? What information was lacking?

Conclude and Communicate

2. Summarize the advantages and disadvantages of using this chemical reaction and energy source.
3. Combine your group's findings with those of the class. As a class, generate a presentation that summarizes all of your findings.

TOPIC 2.4

How do atoms rearrange in different types of chemical reactions?

Key Concepts

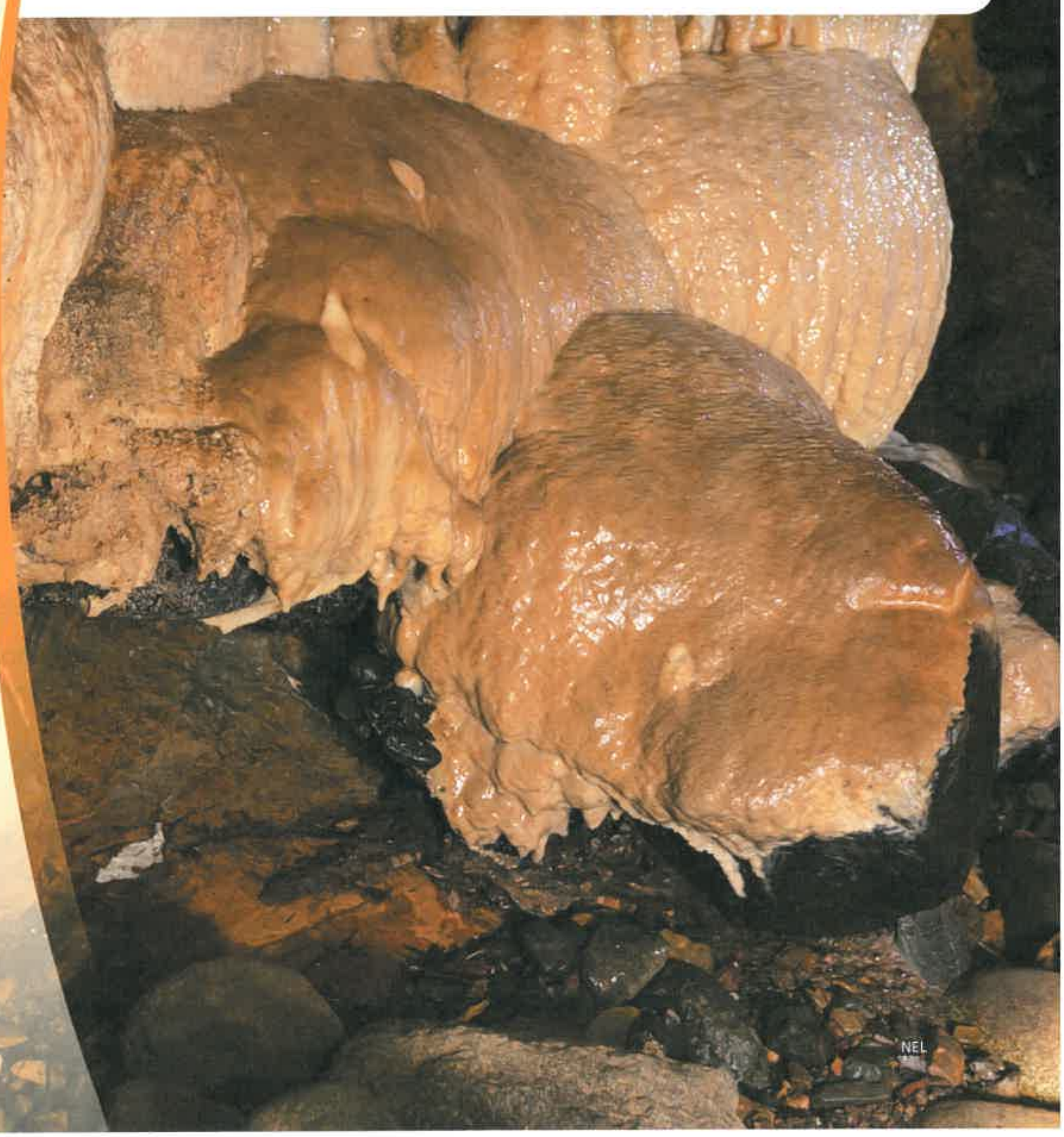
- A compound forms in a synthesis reaction and breaks down in a decomposition reaction.
- In replacement reactions, elements replace other elements.
- Most combustion reactions release heat and light.
- In a neutralization reaction, an acid reacts with a base.

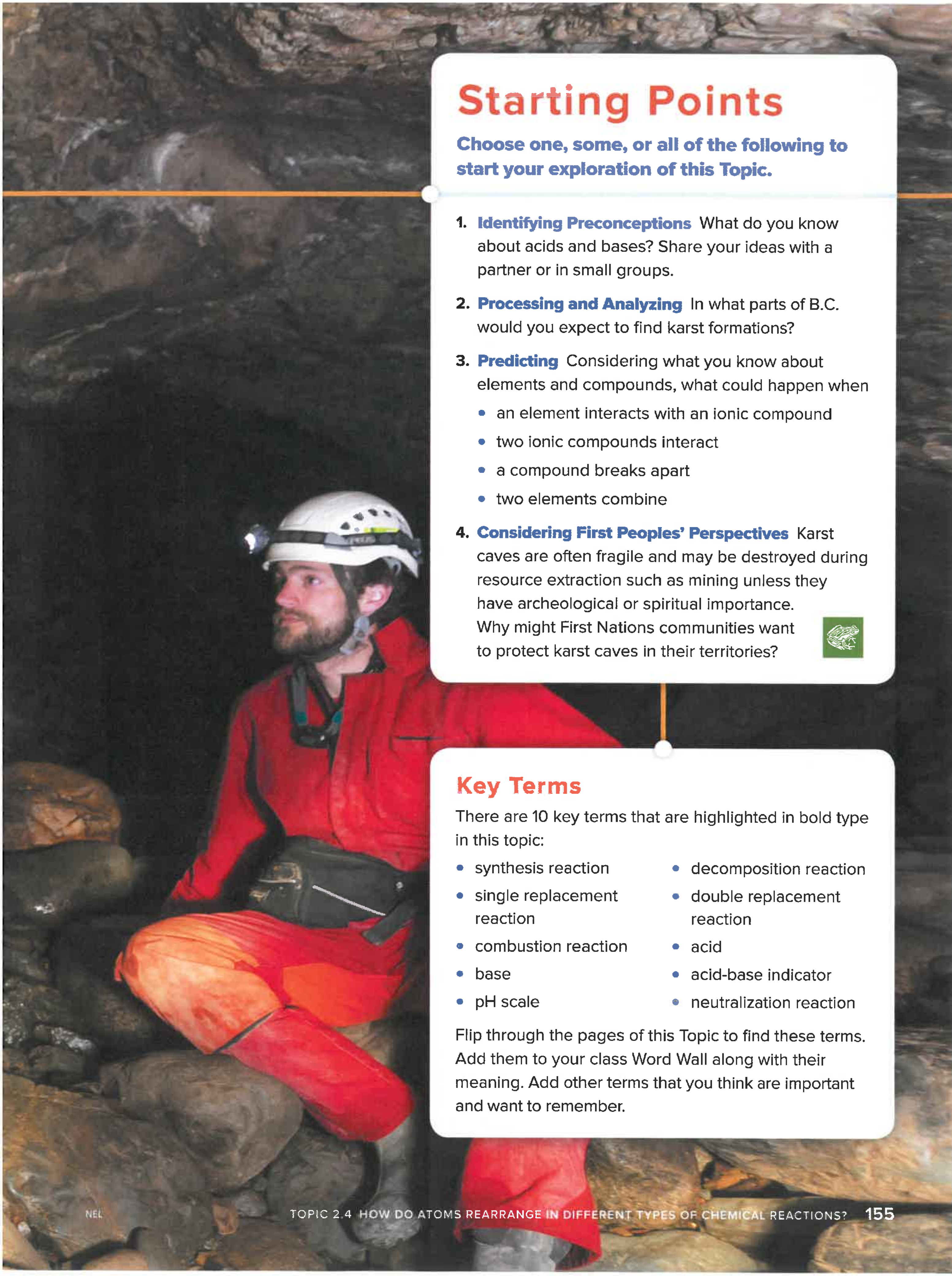
Curricular Competencies

- Formulate multiple hypotheses and predict multiple outcomes.
- Select and use appropriate equipment to systematically and accurately collect and record data.
- Analyze cause-and-effect relationships.
- Evaluate the validity and limitations of a model or analogy.

British Columbia is home to numerous breath-taking and distinctive landscapes, including karst formations that run deep beneath our feet. These are the many caves, sinkholes, and complex underground networks of springs and streams—all the result of chemical reactions between certain kinds of rock, such as limestone, and rainwater.

Carbon dioxide in the atmosphere dissolves in rainwater. A reaction between water and carbon dioxide produces a compound called carbonic acid, $H_2CO_3(aq)$. As rainwater falls and infiltrates the land over thousands of years, carbonic acid reacts with compounds in bedrock such as limestone, slowly dissolving the rock and carving out karst terrain. Each year, spelunkers (cave explorers) from the province, country, and around the world come to study and to marvel at these examples of nature.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you know about acids and bases? Share your ideas with a partner or in small groups.
2. **Processing and Analyzing** In what parts of B.C. would you expect to find karst formations?
3. **Predicting** Considering what you know about elements and compounds, what could happen when
   - an element interacts with an ionic compound
   - two ionic compounds interact
   - a compound breaks apart
   - two elements combine
4. **Considering First Peoples' Perspectives** Karst caves are often fragile and may be destroyed during resource extraction such as mining unless they have archeological or spiritual importance. Why might First Nations communities want to protect karst caves in their territories?

Key Terms

There are 10 key terms that are highlighted in bold type in this topic:

- synthesis reaction
- single replacement reaction
- combustion reaction
- base
- pH scale
- decomposition reaction
- double replacement reaction
- acid
- acid-base indicator
- neutralization reaction

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

A compound forms in a synthesis reaction and breaks down in a decomposition reaction.

Activity

Recognizing Patterns: Building Your Own Summary

Make simple drawings that represent the atoms and bonds in the reactions below. Write the balanced chemical equations. Compare the two reactions. Describe what bonds are broken, what bonds form, and how atoms are rearranged.

hydrogen + oxygen → water

water → hydrogen + oxygen

As you complete this concept, identify the type of reaction each represents. As you study this Topic, add more information to this material. Come up with models for each of the reaction types using examples other than chemical symbols. What do the reactants typically look like in each type of reaction? What do the products typically look like in each type of reaction?

Synthesis Reactions

synthesis reaction
a chemical reaction in which two or more reactants combine to produce a single product

In a **synthesis reaction**, two or more elements or simple compounds combine to form a new compound. The reactants can be any combination of elements or compounds. However, the product is always a single compound. Most synthesis reactions are exothermic.

The general form of a synthesis reaction is shown below in two ways. The first way uses the individual letters A and B to represent the components. The second way uses coloured circles.

$$A + B \rightarrow AB$$

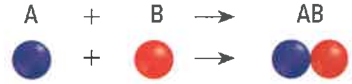


Figure 2.24 shows a few of the many examples of synthesis reactions in the world around you. **Figure 2.25** uses images to show both the visible, large-scale view and the atomic-scale view of a synthesis reaction.

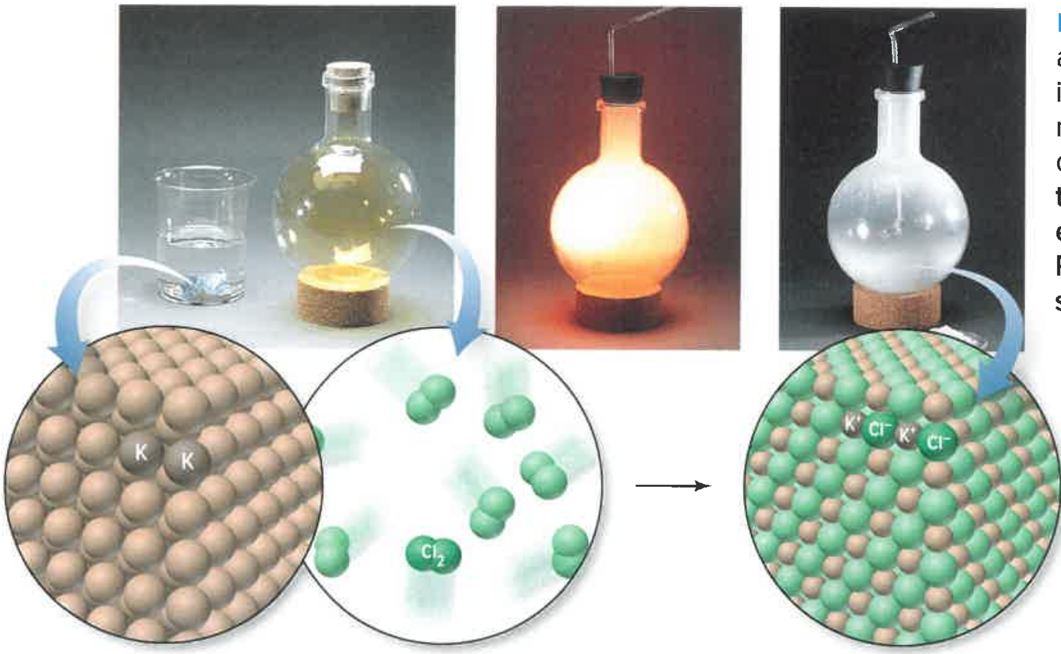
Figure 2.24 Examples of common synthesis reactions.

Dull Aluminum

Shiny aluminum rims would soon become dull after they are installed on a car if they were not protected by a clear coat. The dull sheen that forms on unprotected aluminum is aluminum oxide. Aluminum oxide is seen on any unprotected aluminum that is exposed to air, including boats and window frames.

aluminum + oxygen → aluminum oxide

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$



$2K(s)$ potassium + $Cl_2(g)$ chlorine $\longrightarrow$ $2KCl(s)$ potassium chloride

Figure 2.25 Potassium and chlorine combine in a dramatic synthesis reaction to form potassium chloride. **Analyzing: Is this an exothermic or endothermic reaction? Provide evidence to support your answer.**

Acid Precipitation

Industrial processes and burning coal with sulfur impurities produce sulfur compounds. These combine with moisture in the air to produce acid precipitation (acidic rain, snow, and fog). Acid precipitation damages buildings and harms plants and aquatic life. There are two different synthesis reactions that contribute to acid precipitation.

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

$SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(aq)$

Hydrogen-Powered Vehicles

In hydrogen fuel cells, hydrogen and oxygen are combined to produce water, which is the only chemical product. The energy produced by this reaction is converted to electricity that is used to power vehicles.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

Metal Rusting

Damage to equipment, buildings, and structures caused by metal corrosion costs society billions of dollars each year. Rusting is a type of corrosion that involves the reaction of iron. The process is complex and occurs in multiple steps. The final product is iron(III) oxide, $Fe_2O_3(s)$, which has a brownish-orange colour. A general chemical equation that represents rust formation is

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Decomposition Reactions

decomposition reaction a chemical reaction in which a compound is broken down into elements or simpler compounds

In a **decomposition reaction**, one compound breaks down into two or more elements or simpler compounds. A decomposition reaction occurs when a reactant absorbs enough energy for one or more of its bonds to break. The energy can be in different forms—heat and electricity are two common ones. A decomposition reaction is often the reverse of a synthesis reaction. Therefore, most decomposition reactions are endothermic. The general form of a decomposition reaction is shown here.

$$AB \rightarrow A + B$$

Figure 2.26 shows what happens when mercury(II) oxide decomposes. This compound is used in mercury batteries.

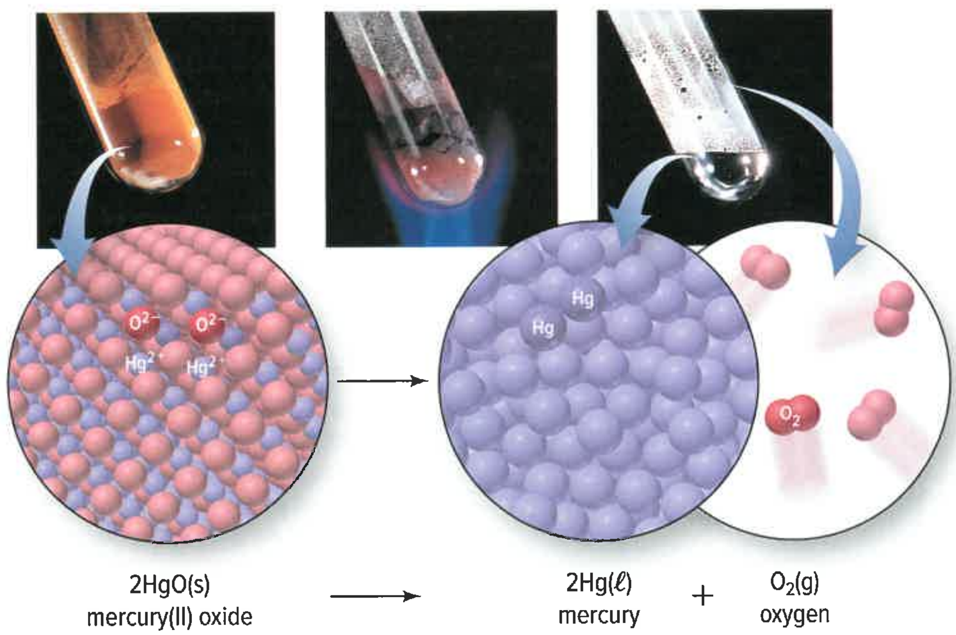


Figure 2.26 Solid mercury(II) oxide breaks down in a decomposition reaction. **Communicating: Describe the overall energy change in this reaction.**

Activity

What Happened to the Baking Soda?

The chemical equation for the reaction in this demonstration is

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

1. Your teacher will set up a system made up of a test tube, test tube clamp, ring stand, 2 g baking soda, and Bunsen burner. Record the mass of the test tube and baking soda your teacher provides.
2. Observe as the baking soda and test tube are heated gently and slowly using a cool flame for about 2 min. Record your observations.
3. Your teacher will measure the mass of the test tube and material after heating. Record it.
4. Compare the mass before and after heating. Account for any differences.
5. Was this system open or closed? Explain.

Figure 2.27 shows a few of the many decomposition reactions in the world around you.

Motorcycle Air Bags

Many motorcycles have air bags that inflate within thousandths of a second in a crash. A motorcycle changes speed very quickly during a crash. This triggers a sensor in the air bag to create an electric impulse. The impulse sparks sodium azide in the air bag. Sodium azide immediately breaks down into solid sodium and nitrogen gas. The nitrogen gas fills the bag to cushion the driver on impact. The decomposition reaction is

$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$

Limestone and Cement

Limestone is a raw material in a host of products used in construction, agriculture, and the pulp and paper industry. The traditional territory of the Lheidli T'Enneh First Nation includes significant limestone deposits that may be quarried. Limestone is calcium carbonate, which yields calcium oxide (quick lime) and carbon dioxide when heated, as shown in the chemical equation below. The calcium oxide produced in this decomposition reaction is the main component of cement. Cement is added to water, sand, and gravel to make concrete. The calcium oxide acts as a binding agent. It holds the mixture together as the concrete dries and cures over time.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Explosion for Demolition Involving TNT

Many explosives produce tremendous force to break apart materials. They can occur as a result of the decomposition of a compound and the rapid heating and expansion of the gases that are produced. For example, trinitrotoluene (TNT) is a commonly used explosive that decomposes into elements and compounds.

$2C_7H_5N_3O_6(s) \rightarrow 3N_2(g) + 5H_2O(g) + 7CO(g) + 7C(s)$

Figure 2.27 The energy used to initiate decomposition reactions may come from heat, electrical energy, and light. **Applying: How many examples of reactions involving these three energy inputs can you discover?**

Before you leave this page . . .

1. In your own words, describe what happens in a synthesis reaction and a decomposition reaction.
2. Which of the following is a synthesis reaction and which is a decomposition reaction? Predict the products formed in each reaction, and give the balanced chemical equations.
   a) $Al(s) + F_2(g) \rightarrow$
   b) $AgCl(s) \rightarrow$
3. Are decomposition reactions endothermic or exothermic? Justify your response through a discussion of the energy changes associated with breaking and forming bonds.

CONCEPT 2

In replacement reactions, elements replace other elements.

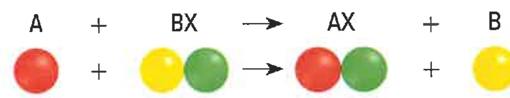
single replacement reaction a chemical reaction in which an element and a compound react to produce another element and another compound

Single Replacement Reactions

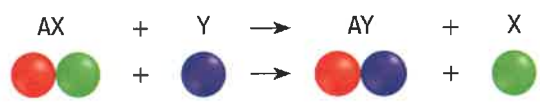
In a **single replacement reaction**, an element and a compound react to produce another element and another compound. In this type of reaction, an element takes the place of another element in a compound.

A single replacement reaction has two general forms. These are shown below. The first equation represents a metal element (A) replacing the metal ion (B) in a compound. The second equation represents a non-metal element (Y) replacing the non-metal ion in a compound (X).

Reactions in which a metal replaces another metal:



Reactions in which a non-metal replaces another non-metal:



A Metal Can Replace a Metal

Figure 2.28 shows the following single replacement reaction, which involves a metal atom replacing a metal ion in a compound.

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

In this example, the metal element copper replaces the silver ion in the compound silver nitrate. Usually, the compound reacting must be dissolved in water to form an aqueous solution. The new compound that forms is copper(II) nitrate, which is dissolved in the solution, and silver now exists as solid crystals on the wire.

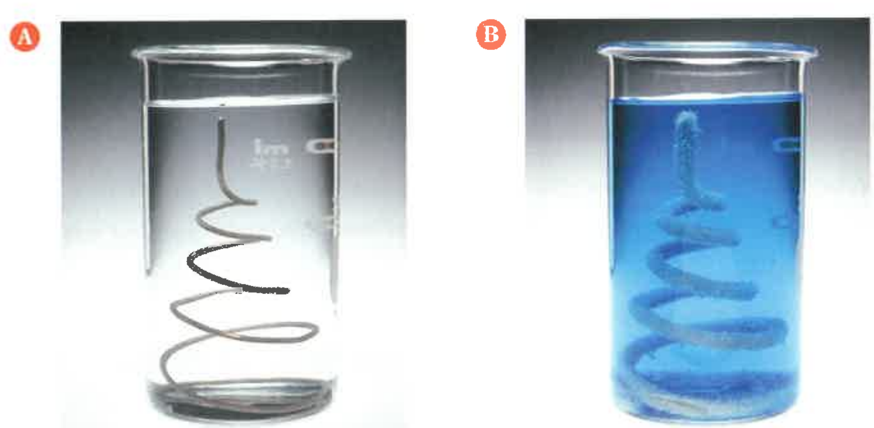
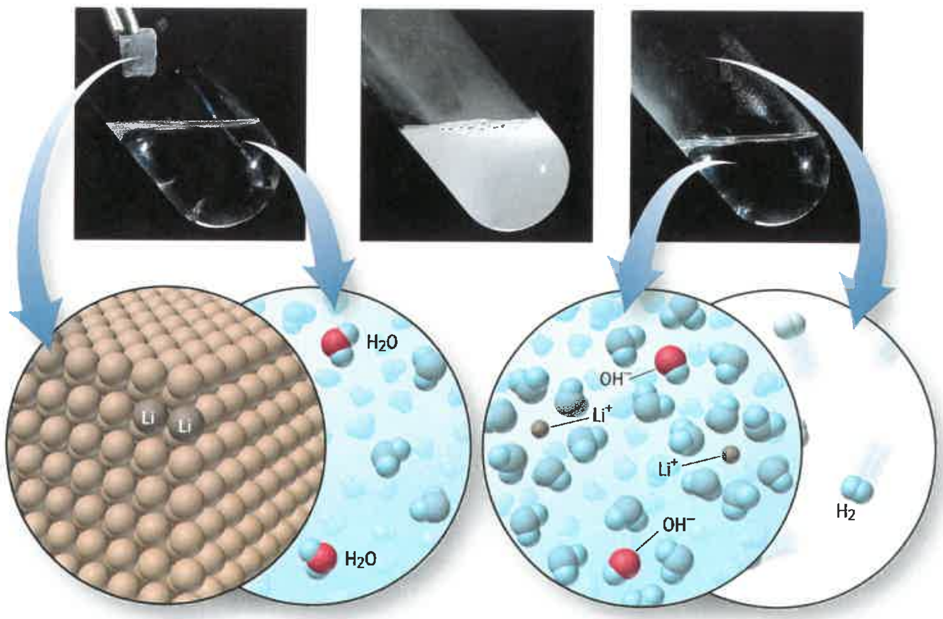


Figure 2.28 In A, a coil of copper wire is placed in a solution of silver nitrate. The fuzzy coating on the copper wire in B is silver metal. The blue colour of the solution is characteristic of Cu^{2+} ions in water.

Hydrogen Can Act as a Metal

In a single replacement reaction, hydrogen in water can behave as a metal. Figure 2.29 shows how lithium replaces hydrogen in water.



$$2Li(s) + 2H_2O(\ell) \longrightarrow 2LiOH(aq) + H_2(g)$$

lithium + water → lithium hydroxide + hydrogen

Figure 2.29 Lithium replaces hydrogen in a single replacement reaction. The bubbles in the test tube are hydrogen gas that forms in the reaction.

A Non-metal Can Replace a Non-metal

An example of the second type of single replacement reaction is the reaction of chlorine gas with a solution of sodium bromide, shown in Figure 2.30. In this reaction, chlorine replaces bromide ions in the solution, resulting in the formation of sodium chloride and bromine. Figure 2.31 on the next page shows a few examples of applications of single replacement reactions.

$$2NaBr(aq) + Cl_2(g) \longrightarrow 2NaCl(aq) + Br_2(\ell)$$

Figure 2.30 Chlorine gas (on the left) is bubbled through an aqueous solution of sodium bromide (on the right). The brown colour is the bromine produced. **Applying: Is this an open or closed system? Why do you think this system was used?**

Fire Retardants

More than half of the bromine produced on Earth is used in flame retardants in mattresses, furniture, and electronics. They make it harder for these items to catch fire and slow the spread of fire so people can escape their homes more easily. Bromine is produced commercially in the single replacement reaction shown in **Figure 2.30**.

Welding Railroad Tracks

Some single replacement reactions release a lot of energy. In the railroad industry, for example, powdered aluminum and iron(III) oxide are mixed together. They react to form iron and aluminum oxide. When aluminum replaces the iron in iron(III) oxide, enough heat is released to melt the iron that is produced and weld the railroad tracks together.

$$2Al(s) + Fe_2O_3(s) \rightarrow 2Fe(\ell) + Al_2O_3(s)$$

Joining Electrical Conductors

Single replacement reactions are used to produce pure copper. This metal is used to join electrical conductors. Aluminum replaces copper in copper(II) oxide. The heat resulting from the reaction melts the copper that forms. The copper flows into a mold around the ends of the conductors. When the metal cools, it conducts electricity between the conductors.

$$2Al(s) + 3CuO(s) \rightarrow 3Cu(\ell) + Al_2O_3(s)$$

Figure 2.31 There is a wide range of uses for single replacement reactions.

Extending the Connections

Mercurial Mysteries in the Arctic

Something strange has been happening in the circumpolar Arctic region. There is steam rising from cracks in Arctic sea ice cover during summer months. This steam is part of the answer to a mystery surrounding the apparent disappearance of mercury from the atmosphere during the Arctic summer. The solution to the mystery has involved scientists from Canada as well as an investigation led by NASA called BROMEX, which stands for Bromine, Ozone, and Mercury Experiment. But this mystery is more than just a matter of scientific curiosity. At stake are the lives, lifestyles, and livelihoods of Arctic First Peoples. What connections can you discover related to mercury, bromine, and single replacement reactions? Why is there more mercury in the Arctic than anywhere else on Earth? And what are the implications of all this mercury for the people, other animals, and the land of the Arctic?

Double Replacement Reactions

In a **double replacement reaction**, the positive ions of two ionic compounds change places to form two new ionic compounds. Double replacement reactions usually occur between ionic compounds in aqueous solution, meaning they are both dissolved in water. Double replacement reactions can be represented by a general chemical equation and pictorially, as shown below. In all double replacement reactions, A and B are positively charged ions. X and Y are negatively charged ions. Notice how the ions in the reactants are exchanged to form the products.

double replacement reaction a chemical reaction in which solutions of two ionic compounds react to produce two new compounds

$$AX + BY \longrightarrow AY + BX$$

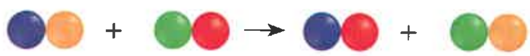
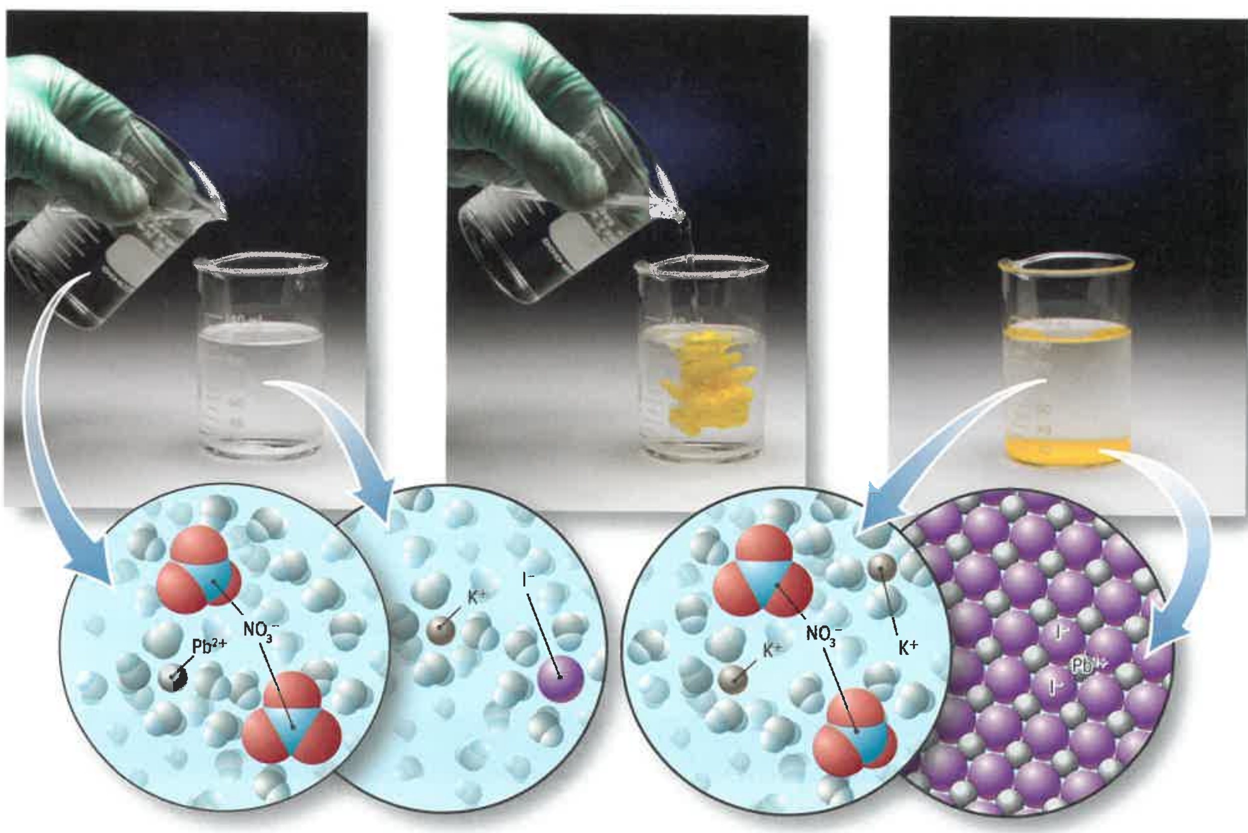


Figure 2.32 shows a double replacement reaction between aqueous solutions of potassium iodide, KI(aq), and lead(II) nitrate, $Pb(NO_3)_2(aq)$. Notice the formation of a bright yellow solid. The formation of a solid, called a precipitate, is common in double replacement reactions.

You or someone in your family may have had first-hand experience with the products of double replacement reactions, such as those shown in **Figure 2.33**.



$$Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow 2KNO_3(aq) + PbI_2(s)$$

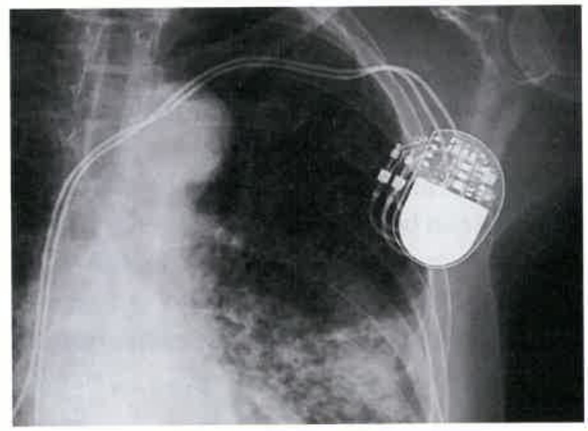
lead(II) nitrate + potassium iodide → potassium nitrate + lead(II) iodide

Figure 2.32 A yellow solid forms when potassium iodide and lead(II) nitrate undergo a double replacement reaction.

Soft Tissue X Rays

X rays are great for diagnosing broken bones. However, they do a poor job of showing soft tissue like the stomach, because X rays pass right through soft tissue. X-ray technicians get around this problem by having patients drink a chalky liquid that contains solid barium sulfate. This ionic compound blocks X rays. As a result, the soft tissue can be seen in the X-ray image. Barium sulfate is produced in a double replacement reaction.

$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow 2NaCl(aq) + BaSO_4(s)$



Pacemaker Batteries

Do you know someone who has a medical device inside their body that runs on batteries? Lithium batteries containing silver chromate, $Ag_2CrO_4(s)$, are used in pacemakers. These devices help maintain the steady beat of the human heart. The silver chromate in these batteries is produced in a double replacement reaction. Solutions of silver nitrate and sodium chromate react to produce solid silver chromate and a solution of sodium nitrate.

$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2NaNO_3(aq)$

Figure 2.33 Two examples of double replacement reactions. **Questioning: Examine the state symbols in the chemical equations—what questions do you have about these types of reactions?**

Activity

Mix and Switch

1. Label two test tubes A and B. To test tube A, add a scoop of solid copper(II) sulfate, $CuSO_4$. Add enough to just fill the rounded end of the test tube. To test tube B, add a similar amount of calcium chloride, $CaCl_2$.
2. Add 10 mL of water to each test tube. Stopper each test tube and gently shake them to dissolve the solids. Record your observations.
3. Coil 10 cm of magnesium ribbon around a pencil. Place the coil in test tube A. Record your observations over 10 min.
4. Use a pipette to transfer 5 mL of liquid from test tube A to test tube B. Record your observations over 10 min.
5. Write balanced chemical equations for the reactions. Identify the types of reactions.

Before you leave this page . . .

1. Give the predicted products and the balanced chemical equations.
   a) $Mg(s) + AgCl(aq) \rightarrow$
   b) $AgNO_3(aq) + K_2CrO_4(aq) \rightarrow$
2. Identify each reaction in question 1 as single or double replacement.
3. In your own words, describe what happens in a single replacement reaction.

CONCEPT 3

Most combustion reactions release heat and light.

A **combustion reaction** is a chemical reaction in which a compound or element reacts with oxygen to form compounds called oxides. The oxides contain oxygen and the elements that make up the reactant compound. For example, sulfur (or compounds containing sulfur) will react with oxygen in a combustion reaction to produce sulfur dioxide, $SO_2(g)$.

$$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$$

This reaction is one of the main sources of air pollution, as shown in Figure 2.34. The diagram also shows the impact of a similar reaction that involves nitrogen and oxygen. These products, sulfur dioxide and nitrogen dioxide, undergo a synthesis reaction with water to produce a type of compound called an acid. You will investigate acids and their impact on the environment in Concept 4.

Another feature of combustion reactions is that many produce heat and light. The burning of fuels such as natural gas and gasoline involves the combustion of a type of compound called a hydrocarbon. Hydrocarbons are compounds made up of just two elements: carbon and hydrogen. A general equation for the combustion of hydrocarbons is

$$C_xH_y + O_2 \longrightarrow CO_2 + H_2O$$

In this general equation, C_xH_y is a general formula for hydrocarbons, with x representing the number of carbon atoms and y representing the number of hydrogen atoms that make up the compound. Figure 2.35 shows some examples of common combustion reactions.

combustion reaction a chemical reaction in which an element reacts with oxygen to produce an oxide of the element and heat; also refers to the burning of hydrocarbons to produce carbon dioxide and water

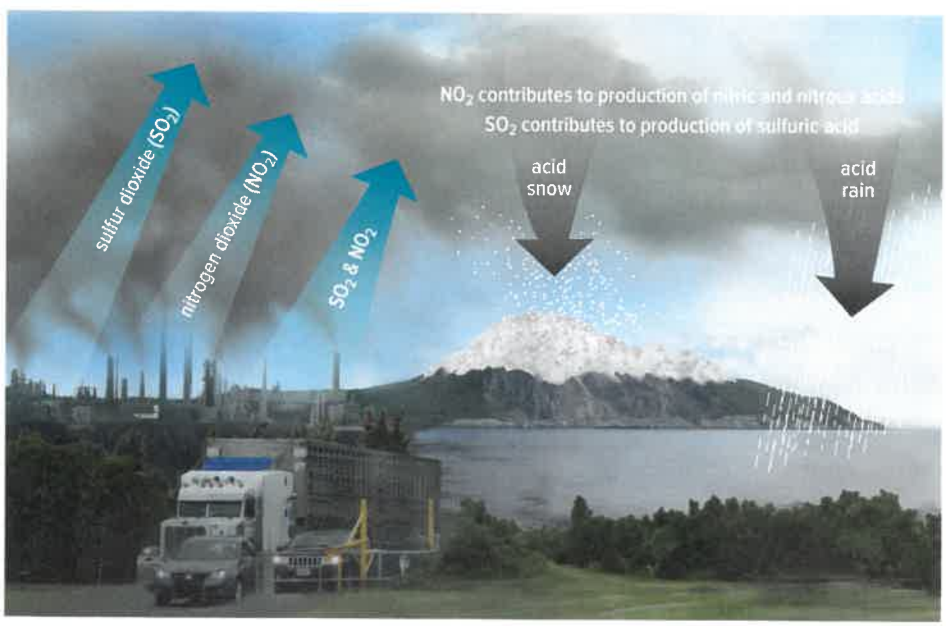


Figure 2.34 Key sources of SO_2 and NO_2. **Questioning: What sources of these pollutants are identified in this Figure? What effects do they have on human health and the environment?**

Methane Combustion

Methane, $CH_4(g)$, is a hydrocarbon that is the main component in natural gas. The flame and heat produced when using a gas stove is due to the combustion of methane. The balanced chemical equation for the complete combustion of methane is

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Gasoline Combustion

Gasoline is a mixture of different hydrocarbons. Fuels are graded based on their octane rating. The greater the amount of octane present, the higher the quality of fuel. The combustion of octane is represented by the equation

$$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$$

Propane Combustion

Propane, $C_3H_8(g)$, is a common fuel with several applications. Small propane torches like this one are often used by professionals, such as plumbers, and many people have them in their homes. Propane is also used as a heating fuel, with both indoor and outdoor heaters available. You are probably most familiar with its use as fuel for barbecues. Regardless of what the combustion of propane is used for, its combustion is represented by the equation

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

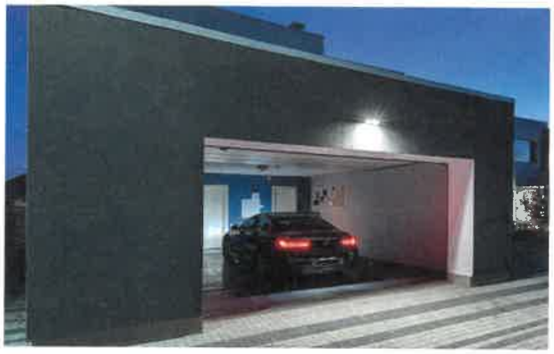
Figure 2.35 Our society depends on combustion reactions for transportation, cooking, and heating **Analyzing: Are these combustion reactions exothermic or endothermic? What evidence supports your answer?**

Extending the Connections

Combustion and Greenhouse Gases

The greenhouse effect is a natural part of Earth's climate system and helps to regulate Earth's temperature. Which greenhouse gases occur naturally, and which are the result of human activity? What role does combustion play in the greenhouse effect? Develop three questions that you have about this topic, and decide how you could investigate answers to them.

Figure 2.36 These are places where carbon monoxide produced from the incomplete combustion of fuels can occur. Accumulation of carbon monoxide in the air can be hazardous. **Applying: Identify sources in your home where carbon monoxide could be produced.**



Incomplete Combustion

If the supply of oxygen is too low, incomplete combustion occurs. Like complete combustion, incomplete combustion produces carbon dioxide and water. But it also results in other products such as carbon (soot) and carbon monoxide. Carbon monoxide is a colourless, odourless, highly toxic gas. You have probably heard or read warnings about the dangers associated with using camp stoves or propane barbecues indoors, or ever letting a car run in a closed garage. A poorly ventilated fireplace can also be dangerous. In fact, the burning of any fuels, such as gasoline, natural gas, oil, or wood, within a home or garage is potentially dangerous (Figure 2.36). If there is not enough oxygen, incomplete combustion results and carbon monoxide is produced. That's why carbon monoxide detectors like the one shown in Figure 2.37 are necessary.

Figure 2.37 Homes with appliances or other equipment that burn fossil fuels and/or wood should have carbon monoxide detectors.

Activity

Considering Combustion

Methane is the hydrocarbon in natural gas used for school Bunsen burners. The photo shows two sets of burner flames. One set shows complete combustion; the other shows incomplete combustion. Which is which? What could explain the differences you observe in the flames? Share your ideas and reasoning with your teacher, who will decide how they can be explored safely in the lab or with video demonstrations.

Before you leave this page . . .

1. What energy changes are associated with hydrocarbon combustion?
2. What are the products of the complete combustion of a hydrocarbon?

CONCEPT 4

In a neutralization reaction, an acid reacts with a base.

Activity

What Reaction Type Is Neutralization?

Complete your summary of reaction types when you finish this concept. What are some ways that have helped you remember what happens to the atoms in the different types of reactions? After learning about neutralization reactions, describe another way you might classify this type of reaction.

Figure 2.38 Acids in citrus fruits such as this fingered citron makes them taste sour.

Many substances that you encounter every day are acids or bases. For example, the sour taste of citrus fruits such as grapefruit and lemons is due to the presence of acidic compounds (Figure 2.38). The bitter taste of coffee and the slippery feel of soap are due to the presence of basic compounds. Compounds may be classified as acids or bases depending on how they interact with water.

Acids

acid compound that forms H^+ ions when dissolved in water

An **acid** is a substance that releases hydrogen ions, $H^+(aq)$, in an aqueous solution. For example, when hydrogen chloride gas is mixed with water, $H^+(aq)$ and $Cl^-(aq)$ form. Therefore, HCl(aq) is called an acidic solution.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

Acids include two broad categories. *Binary acids* are composed of two elements: hydrogen and a non-metal, such as HCl(aq). *Oxyacids* are composed of hydrogen, oxygen, and another element—for example, an acid with a polyatomic ion, such as $H_2CO_3(aq)$. The chemical formula of an acid can often be recognized by the presence of one or more hydrogen ions with a negative ion. Table 2.1 lists some common acids.

Table 2.1 Common Acids and Their Uses

Chemical Formula	Classical Name	IUPAC Name	Uses
HCl(aq)	hydrochloric acid	aqueous hydrogen chloride	producing plastics and processing metals
HF(aq)	hydrofluoric acid	aqueous hydrogen fluoride	manufacturing and etching glass
$H_2SO_4(aq)$	sulfuric acid	aqueous hydrogen sulfate	in car batteries
$HNO_3(aq)$	nitric acid	aqueous hydrogen nitrate	making explosives and fertilizers
$H_2CO_3(aq)$	carbonic acid	aqueous hydrogen carbonate	in carbonated drinks
$CH_3COOH(aq)$	acetic acid	aqueous hydrogen acetate, or ethanoic acid	in vinegar

Bases

A **base** is a substance that releases hydroxide ions, $OH^-(aq)$, in an aqueous solution. For example, when sodium hydroxide crystals dissolve in water, the ions $Na^+(aq)$ and $OH^-(aq)$ form.

$$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$$

Therefore, $NaOH(aq)$ is called a basic solution.

base a compound that forms OH^- ions when dissolved in water

Table 2.2 lists the names, chemical formulas, and uses for some common bases. Many bases are ionic compounds composed of metal ions and hydroxide ions. The chemical formula for a base includes enough hydroxide ions in the formula to make the total charge of the compound zero.

Table 2.2 Common Bases and Their Uses

Chemical Formula	Common Name	IUPAC Name	Uses
$NaOH(aq)$	lye, caustic soda	sodium hydroxide	in drain cleaners, used in making soaps and paper
$Mg(OH)_2(aq)$	Milk of Magnesia®	magnesium hydroxide	antacids and laxatives
$Ca(OH)_2(aq)$	lime water	calcium hydroxide	soil and water treatment

Extending the Connections

Naming Acids and Bases

Like other compounds, acids and bases are named according to certain guidelines. Find out how the naming of acids and bases compares with naming other compounds.

Identifying Acids and Bases

Most common acids and bases form colourless solutions in water. One way to identify them is to use an **acid-base indicator**. This is a chemical that changes colour in response to whether it is exposed to an acid or a base. A common acid-base indicator is litmus. Litmus solution is often dried on thin paper strips (Figure 2.39).

acid-base indicator a chemical that changes colour in response to the concentration of hydrogen ions in a solution

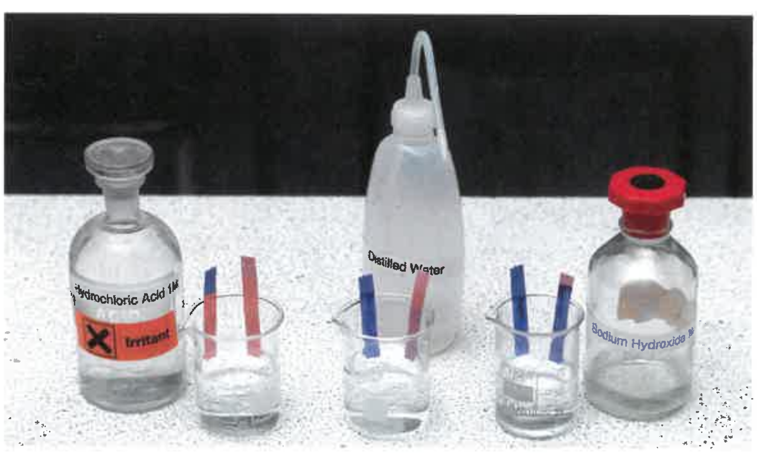


Figure 2.39 Blue litmus paper turns red in an acidic solution, and red litmus paper turns blue in a basic solution. **Evaluating: Why did neither change colour in the water?**

Activity

The Litmus Test

Your teacher will supply you with samples of materials to test. Make a prediction for each. Which samples do you think are basic, acidic, or neither? Place a small amount of each sample in a well of a spot plate. Make sure to keep track of what sample was added to which well. Dip a small piece of blue and red litmus paper into each well. Record your observations. How did your results compare with your predictions?

The pH Scale

To more accurately determine how acidic or basic a solution is, chemists use the pH scale and instruments to measure pH. The **pH scale** typically ranges from 0 to 14. It provides a way to measure the acidity and basicity of solutions. Figure 2.40 shows the pH scale and pH values of some common substances.

pH scale a numbered scale between 0 and 14 that indicates the acidity or basicity of a solution

Acidic Solutions: pH < 7

Acids have pH values below 7. The lower the pH value, the more acidic the solution. This means there are many more hydrogen ions in the solution than hydroxide ions. For example, a lemon at pH = 2 is more acidic than milk at pH = 6 and has a greater number of H^+ ions. Each time the pH value changes by one unit, the number of H^+ ions changes by 10 times. The lemon at pH = 2 has 10^4 or 10 000 times more hydrogen ions than milk at pH = 6.

Connect to Investigation 2-G on page 178

Basic Solutions: pH > 7

Bases have pH values above 7. This means there are many more hydroxide ions in the solution than hydrogen ions. The higher the pH, the more basic the solution is. For example, oven cleaner at pH = 13 is more basic than eggs at pH = 8.

Neutral Solutions: pH = 7

A solution that is neither acidic nor basic is neutral and falls in the middle of the pH scale at pH = 7. This means there are equal numbers of hydrogen ions and hydroxide ions in the solution. Pure water has a pH of 7, as do solutions of some compounds such as sodium chloride.

Figure 2.40 The pH scale ranges from 0 to 14.

Extending the Connections

Measuring pH

In the laboratory, there are several ways to determine how acidic or basic a solution is. Some indicators can provide a range of possible pH values for the solution, while universal indicators turn different colours at particular pH values. The most accurate method is to use a pH meter, which directly measures the pH. Choose one of these approaches to investigate further. What questions do you have? How can you answer them?

Acid-Base Neutralization

A **neutralization reaction** is a chemical reaction between an acid and a base that produces water and a salt (a type of ionic compound). A general equation for the reaction between an acid and a base can be represented as

$$\underset{\text{Acid}}{HA} + \underset{\text{Base}}{BOH} \rightarrow \underset{\text{Salt}}{BA} + \underset{\text{Water}}{HOH}$$

neutralization reaction a chemical reaction in which an acid reacts with a base to form a salt and water

Connect to Investigation 2-H on page 180

Notice that this reaction is actually a type of double replacement reaction. The ions of the reactants switch places to form two new compounds. The water forms as the hydrogen ions of the acid and the hydroxide ions of the base combine. The other ions form the salt.

When an acid and a base are added together, it results in the removal of hydrogen ions and hydroxide ions from the solution, since their combination produces water. This causes the pH of the solution to approach 7. Figure 2.41 shows a neutralization reaction. Notice how all the solutions are colourless. The progress of a neutralization reaction can be followed by measuring the pH of the solution as the acid and base are combined.

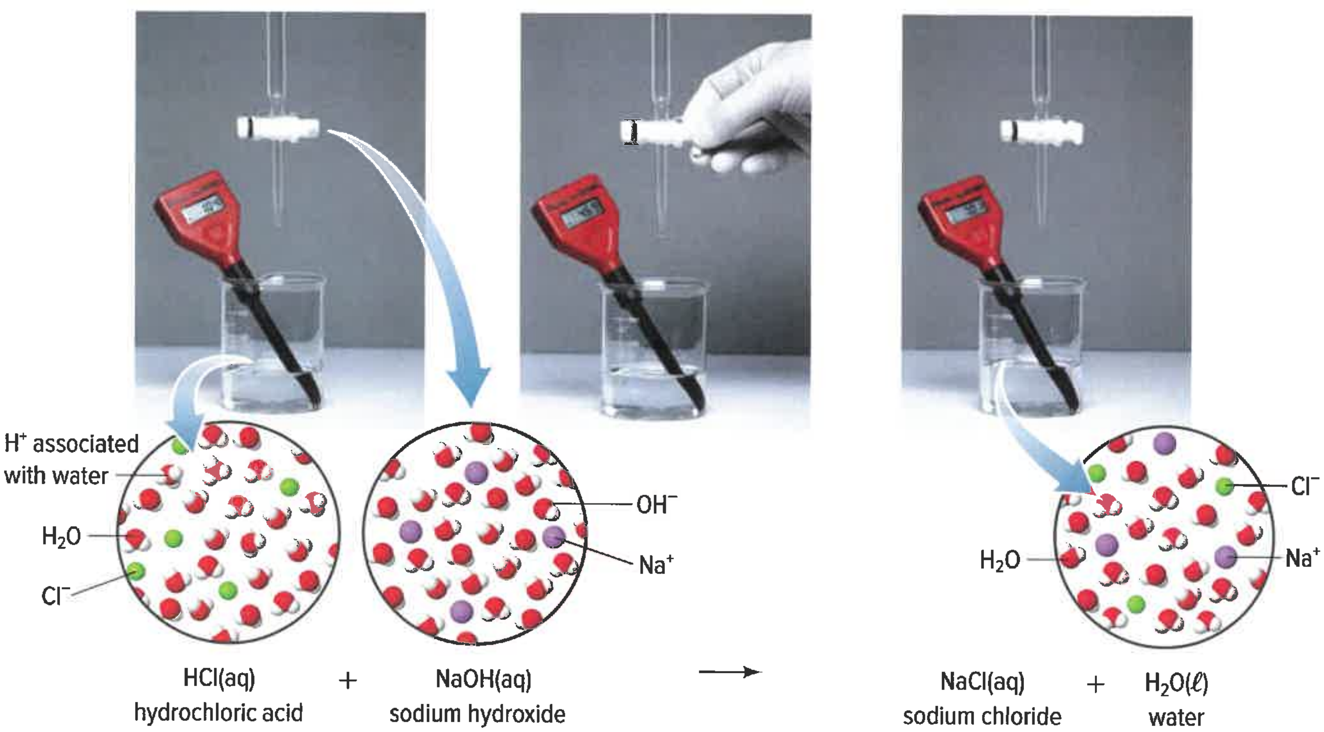


Figure 2.41 For all neutralization reactions, there is a net transfer of energy from the system to the surroundings. **Applying: Are neutralization reactions exothermic or endothermic?**

Neutralization Reactions in Our World

Neutralization is not just a chemical reaction that scientists carry out in the laboratory. It is one of the most common chemical reactions in everyday life. **Figure 2.42** shows a few examples of how we rely on reactions between acids and bases.

Figure 2.42
From medicinal products to our environment, neutralization reactions have many applications.

Antacids
The gastric pits in stomach lining secrete hydrochloric acid. Excess acid can cause a burning sensation in the stomach, chest, and throat. Antacids ease these symptoms, because they include basic hydroxide or carbonate compounds.

pH Adjustments
Monitoring pH is part of the regular maintenance of swimming pools and aquariums. Setting the correct pH relies on neutralization reactions so the water is safe to use.

Acid Precipitation
Acid precipitation can harm crops and aquatic ecosystems. Adding crushed limestone (called liming) is used to raise the pH of an affected area. Crushed limestone is mostly calcium carbonate.

Fishy Food
Fish odours are due to molecules that are bases. Lemon juice "neutralizes" the odour because the citric acid in the lemons reacts with the fishy-smelling base to produce water and a salt, which have no odour.

Chemical Spills
In 2005, a train derailment spilled 40 000 L of caustic soda (sodium hydroxide) into the Cheakamus River near Squamish, killing 500 000 fish. What is the condition of this river today, and who is responsible?

Connect to Investigation 2-I on page 183

Before you leave this page . . .

1. In your own words, describe what an acid and a base are.
2. Why is a neutralization reaction a type of double replacement reaction?
3. Write the predicted products and balance the chemical equation for the following neutralization reaction. You do not need to include the states of the products.

   $HCl(aq) + Mg(OH)_2(aq) \longrightarrow$

Identifying Reaction Types

Now that you have learned about the six types of reactions, use the following Sample and Practice Problems to help you identify the type of reaction that a chemical equation represents.

Sample Problem 1:

Predicting the Products of a Synthesis Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Al + F_2 \longrightarrow$$

Solution

1. This reaction has two reactants and both are elements. Therefore, this is a synthesis reaction.
2. Since one reactant is a metal and the other reactant is a non-metal, the product will be a binary ionic compound composed of ions of both elements. Aluminum forms a Al^{3+} ion and fluorine forms a F^{-} ion. Therefore, they will produce the compound, AlF_3
3. Write the skeleton equation with the reactants and predicted product.

   $Al + F_2 \longrightarrow AlF_3$
4. Write the balanced chemical equation.

   $2Al + 3F_2 \longrightarrow 2AlF_3$

Sample Problem 2:

Predicting the Products of a Decomposition Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Mg_3N_2 \longrightarrow$$

Solution

1. This reaction has only one reactant. Therefore, this is a decomposition reaction.
2. The products will be the separate elements, Mg and N_2.
3. Write the skeleton equation with the reactant and predicted products.

   $Mg_3N_2 \longrightarrow Mg + N_2$
4. Write the balanced chemical equation.

   $Mg_3N_2 \longrightarrow 3Mg + N_2$

Sample Problem 3:

Predicting the Products of a Replacement Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Al + Pb(NO_3)_2 \longrightarrow$$

Solution

1. This reaction has two reactants; one is an element and the other is a compound. Therefore, this is a single replacement reaction.
2. Aluminum is a metal and it will replace lead(II) ions in the compound to form the compound $Al(NO_3)_3$. The element lead will be the other product.
3. Write the skeleton equation with the reactants and predicted products.

   $Al + Pb(NO_3)_2 \rightarrow Pb + Al(NO_3)_3$
4. Write the balanced chemical equation.

   $2Al + 3Pb(NO_3)_2 \rightarrow 3Pb + 2Al(NO_3)_3$

Sample Problem 4:

Predicting the Products of a Hydrocarbon Combustion Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$C_3H_8 + O_2 \rightarrow$$

1. This reaction has two reactants; one is oxygen and the other is a hydrocarbon, which is called propane. Therefore, this represents the combustion of a hydrocarbon.
2. The products of the combustion of a hydrocarbon are carbon dioxide and water.
3. Write the skeleton equation with the reactants and predicted products.

   $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
4. Write the balanced chemical equation. A common strategy for balancing these types of equations involves balancing the carbons first, then the hydrogens, and then the oxygens.

   $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Practice Problems

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

1. $Al + CuCl_2 \rightarrow$
2. $NaCl + AgNO_3 \rightarrow$
3. $C_6H_{14} + O_2 \rightarrow$
4. $Ca(OH)_2 + HCl \rightarrow$
5. $KI \rightarrow$
6. $Zn + N_2 \rightarrow$
7. $Cd + Au(NO_3)_3 \rightarrow$
8. $Fe_2O_3 \rightarrow$
9. $K + Cl_2 \rightarrow$
10. $Cl_2 + CsBr \rightarrow$

Check Your Understanding of Topic 2.4

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Synthesis reactions are also often referred to as combination reactions. Explain why this other name makes sense. PA

2. Explain why most synthesis reactions are exothermic. What does this imply about the energy needed to break the reactant bonds compared to energy released when the product bonds form? Draw an energy level diagram that could represent a synthesis reaction. PA

3. Develop a general equation that could represent a decomposition reaction. Why can you consider a decomposition reaction to be the reverse of a synthesis reaction? AI

4. Copy and complete the following table in your notebook. PA C

	H^+ concentration greater than, less than, or equal to OH^- concentration?	pH greater than, less then, or equal to 7?
Acid solution		
Base solution		
Neutral solution		

Connecting Ideas

5. Use the following chemical equations to answer the questions below. PA C

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

$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + NaCl(aq)$

a) Identify each type of reaction.

b) Write the balanced chemical equation for each.

6. For each skeleton equation below, classify the type of reaction as a synthesis, decomposition, single replacement, double replacement, neutralization, or combustion reaction. Justify your classification. Then write the balanced chemical equation for each. PA E

a) $C_4H_{10}(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

b) $Li(s) + N_2(g) \rightarrow Li_3N(s)$

c) $AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow NaNO_3(aq) + Ag_2CrO_4(s)$

d) $MgO(s) \rightarrow Mg(s) + O_2(g)$

e) $HI(aq) + KOH(aq) \rightarrow KI(aq) + H_2O(\ell)$

f) $AlPO_4(aq) + Mg(s) \rightarrow Al(s) + Mg_3(PO_4)_2(aq)$

7. For each of the following, identify the type of reaction that is represented. Then, predict the products and write the balanced chemical equations. You do not need to provide the states of the products. PA E

a) $HCl(aq) + Mg(OH)_2(aq) \rightarrow$

b) $Al_2O_3(s) \rightarrow$

c) $Na(s) + Cl_2(g) \rightarrow$

d) $NH_4Cl(aq) + AgCH_3COO(aq) \rightarrow$

e) $NaI(aq) + Br_2(g) \rightarrow$

f) $Al(s) + CuCl_2(aq) \rightarrow$

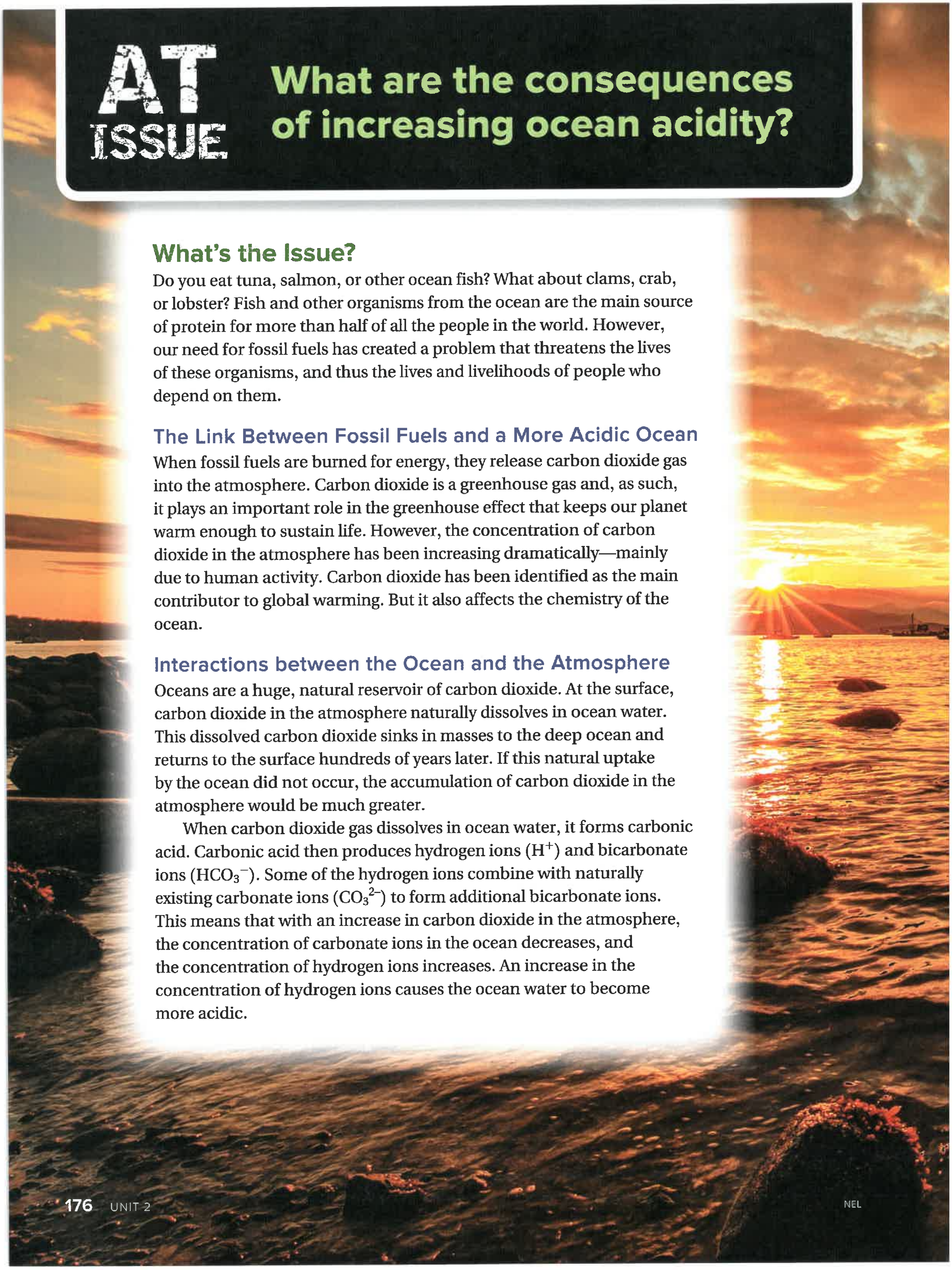
Making New Connections

8. Society relies on hydrocarbon combustion.

a) What are the dangers associated with incomplete combustion of hydrocarbons?

b) Do you think hydrocarbons with a greater number of carbon and hydrogen atoms will produce more or less energy than smaller hydrocarbons? Explain.

c) Describe one advantage and one disadvantage of our use of hydrocarbon combustion. E C



AT ISSUE What are the consequences of increasing ocean acidity?

What's the Issue?

Do you eat tuna, salmon, or other ocean fish? What about clams, crab, or lobster? Fish and other organisms from the ocean are the main source of protein for more than half of all the people in the world. However, our need for fossil fuels has created a problem that threatens the lives of these organisms, and thus the lives and livelihoods of people who depend on them.

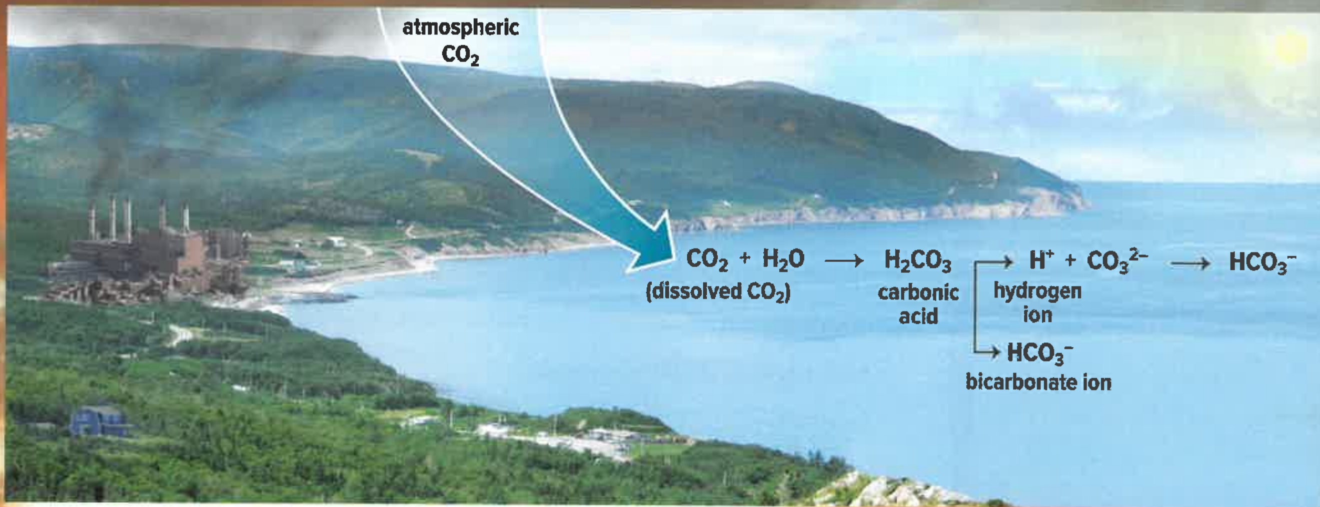
The Link Between Fossil Fuels and a More Acidic Ocean

When fossil fuels are burned for energy, they release carbon dioxide gas into the atmosphere. Carbon dioxide is a greenhouse gas and, as such, it plays an important role in the greenhouse effect that keeps our planet warm enough to sustain life. However, the concentration of carbon dioxide in the atmosphere has been increasing dramatically—mainly due to human activity. Carbon dioxide has been identified as the main contributor to global warming. But it also affects the chemistry of the ocean.

Interactions between the Ocean and the Atmosphere

Oceans are a huge, natural reservoir of carbon dioxide. At the surface, carbon dioxide in the atmosphere naturally dissolves in ocean water. This dissolved carbon dioxide sinks in masses to the deep ocean and returns to the surface hundreds of years later. If this natural uptake by the ocean did not occur, the accumulation of carbon dioxide in the atmosphere would be much greater.

When carbon dioxide gas dissolves in ocean water, it forms carbonic acid. Carbonic acid then produces hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). Some of the hydrogen ions combine with naturally existing carbonate ions (CO_3^{2-}) to form additional bicarbonate ions. This means that with an increase in carbon dioxide in the atmosphere, the concentration of carbonate ions in the ocean decreases, and the concentration of hydrogen ions increases. An increase in the concentration of hydrogen ions causes the ocean water to become more acidic.



Consequences of Acidic Oceans

Many ocean organisms make their shells and skeletons from calcium carbonate, $CaCO_3$. As the concentration of carbonate ions decreases, the ability of ocean organisms to make their shells and skeletons also decreases. Increased acidity of ocean water also causes the shells and skeletons of ocean organisms to become weaker. Some people have reported seeing holes in the shells of oysters and clams. As a result, the health and survival of these organisms are threatened.

A second problem involves microscopic plankton that form the base of food chains in many ocean ecosystems. If they cannot form their shells, they will die, their numbers will decrease, and food chains will be affected. Corals also use carbonate ions to build the skeletons of enormous reefs that support great numbers of organisms. Many of the fish and shellfish that people depend on live among coral reefs during their early years. As well, snails and other shelled organisms are food sources for other organisms— including people. Coral reefs also protect coastlines from damage during storms.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What type of compound is calcium carbonate? What ions form when this compound is dissolved in water?
2. What is happening to the pH of our oceans? Explain your answer.
3. Brainstorm a list of possible solutions for the problems described in this feature. What changes could people make in their lives that could contribute to solutions?
4. What questions does this feature raise in your mind? In terms of further study, speculate on possible directions in which your questions could lead you.

INVESTIGATION

2-G

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Wear safety goggles and gloves.
- The materials can become quite hot. Avoid touching the hot liquid or glass. Use a thermal glove or tongs.

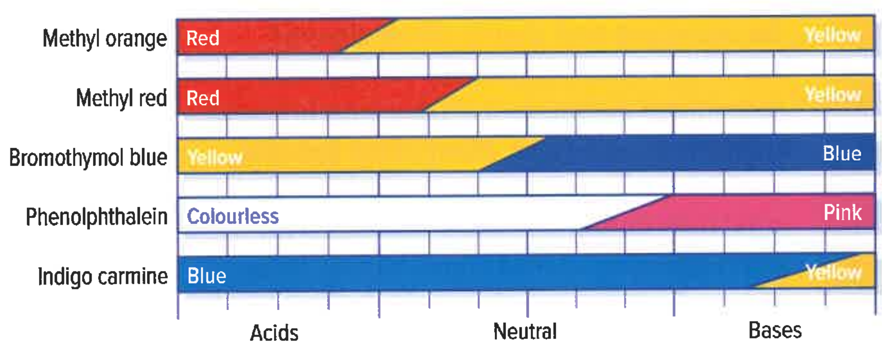
What You Need

- spot plates
- small test tubes
- masking tape
- unknowns 1, 2, 3, and 4
- Mg ribbon
- red and blue litmus paper
- bromothymol blue indicator
- methyl red indicator
- methyl orange indicator
- phenolphthalein indicator
- distilled water

Using Acid and Base Properties to Identify Four Unknowns

The following chart indicates the colour changes of some common acid-base indicators. The table below summarizes additional properties of acids and bases.

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl orange	3.2–4.4	red to yellow
Methyl red	4.8–6.0	red to yellow
Bromothymol blue	6.0–7.6	yellow to blue
Phenolphthalein	8.2–10.0	colourless to pink
Indigo carmine	11.2–13.0	blue to yellow



Property	Acid	Bases
Litmus test	turns blue litmus red	turns red litmus blue
Reaction with metal	yes (most)	no (most)
pH	less than 7	greater than 7

In this investigation, you will use the properties of four unknowns to help you identify them as acidic, basic, or neutral and determine the pH range of the solutions.

Question

How can the properties of a solution be used to identify it as acidic, basic, or neutral?

Procedure

1. Read through the information on the previous page and the list of chemicals provided. Your teacher may provide an additional list of available materials and associated information to use. Based on what is provided, design a procedure to identify each unknown as an acidic, basic, or neutral solution and to determine the pH or pH range of the solution. In designing your procedure, consider the following:
   - What tests will you perform and what information does each provide?
   - Will the tests provide all the information you need?
   - What materials do you need to perform the tests?
   - How much of the unknowns will you test? Are they provided as solids or liquids? What do you need to do if an unknown is a solid?
   - How will you keep track of the different unknown samples you are testing?
   - How will you record and organize the data you will be collecting?
2. As part of your procedure, include all safety precautions that must be taken, as well as clean-up and disposal instructions.
3. Have your teacher approve your procedure before proceeding.

Process and Analyze

1. Which unknowns were acidic and which were basic? Were any of the unknowns neutral? Provide evidence from your data that supports your answer.
2. What was the pH or pH range for each solution?

Conclude and Communicate

3. Arrange the unknowns in order of most acidic to least acidic.
4. Why might the pH range, and not the exact pH value, have been determined for a solution?
5. Why does using a universal indicator or pH meter provide more accurate results than acid-base indicators such as methyl red?

INVESTIGATION

2-H

STRUCTURED AND GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Wear safety goggles, gloves, and a lab coat or apron.
- Handle chemicals safely. Avoid touching all reactants and products.
- Acid and base solutions are corrosive. Use them with care.
- When using a Bunsen burner, be sure you understand how to light and use it safely.
- Wash your hands thoroughly after completing this investigation.

What You Need

Part 1:

- Bunsen burner with matches or striker to light
- copper wire, 6 cm in length
- metal tongs

Part 2:

- 60 mL 3% hydrogen peroxide solution
- 250 mL beaker
- thermometer
- pinch of manganese dioxide, $MnO_2(s)$
- stirring rod

Part 3:

- 50 mL copper(II) sulfate solution, 0.1 mol/L $CuSO_4(aq)$
- 250 mL beaker
- thermometer
- shiny iron nail

Part 4:

- 20 mL calcium chloride solution, 0.1 mol/L $CaCl_2(aq)$
- 250 mL beaker
- thermometer
- graduated cylinder
- 20 mL sodium carbonate solution, 0.1 mol/L $Na_2CO_3(aq)$
- stirring rod

Part 5:

- tea light-style candle with base
- aluminum dish to collect wax drippings
- matches
- 100 mL beaker

Part 6:

- 0.1 mol/L HCl(aq)
- 0.1 mol/L NaOH(aq)
- graduated cylinder
- 100 mL beaker
- stirring rod
- pH paper (with universal indicator) and colour chart
- thermometer

Six Types of Reactions

In this investigation, you will carry out examples of different types of chemical reactions that you have studied. Use your understanding of reaction types to identify the types of reactions you perform.

Question

How can you use your knowledge of chemical reactions to classify reactions you carry out in the laboratory?

Procedure

Part 1: $Cu(s) + O_2 \longrightarrow CuO$

1. Make a table for your observations.
2. Record the appearance of the copper wire.
3. Follow your teacher's instructions to light the Bunsen burner. Adjust the flame to obtain a blue flame with two distinct cones.
4. Use metal tongs to hold the middle of the wire in the hottest part of the flame (the top of the inner cone). Hold it there for about 1 min, then remove it. CAUTION: THE WIRE WILL BE VERY HOT. DO NOT TOUCH IT. HOLD IT WITH THE TONGS AS IT COOLS.
5. Record all observations while the wire is in the flame and after it is removed.
6. Clean up your work area and dispose of all materials as instructed by your teacher.

Part 2: $H_2O_2 \longrightarrow H_2O + O_2$

1. Make a table for your observations.
2. Add 60 mL of 3% hydrogen peroxide solution to the beaker.
3. Place a thermometer in the beaker and record the temperature of the solution.
4. Your teacher will add tiny amount of manganese dioxide into the hydrogen peroxide. Using a stirring rod, stir the solution. (The manganese dioxide is not a reactant. It helps make the reaction go faster.)
5. Record the temperature every 30 seconds as the reaction occurs.
6. Record your measurements and any other observations for about 10 minutes, until the reaction has slowed down or stopped.
7. Clean up your work area and dispose of all chemicals as instructed by your teacher.

Part 3:
$Fe(s) + CuSO_4 \longrightarrow FeSO_4(aq) + Cu(s)$

1. Make a table for your observations.
2. Place 50 mL of copper(II) sulfate solution into a beaker.
3. Carefully place a thermometer in the solution. Record the temperature and any other observations of this solution.
4. Place the iron nail into the solution in the beaker.
5. Record the temperature every 30 seconds and monitor what happens over several minutes. Record all your observations.
6. Put this reaction aside while you perform the remainder of the investigation. Then, record your final observations at the end of the investigation.

Part 4: $CaCl_2(aq) + Na_2CO_3(aq) \longrightarrow NaCl(aq) + CaCO_3(s)$

1. Make a table for your observations.
2. Place 20 mL of calcium chloride solution into a small beaker. Using a thermometer, measure the temperature of the solution.
3. Rinse the graduated cylinder with water and then measure 20 mL of sodium carbonate solution. Pour this into the beaker containing calcium chloride.
4. Use a stirring rod to mix the solutions. Then record the temperature of the mixture.
5. Record the temperature every 30 seconds and monitor what happens over several minutes. Record all your observations.
6. Clean up your work area and dispose of all chemicals as instructed by your teacher.

Part 5:

$C_{25}H_{52}(s) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

Candle wax is a mixture, but the formula $C_{25}H_{52}(s)$ can be used to represent it.

1. Place the candle on the aluminum plate. Light the candle and place the beaker over it.
2. When the flame goes out, examine the inside of the beaker. Record your observations.
3. Clean up your work area and dispose of all materials as directed by your teacher.

Part 6:

$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(\ell)$

Guided Inquiry

1. Using the materials provided, design a procedure for performing the neutralization reaction shown above. As part of your procedure include all safety precautions that must be taken, as well as proper clean-up and disposal that must be done.
2. Have your teacher approve your procedure before you begin.
3. Carry out your procedure and record all your observations.

Remember to go back to record your final observations of the reaction in Part 3. Then clean up your work area and dispose of any chemicals according to your teacher's instructions.

Process and Analyze

1. For each reaction, list the evidence for chemical change that you observed.
2. Based on your observations for the combustion reaction, did complete combustion or incomplete combustion occur? How do you know?

Conclude and Communicate

3. Write a word equation and a balanced chemical equation for each reaction. For Part 5, assume complete combustion.
4. Classify each of the reactions as a decomposition, synthesis, single replacement, double replacement, neutralization, or combustion reaction. Provide an explanation for each.
5. Where possible, identify the reaction as exothermic or endothermic. Provide an explanation for each.

Apply and Innovate

6. Hydrogen peroxide slowly decomposes over time, without the addition of any other chemical. What does that tell you about the hydrogen peroxide solution that can be purchased in the store? What is one potential safety hazard associated with this?

INVESTIGATION

2-1

OPEN INQUIRY

Evaluate the Effectiveness of Antacids

Many kinds of antacids are available. In this investigation, you will design an experiment to determine which antacid is the best, based on the properties that you decided are the most important for an antacid.

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Safety goggles, a lab coat or apron, and gloves must be worn throughout the investigation.

What You Need

- 0.1 mol/L HCl(aq), to mimic stomach acid
- three different antacid tablets
- other materials, as determined by your procedure

Procedure

1. As a class, decide what properties make the best antacid. Different aspects to consider include:
   - How much is needed to neutralize a certain amount of acid?
   - What is the cost of the antacid?
   - Do some antacids have fewer side effects than others?
2. Working in small groups, design a procedure to determine the best antacid. Decide which antacids you will test, and make a list of equipment and materials you will need. Include all safety precautions, as well as how the materials will be disposed of.
3. Identify the variables for your experiment. There should be one independent variable (what you are changing from one trial to the next), and one dependent variable (what you are going to measure in each trial). All other factors in the experiment should be controlled (should stay the same in every trial).
4. Have your teacher approve your procedure and materials list.
5. Make a table to record your observations.
6. Carry out your procedure and record your results.
7. Clean up your work area and dispose of any chemicals according to your teacher's instructions.

Process and Analyze

1. What properties did the class decide were the most important in an antacid? Explain the rationale.
2. Write the balanced chemical equation for each neutralization reaction that occurs for each antacid.

Conclude and Communicate

3. Which antacid would you advise someone to use? Use your results to support your answer.

UNIT 2

Summary

ESSENTIAL QUESTION

What happens to the energy and atoms of substances in chemical reactions?

TOPIC 2.1:

How are chemical processes part of our lives?

- Applications of chemistry are everywhere in the world around you.
- Knowing how to handle chemicals helps keeps us and our environment safe.

Key Term

chemical reaction

TOPIC 2.2:

What happens to atoms in a chemical reaction?

- Atoms bond together to form ionic and covalent compounds.
- Bonds are broken, atoms are rearranged, and new bonds are formed.
- Mass cannot be created or destroyed in a chemical reaction.
- A chemical equation represents what happens to the atoms in a reaction.

Key Terms

ionic compound	molecule	reactant
ionic bond	law of conservation of mass	product
covalent compound	chemical equation	coefficient
covalent bond		

TOPIC 2.3:
How is energy involved in chemical processes?

- Matter and energy interact in physical and chemical changes.
- Energy is transferred between chemical reactions (the system) and the surroundings.

Key Terms

exothermic reaction
endothermic reaction

TOPIC 2.4:
How do atoms rearrange in different types of chemical reactions?

- A compound forms in a synthesis reaction and breaks down in a decomposition reaction.
- In replacement reactions, elements replace other elements.
- Most combustion reactions release heat and light.
- In a neutralization reaction, an acid reacts with a base.

Key Terms

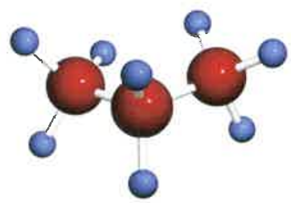
synthesis reaction	acid
decomposition reaction	base
single replacement reaction	acid-base indicator
double replacement reaction	pH scale
combustion reaction	neutralization reaction

UNIT 2 Review

What Do You Know? Connecting to Concepts

Visualizing Ideas

1. A ball-and-stick model of propane, C_3H_8, is shown. Use the model to answer the following questions.



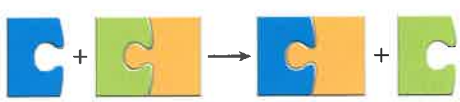
   a) Is this an ionic or covalent compound? Explain how you know.

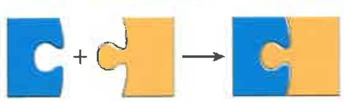
   b) Using Bohr or Lewis diagrams, show how electrons are involved in the formation of one of the bonds in this compound.

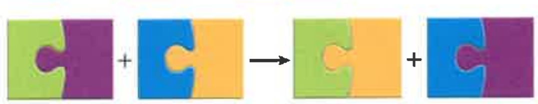
   c) Describe the bonds that are broken and new bonds that form when propane undergoes a combustion reaction.

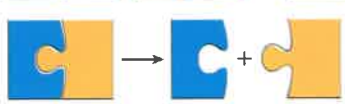
   d) Sketch an energy level diagram that would represent the combustion of propane. Label your diagram as endothermic or exothermic, and provide evidence that supports your decision.

2. For each image below, identify the reaction type it represents, and explain why it represents that type of reaction.

   a) 

   b) 

   c) 

   d) 

Using Key Terms

3. What does the term *formula unit* refer to?

4. What do coefficients in balanced chemical equations represent? Give an example of a chemical formula with a coefficient.

5. Describe, in sentences or with a graphic organizer, the relationships between the following terms: *bond breaking*, *bond forming*, *energy release*, *energy absorption*, *exothermic*, *endothermic*.

6. Describe what an acid and a base are. Give the name and chemical formula for an example of each.

7. Use a graphic organizer to compare and contrast ionic and covalent bonds.

Communicating Concepts

8. Determine the number of atoms of each element for the following compounds.

   a) $4CO$ b) $3MgCl_2$ c) $2(NH_4)_2SO_4$

9. Why is it incorrect to change the subscripts in chemical formulas when you are balancing a chemical equation?

10. Balance each of the following chemical equations.

   a) $Na(s) + O_2(g) \longrightarrow Na_2O(s)$

   b) $KCl(s) \longrightarrow K(s) + Cl_2(g)$

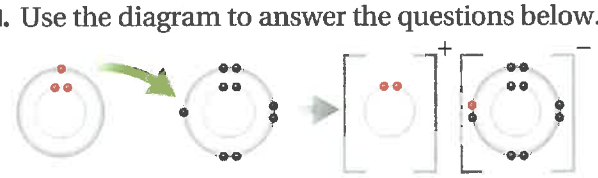
   c) $N_2(g) + O_2(g) \longrightarrow NO_2(g)$

   d) $CuSO_4(aq) + Na(s) \longrightarrow Cu(s) + Na_2SO_4(aq)$

   e) $Pb(NO_3)_2(aq) + KI(aq) \longrightarrow PbI_2(s) + KNO_3(aq)$

   f) $Al(s) + Cl_2(g) \longrightarrow AlCl_3(s)$

11. Use the diagram to answer the questions below.



   a) Two atoms are shown. What elements are represented? Explain how you know.

   b) What type of bond is represented? Why?

   c) Is energy released or absorbed in this process?

12. Why are ionic compounds not considered molecules?

13. Draw a Bohr diagram that represents the chemical bond in a molecule of Cl_2.

14. What elements exist as diatomic or polyatomic molecules? Write their names and chemical formulas.

15. Indicate if each of the following is an acidic, basic, or neutral solution.
   a) lemon juice
   b) a solution with pH = 9
   c) an aqueous solution of sodium chloride, using water with a pH = 7

16. Bacteria are used to make cheese (pH = 5.5) and yogurt (pH 4.5) from milk (pH 6.5). Place these foods in the order of least acidic to most acidic.

17. The photo shows what happens when zinc metal is placed in a solution of hydrochloric acid.

   a) What evidence suggests that a chemical change is occurring?
   b) How does the mass of zinc metal change as the reaction proceeds?
   c) Name the gaseous product that forms bubbles in this reaction. How do you know?
   d) Write the balanced chemical equation for this reaction.
   e) What type of reaction is this? Explain your choice.
   f) After the reaction, the test tube feels warm. Describe the overall energy change for this reaction.

18. You have learned about single replacement and double replacement reactions in this unit. Explain why the names of these types of reactions are appropriate.

What Do You Know?
Connecting to Competencies

Developing Skills

19. Represent these reactions using word, skeleton, and balanced chemical equations. Include the states of reactants and products.
   a) Freshly cut sodium reacts with oxygen gas in air and forms solid sodium oxide.
   b) When a piece of magnesium ribbon is placed into an aqueous solution of copper(II) chloride, copper metal and an aqueous solution of magnesium chloride form.
   c) Solid magnesium oxide and carbon dioxide gas form when powdered magnesium carbonate is heated.
   d) When aqueous solutions of chromium(III) chloride and potassium hydroxide are mixed, a solution of potassium chloride and a precipitate of chromium(III) hydroxide form.

20. Identify the type of reaction for each part in question 19. Explain your reasoning.

21. For the following reactants, identify the type of reaction they will undergo, predict the products, and write the balanced chemical equations. (Do not include the states of the products.)
   a) $Au(NO_3)_3(aq) + Ag(s) \rightarrow$
   b) $CuO(s) \rightarrow$
   c) $BaCl_2(aq) + K_2SO_4(aq) \rightarrow$
   d) $C(s) + O_2(g) \rightarrow$
   e) $HBr(aq) + Al(OH)_3(aq) \rightarrow$
   f) $AgCl(s) \rightarrow$
   g) $Ca(s) + S_8(s) \rightarrow$
   h) $Mg(s) + HCl(aq) \rightarrow$
   i) $NaCl(aq) + AgNO_3(aq) \rightarrow$
   j) $C_4H_{10}(\ell) + O_2(g) \rightarrow$

Thinking Critically and Creatively

22. An element in Group 1 on the periodic table forms ionic compounds with elements in Group 17 in a 1:1 ratio. In what ratio would you expect an element from Group 2 and elements from Group 16 to react when they form ionic compounds? Explain your answer.

23. In this unit, pictorial representations were used to help you understand what happens to elements and compounds in the different types of chemical reactions. These representations used coloured spheres. Develop a different method to represent what happens in the types of chemical reactions you have learned about. Be creative—for example, you might consider using cartoons of different people dancing.

24. Draw a sketch that represents how energy can be exchanged between a system and its surroundings.

- **a)** For chemical reactions, what represents the system and what represents the surroundings?
- **b)** If there is a net absorption of energy by a chemical reaction, what does that tell you about the energy of the surroundings?

What Do You Know?
Making New Connections

Applying Your Understanding

25. Develop an image that represents energy changes that occur during a chemical reaction. Your image should include the following labels: endothermic, exothermic, bond formation, bond breaking, reactant, product, and energy.

26. The photo below shows wood burning.

- **a)** What type of chemical reaction is this?
- **b)** Is it exothermic or endothermic? What evidence supports your answer?
- **c)** Does this reaction require an input of energy to get started? How do you know?

27. When wood burns completely, a pile of ash remains. The mass of the ash is much less than the mass of the original wood.

- **a)** Does this observation invalidate the law of conservation of mass? Why or why not?
- **b)** Describe an experiment that would provide evidence to support your answer to part **a)**.

28. Think of five ways you rely on chemistry in your daily life.

- **a)** Discuss the advantages and the disadvantages that are associated with using the chemicals.
- **b)** What alternatives are available that might counter the disadvantages?

29. In a highly exothermic reaction, solid carbon dioxide (dry ice) sublimes and reacts with hot magnesium to produce solid magnesium oxide and solid carbon.

Fire extinguishers commonly contain carbon dioxide, which is heavier than air and smothers a fire. How does the chemical reaction described above demonstrate the limited usefulness of carbon dioxide fire extinguishers?

Thinking Critically and Creatively

30. A chemist performs an experiment that involves reacting 1.6 g of sodium carbonate with 1.1 g of calcium chloride in an aqueous solution.

a) What type of chemical reaction is this? Describe what is happening to the ions during the reaction.

b) Predict the products of this reaction.

c) Write the word equation, skeleton equation, and balanced chemical equation for this reaction. One product is not soluble in water and forms a precipitate. The other product is soluble in water.

d) The precipitate that forms is isolated using a filtration apparatus, shown here. The filter paper and solid are dried overnight. The next day the mass of the solid product is determined to be 1.0 g. What is the mass of the second product expected to be? How do you know?

e) The chemist expected to isolate a greater amount of precipitate. Describe one thing that might have contributed to the lower amount actually obtained.

31. The photo shows a pH meter is being used to measure the pH of a solution.

a) The number displayed represents the pH of the solution. Is it acidic or basic?

b) Should HCl(aq) or KOH(aq) be added to neutralize this solution? Explain your reasoning.

Connecting to Self and Society

32. Baking soda, sodium hydrogen carbonate, can be used to neutralize an acid spill. The chemical equation is

$HCl(aq) + NaHCO_3(s) \longrightarrow$
$NaCl(aq) + CO_2(g) + H_2O(\ell)$

a) Will the pH increase or decrease by adding baking soda? Explain.

b) Why is baking soda a safer alternative to other bases, such as NaOH(aq)?

c) Write the balanced chemical equation for the neutralization of hydrochloric acid with magnesium hydroxide.

33. One way to treat a body of water polluted with acid precipitation is to add calcium hydroxide, $Ca(OH)_2$.

a) How does this help?

b) In what way is liming a lake similar to taking an antacid for heartburn?

c) Why is lake liming a short-term solution to the problem?

d) Describe a longer-term solution to the problem of acidic lakes due to acid precipitation?

34. While working in a laboratory as a summer student, you notice that the Safety Data Sheets for many of the chemicals cannot be found. What could you say to your supervisor to help convey the importance of maintaining up-to-date SDS records?

35. What decisions about chemical products and processes do you make, personally, on a daily basis? What are the benefits and risks associated with your decisions? How can an understanding of chemistry help you better assess the benefits and risks?

Unit Assessment

How do chemicals affect agriculture in B.C.?

B.C.'s diverse geography and climates support a wide variety of fruits, vegetables, and grains, as well as livestock. The physical and chemical conditions of the soil of a given region help us decide what can be grown and raised. Adding chemicals such as fertilizers, elemental sulfur, and lime can enhance soil structure and nutrient content, as well as maintain its fertility. Understanding the properties of these chemicals and how they interact with their surroundings helps to promote sustainable yields and can reduce risks to society and the environment.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the questions asked in their captions.

STEP 2 ► Brainstorm at least three more options and questions of your own about chemicals in agriculture.

STEP 3 ► Decide on one of the six questions to investigate.

STEP 4 ► Plan and conduct a scientific inquiry to explore your question.

STEP 5 ► Organize and analyze the data and information that you find and collect.

STEP 6 ► Communicate the results of your inquiry in a suitable manner.

OPTION A

Agricultural Chemistry

What chemicals are used for growing crops in the field and in hydroponics to modify pH conditions, and for what reasons?

OPTION B

Crops around the World

How do agricultural chemicals affect the stability, fertility, and productivity of the soil in different geographical locations?

OPTION C

Impacts of Human Activity

What chemical reactions naturally occur in soil ecosystems, how does human agricultural activity alter them, and with what consequences?

Assessment Criteria

Did I and my group...

- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Analyze, reflect on, and draw meaningful conclusions as related to the inquiry? PA
- Evaluate the process and results of the inquiry, troubleshooting problems if they arose? E
- Consider the role of scientists in innovation? AI
- Present the results of the inquiry using language, conventions, and representations appropriate for a specific purpose and audience? C

UNIT 3

Energy is conserved and its transformation affects living things and the environment.

It takes an enormous amount of electrical energy to light up a city. This energy is transformed from other types of energy—the energy stored in fossil and nuclear fuels, and the energy of the Sun, moving water, and wind. In the future, buildings and the materials used to make them may play a role in transforming energy as well.

"In the cities of the future, advances such as glass that can harness the sun's power—so skyscrapers could be covered in windows that double as solar panels—have the potential to propel widespread use of solar energy."

Dr. James Tansey,
executive director of the UBC Sustainability Initiative and the Sauder Centre for Social Innovation and Impact Investing, University of British Columbia