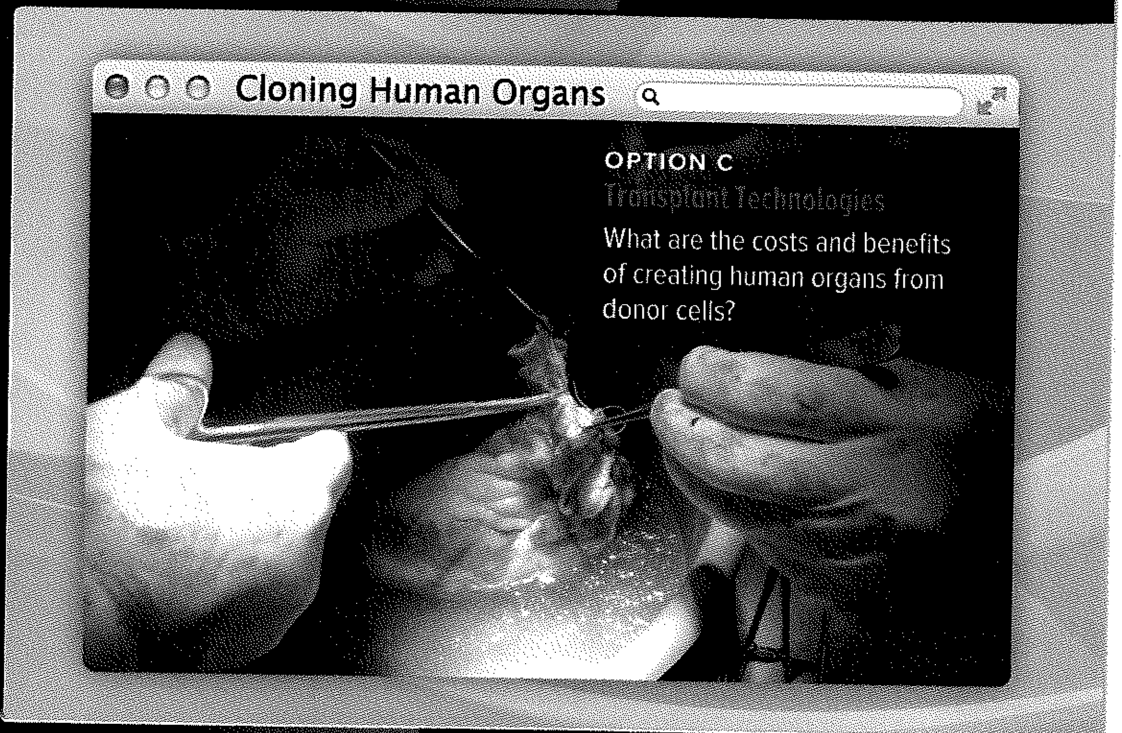


OPTION C

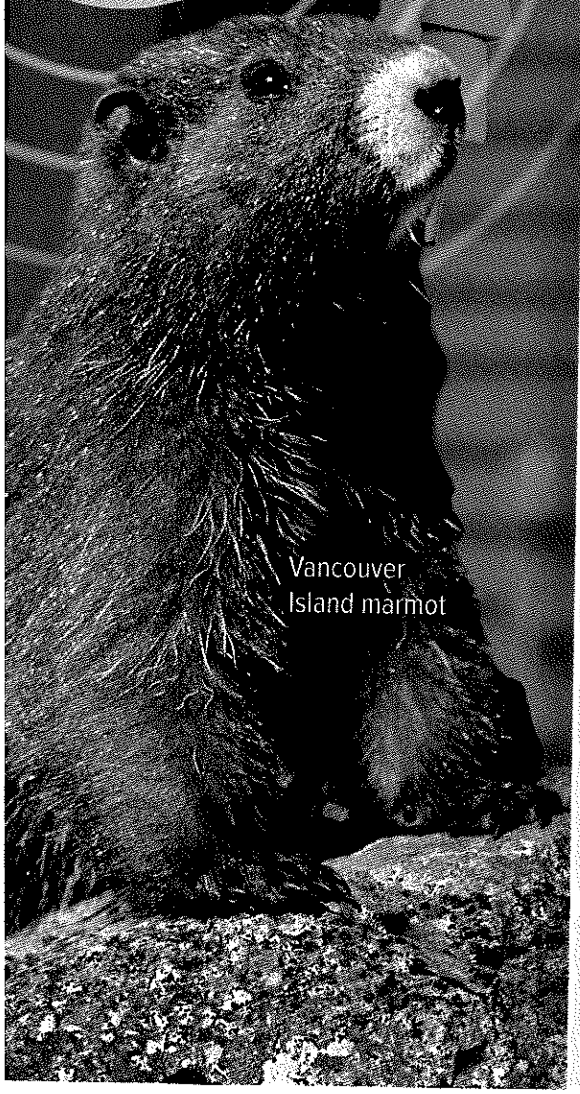
Transplant Technologies

What are the costs and benefits of creating human organs from donor cells?

OPTION B

Saving Species

Should we use cloning to help endangered species or bring extinct ones back to life?



Vancouver Island marmot

Assessment Criteria

Did I and my group...

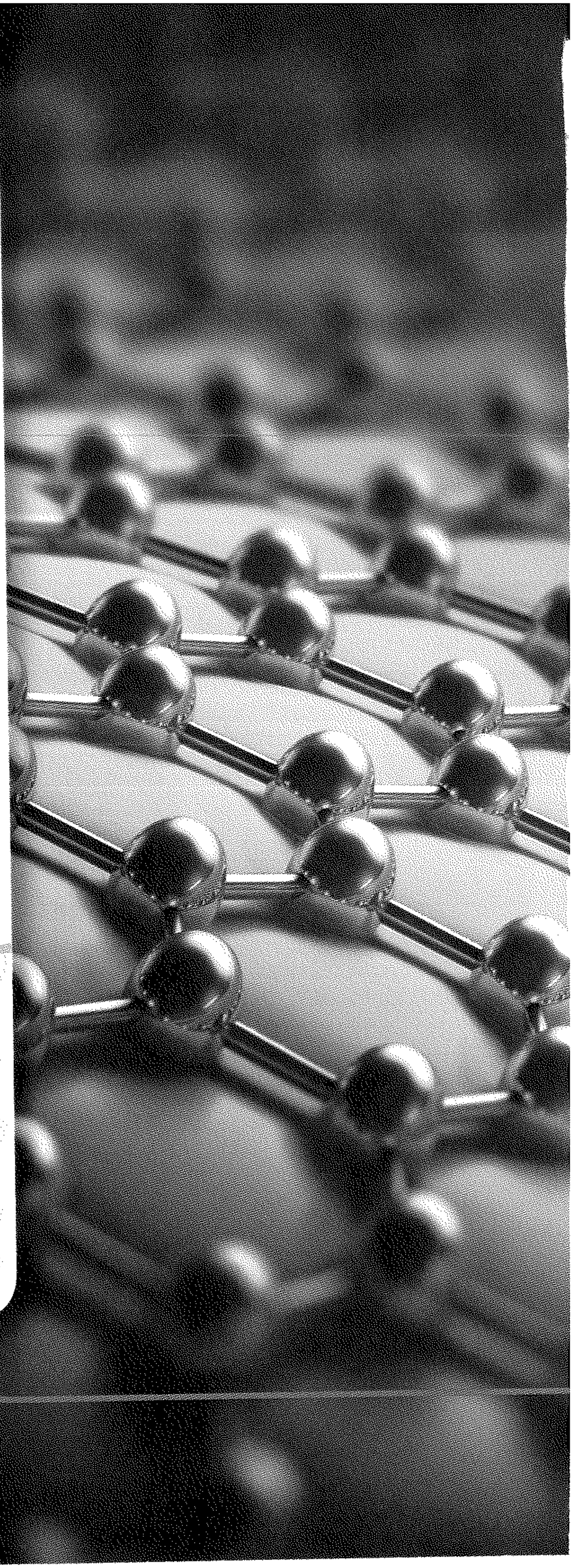
- Develop one or more questions that provided opportunities for rich investigation? QP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect on, and draw meaningful conclusions that are consistent with evidence? PA
-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

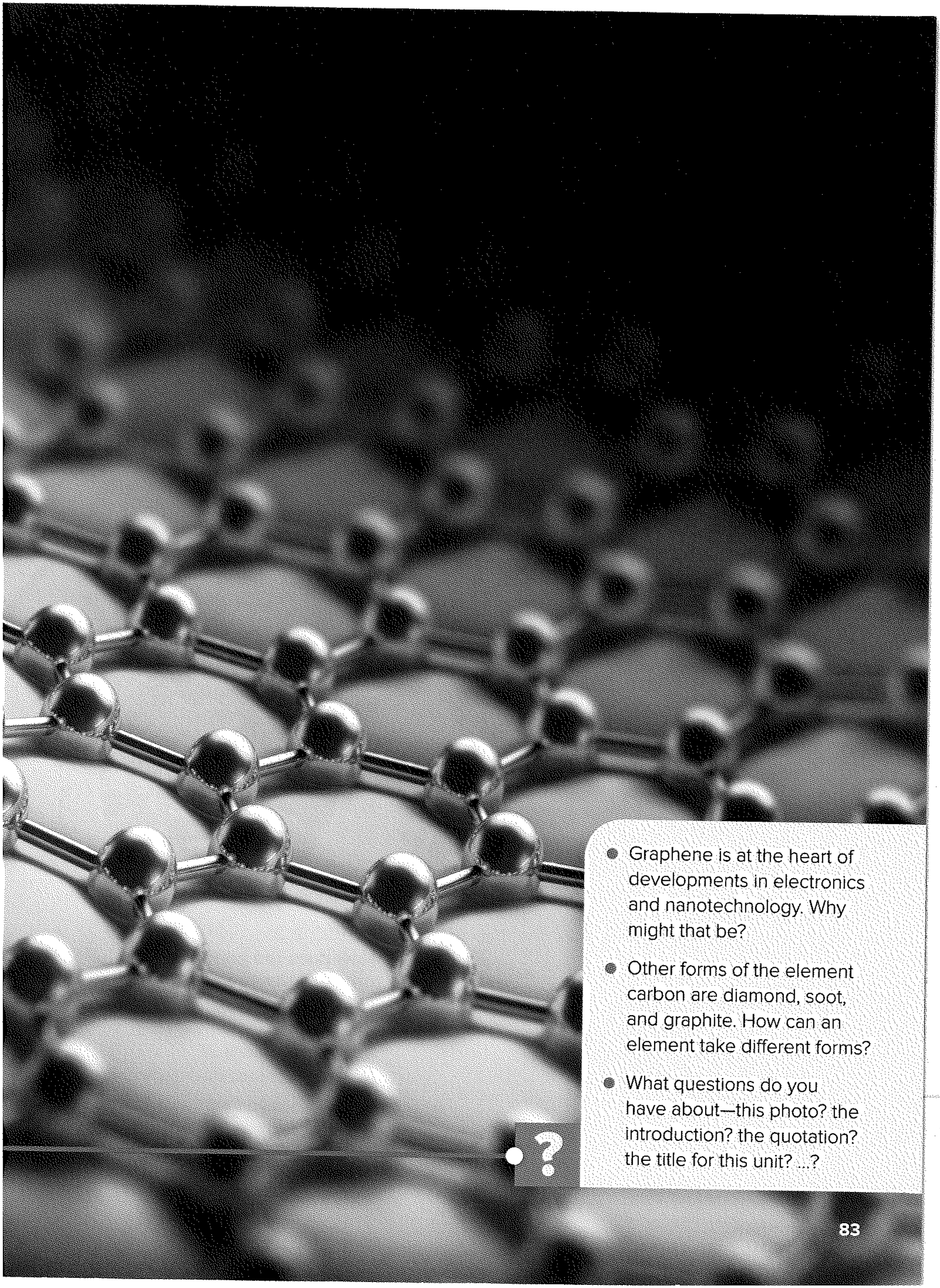
UNIT 2

The electron arrangement of atoms impacts their chemical nature

Graphene forms a flexible honeycomb structure that is just one atom thick, but it is stronger than steel and an excellent conductor of electric current. It is one of several forms of the element carbon, and carbon is just one of the hundred or so elements that make up the millions of compounds in the universe. Why does carbon have different forms? What are the properties of elements, and how can we organize and explain them? Why do elements combine to form compounds? The answers lie in the arrangement of electrons in atoms.

> **“I kept dreaming of the periodic table in the excited half-sleep of that night—I dreamed of it as a flashing, revolving pinwheel ... and then as a great nebula, going from the first element to the last, and whirling beyond uranium, out to infinity.”**
>
> *Oliver Sacks, MD*
> *Neurologist, naturalist, author*





- Graphene is at the heart of developments in electronics and nanotechnology. Why might that be?
- Other forms of the element carbon are diamond, soot, and graphite. How can an element take different forms?
- What questions do you have about—this photo? the introduction? the quotation? the title for 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 a variety of elements
- Use scientific understandings to describe and evaluate the development of the periodic table
- Develop and use models and other methods to represent atoms, ions, and the ability of atoms to form compounds
- Seek patterns and connections to describe, name, and write formulas for a variety of chemical compounds

ESSENTIAL QUESTION

How do the electron arrangements of atoms determine the chemical and physical properties of elements and compounds?

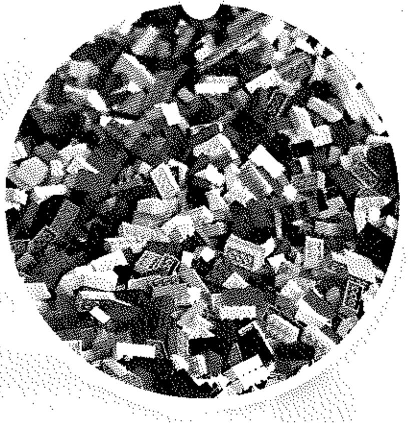
TOPIC 2.1:
How and why do we study matter?

Some things you will do:

- choose and use equipment safely and accurately
- contribute to care for self, others, community, and world

Some things you will come to know:

- You can describe and explain much about matter based on its properties and interactions.
- You must handle matter and equipment used to investigate it safely.



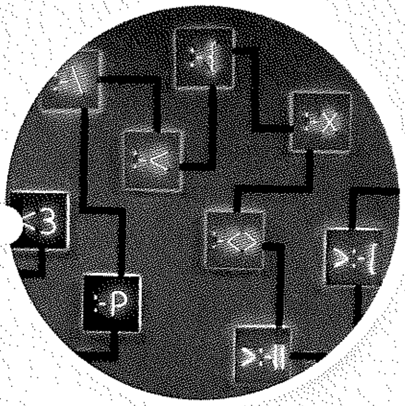
TOPIC 2.2:
How does the periodic table organize the elements?

Some things you will do:

- seek and analyze patterns, trends, and connections in data
- analyze cause-and-effect relationships

Some things you will come to know:

- The periodic table is an extremely powerful tool for organizing our knowledge about the matter of the universe.



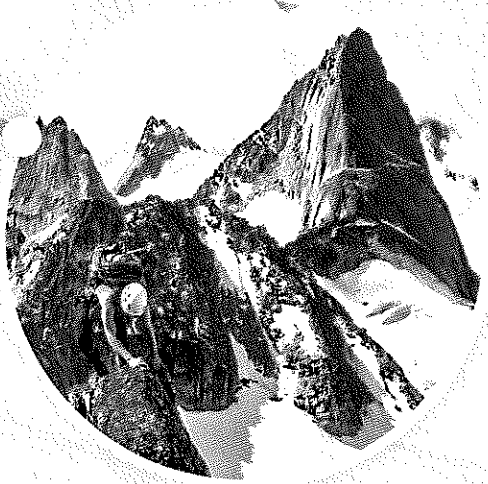
TOPIC 2.3:
How can atomic theory explain patterns in the periodic table?

Some things you will do:

- identify questions of interest based on curiosity and learning
- construct, analyze, and interpret graphs, models, and/or diagrams
- draw conclusions that are consistent with evidence

Some things you will come to know:

- You can use simple diagrams to represent the structure of atoms.
- You can use the periodic table to predict relationships between atoms of different elements.



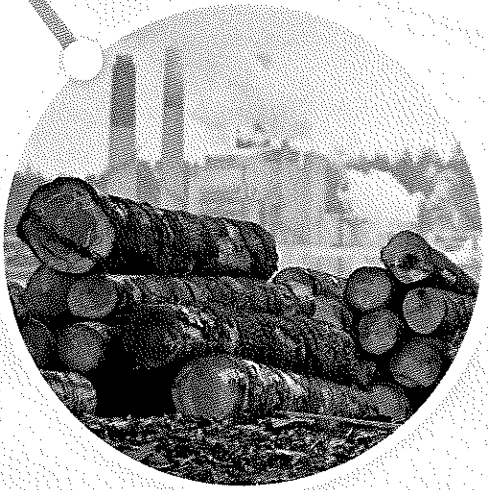
TOPIC 2.4:
How do elements combine to form compounds?

Some things you will do:

- use scientific concepts to draw conclusions
- use physical or mental models to describe phenomena

Some things you will come to know:

- Forming compounds is all about the stability of a full valence shell.
- Some compounds are made up of ions, while others are made up of molecules.



TOPIC 2.5:
How do we name and write formulas for compounds?

Some things you will do:

- work together to develop a game about naming and writing formulas for compounds
- analyze patterns, trends, and connections in data to help you name and write formulas for compounds

Some things you will come to know:

- You can name and write formulas for compounds if you know their structures or compostions.
- The periodic table can help you name and write formulas.

TOPIC 2.1

How and why do we study matter?

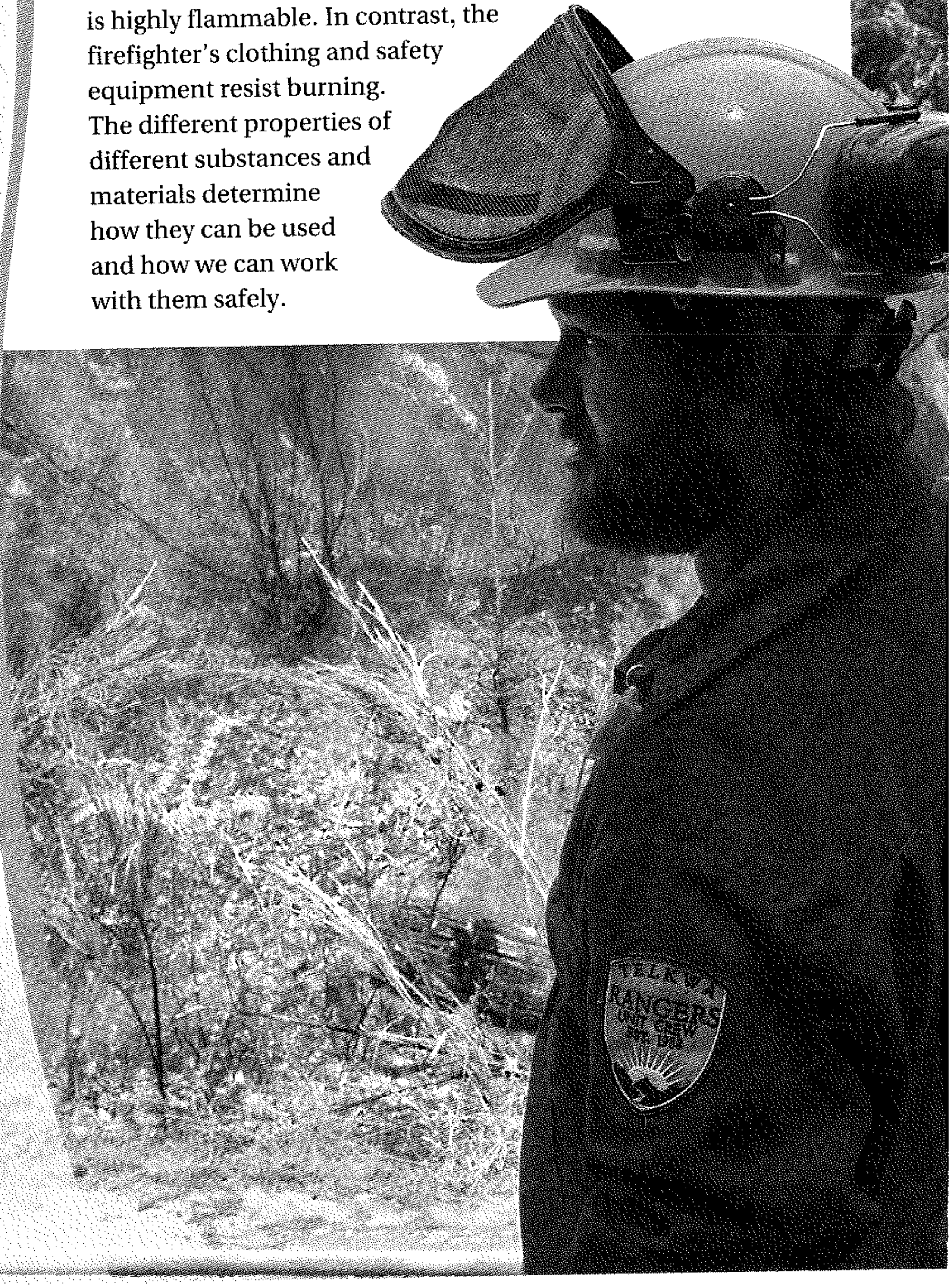
Key Concepts

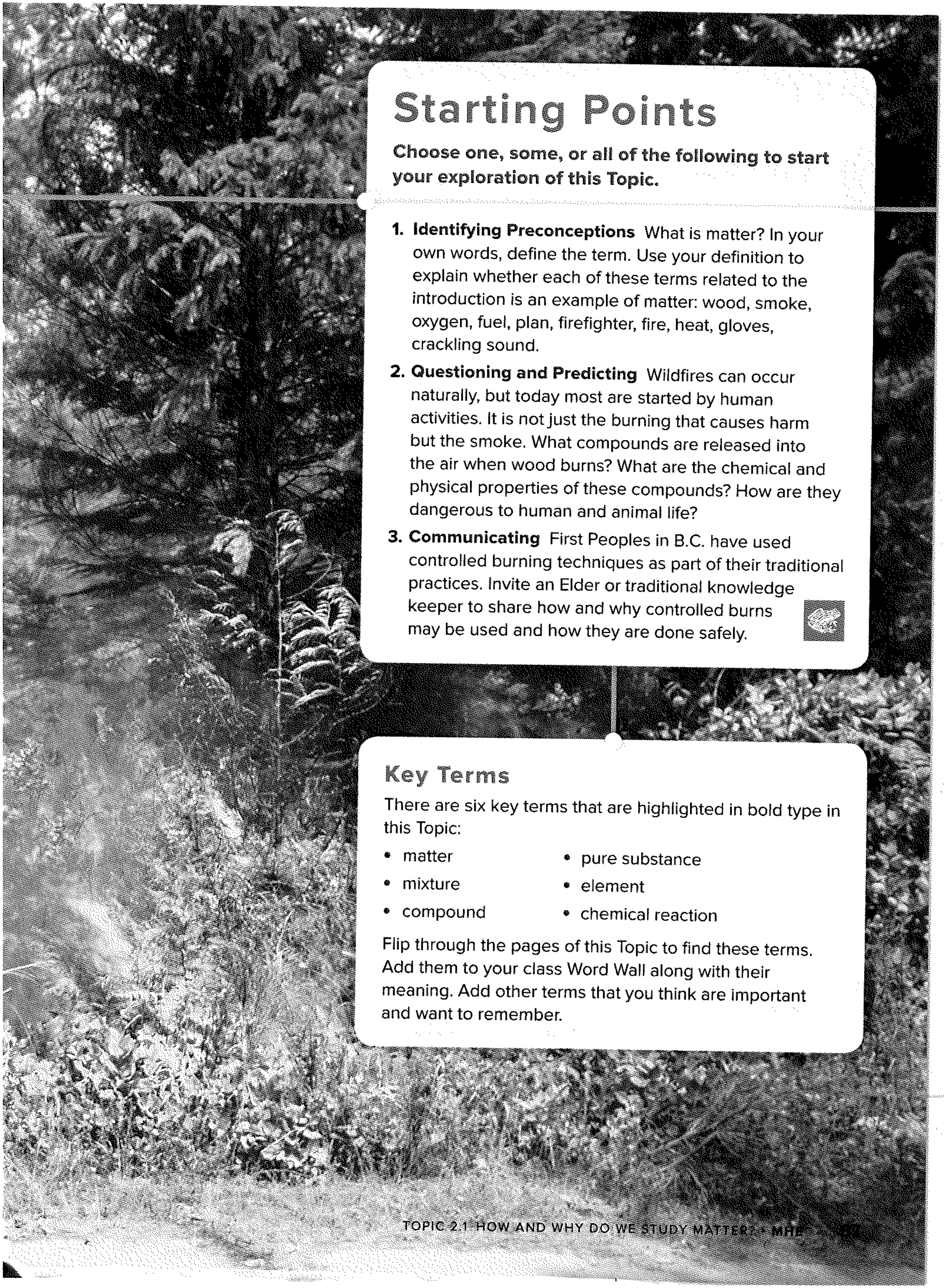
- Matter and its interactions make up our world.
- Safety is key when working with matter.

Curricular Competencies

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.
- Ensure that safety and ethical guidelines are followed in your investigations.
- Critically analyze the validity of information in secondary sources and evaluate the approaches used to solve problems.

According to the B.C. government, about 2000 wildfires occur in the province each year. One strategy to prevent wildfires or to fight existing ones is to carry out planned, or prescribed, burns. The firefighter shown here is working at a prescribed burn, which was started on purpose and is carefully kept within planned boundaries. The fuel used to start the fires is highly flammable. In contrast, the firefighter's clothing and safety equipment resist burning. The different properties of different substances and materials determine how they can be used and how we can work with them safely.





Starting Points

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

1. **Identifying Preconceptions** What is matter? In your own words, define the term. Use your definition to explain whether each of these terms related to the introduction is an example of matter: wood, smoke, oxygen, fuel, plan, firefighter, fire, heat, gloves, crackling sound.
2. **Questioning and Predicting** Wildfires can occur naturally, but today most are started by human activities. It is not just the burning that causes harm but the smoke. What compounds are released into the air when wood burns? What are the chemical and physical properties of these compounds? How are they dangerous to human and animal life?
3. **Communicating** First Peoples in B.C. have used controlled burning techniques as part of their traditional practices. Invite an Elder or traditional knowledge keeper to share how and why controlled burns may be used and how they are done safely.

Key Terms

There are six key terms that are highlighted in bold type in this Topic:

- matter
- mixture
- compound
- pure substance
- element
- chemical 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 its interactions make up our world.

Activity

Describe It, Separate It

Your teacher will provide your group with a mixture. You will have access to equipment such as magnets, filters, and sieves. Before starting, examine Figure 2.1 below.

1. Is your mixture heterogeneous or homogeneous (a solution)? How do you know?
2. Can you separate your mixture into parts? Try to do so.
3. Are the parts of your sample mixtures or pure substances? Explain.
4. What further tests would you like to conduct to gather more information about the components of your sample?

You are surrounded by **matter**, and chemistry is the science of matter and its interactions. By studying chemistry, we can better understand the properties and behaviour of matter on Earth and beyond. Matter can be classified as either a **pure substance** or a **mixture**. Pure substances are made up of one type of particle. Mixtures are made up of two or more pure substances, and therefore two or more types of particles. Figure 2.1 summarizes the classification of matter.

matter anything that has mass and takes up space

pure substance matter that has a definite composition and cannot be separated by physical means

mixture a blend of two or more pure substances in which each substance retains its individual properties; can be separated by physical means

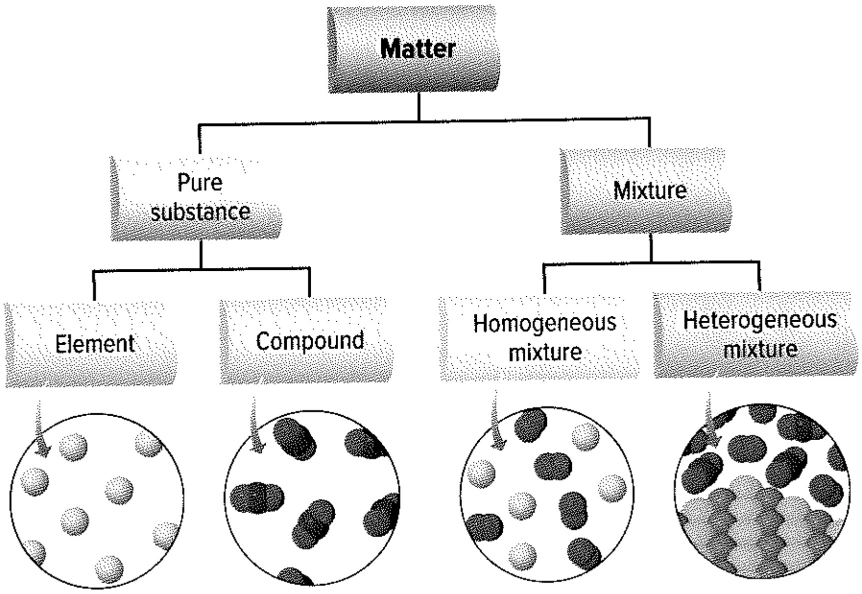
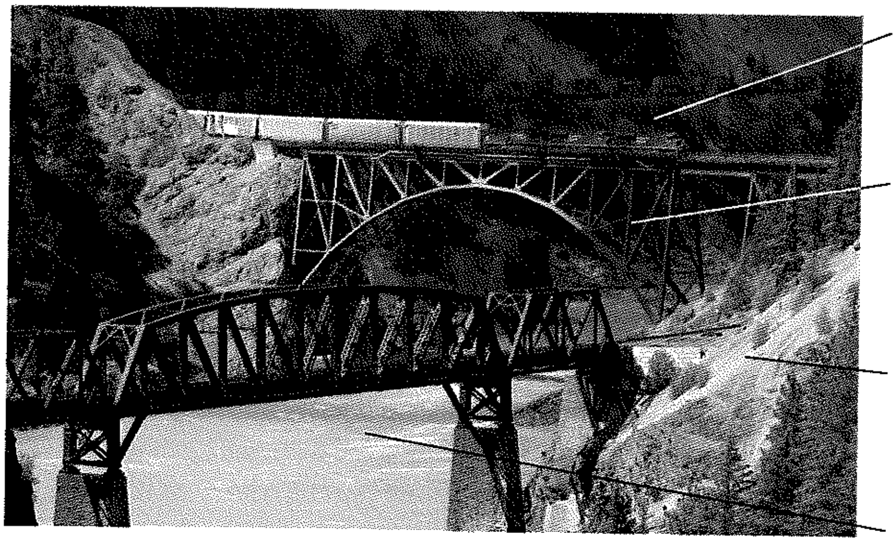


Figure 2.1 Matter is either a mixture or a pure substance. A mixture can be homogeneous or heterogeneous. A pure substance can be an element or a compound. **Give one example of each of these: a mixture, an element, and a compound.**



This train runs on diesel fuel. Diesel is a mixture of chemical compounds made of the elements hydrogen and carbon.

The metal used to make the bridge is steel. Steel is a very strong solid mixture—an alloy—composed of iron and small amounts of other elements, such as carbon.

The rock of the hillside is a mixture that includes quartz, which is a compound made of the elements silicon and oxygen.

This river water is a mixture made up of the compound water, a variety of compounds and elements dissolved in the water, and suspended bits of rock.

Figure 2.2 This pair of railway bridges, called the Cisco bridges, is found at Siska, B.C. **Make a table to list the mixtures, compounds, and elements mentioned. Add one example not mentioned.**

Mixtures, Compounds, and Elements

Most of the materials we interact with each day are mixtures. Figure 2.2 shows and describes some examples of solid, liquid, and gas mixtures. Some—such as air and steel—are homogeneous mixtures, or *solutions*. They are mixed uniformly throughout, and you cannot see their components, even with a microscope. Others, such as rock, have different parts that you can see. These are *heterogeneous mixtures*. But all are made up of two or more different pure substances.

Pure substances can be elements or compounds. **Elements** are made up of just one type of atom and cannot be broken down into simpler substances by chemical means. **Compounds** are made up of atoms of two or more elements.

element a pure substance that cannot be broken down into simpler substances by physical or chemical means

compound a pure substance made up of two or more elements; can be broken down into elements by chemical means

Properties of Matter

The steel of the railway tracks in Figure 2.2 is a strong, hard, shiny solid. Rock is also a hard solid, but it is brittle. Air is a clear, colourless gas. These descriptions all use *physical properties*. These are characteristics of matter that can be observed or measured without changing its chemical identity. In contrast, *chemical properties* describe the ability of matter to react with another substance to form one or more different substances. Table 2.1 gives further examples.

Table 2.1 **Physical and Chemical Properties**

Physical Properties		Chemical Properties
• colour	• state of matter	• combustibility
• malleability	• melting point	• reactivity with acids
• texture	• boiling point	• reactivity with oxygen
• viscosity	• hardness	• lack of reactivity
• ability to conduct heat and electricity	• solubility	

Chemical Reactions

An important part of studying matter is carrying out and observing chemical reactions. In a **chemical reaction**, one or more pure substances interact to form a different substance or substances. For example, elements can react to form compounds, compounds and elements can react to form different compounds, and compounds can break apart to form elements and simpler compounds.

chemical reaction a process in which the atoms of one or more pure substances are rearranged to form a different substance or substances.

A fire is a common example of a chemical reaction. In a forest fire, compounds in plants react with oxygen in the air to form many compounds, including carbon dioxide, carbon monoxide, and water, as well as the element carbon. You cannot see or smell carbon dioxide or carbon monoxide, but water is a visible part of smoke as it cools and forms droplets in the air. You can see the carbon as the black charcoal left behind by the fire. Energy is also released in the form of light and heat. Figure 2.3 shows other examples of chemical reactions.

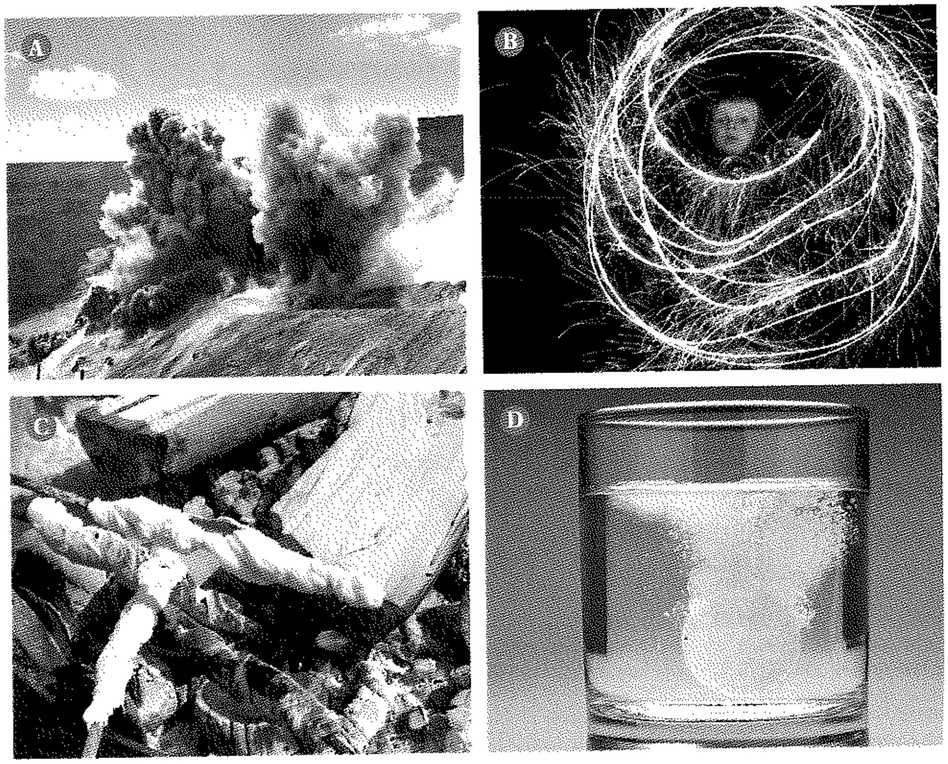


Figure 2.3 Ⓐ Explosive chemical reactions are used in mining to break apart rock and soil. Ⓑ In a sparkler, metals react with air and release energy in the form of light and sound. Ⓒ Exposing food to heat results in chemical reactions that change its taste and appearance. Ⓓ The chemical reaction between substances in this tablet and water produces gas, which you can see as bubbles in the water.

Before you leave this page . . .

1. What is the difference between a pure substance and a mixture? Use diagrams in your answer.
2. List three physical properties of water at room temperature.
3. Give one example of an element and one example of a compound. Explain how they are different.
4. What happens in a chemical reaction?

CONCEPT 2

Safety is key when working with matter.

Activity

Be Prepared; Be Safe

Figure 2.4 shows two students carrying out Investigation 2A. How have they ensured that they are doing their investigation safely? First do the following:

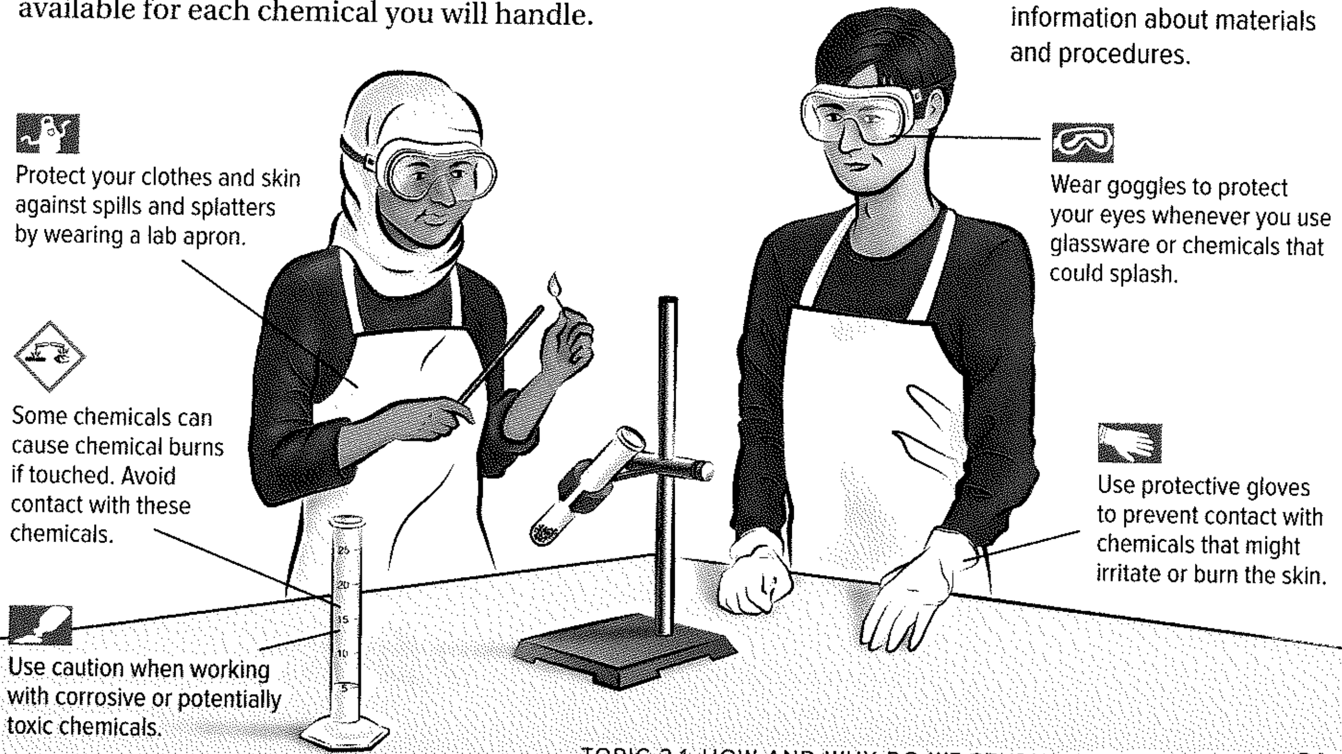
- Read Safety in Your Science Classroom on page xiv–xvii.
- Review the safety guidelines in Figure 2.5 on the next page.
- Read Investigation 2A on pages 96–97.

Then answer these questions.

1. What is the meaning of each safety symbol in Investigation 2A?
2. Why should the test tube be angled away from you and your partner?
3. What would you do if some hydrochloric acid spilled on the lab bench?
4. Where are the fire extinguishers in your classroom and how are they used?

Making sure that you know how to handle materials safely in the laboratory is an essential part of studying chemistry. Figure 2.4 shows some of the blue safety icons that you will see attached to investigations in this unit. You will also see Workplace Hazardous Materials Information System (WHMIS 2015) symbols, which alert you to potential hazards when working with specific substances in the lab. As part of the WHMIS 2015 system, Safety Data Sheets (SDS) are available for each chemical you will handle.

Connect to Investigation 2A on pages 96–97



Protect your clothes and skin against spills and splatters by wearing a lab apron.

Some chemicals can cause chemical burns if touched. Avoid contact with these chemicals.

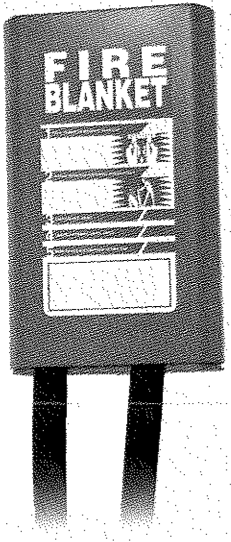
Use caution when working with corrosive or potentially toxic chemicals.

Wear goggles to protect your eyes whenever you use glassware or chemicals that could splash.

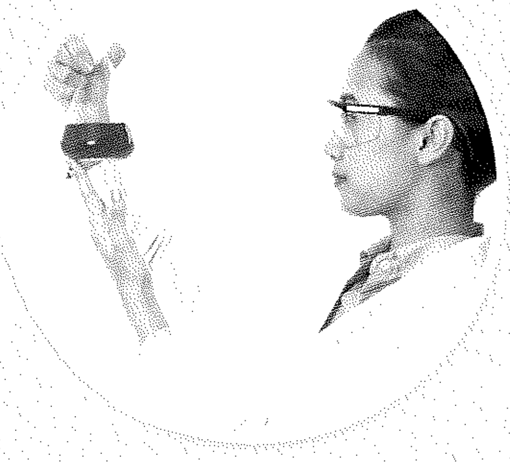
Use protective gloves to prevent contact with chemicals that might irritate or burn the skin.

Figure 2.4 Safety icons (blue and white) and WHMIS symbols (black and red) communicate important information about materials and procedures.

Staying Safe in Your School Laboratory



1. **Before you begin**
   - Inform your teacher if you have any allergies or medical conditions, or if there are other factors that could affect your work in the chemistry lab.
   - Know the location of the nearest fire alarm, fire extinguisher, fire blanket, first-aid kit, safety shower (if there is one), and eye wash station. Know how to use them.
   - Study your activity, investigation, or other lab assignment carefully before you start. Ask for help if you have questions.
   - Be sure you understand the safety icons.



2. **Dressing the part**
   - Wear protective clothing as appropriate and as directed, such as a lab apron, gloves, and safety glasses.
   - Tie back long hair, and secure or remove scarves, caps, ties, or long necklaces.
   - Wear footwear that covers your entire foot, including toes.

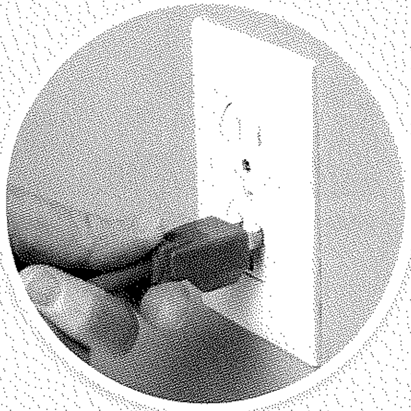
3. **Acting responsibly**
   - Never chew gum, eat, or drink in the lab.
   - Work carefully with your partner or group and make sure you keep your work area clear.
   - Stay focused on what you are doing. Acting irresponsibly is dangerous in the lab.

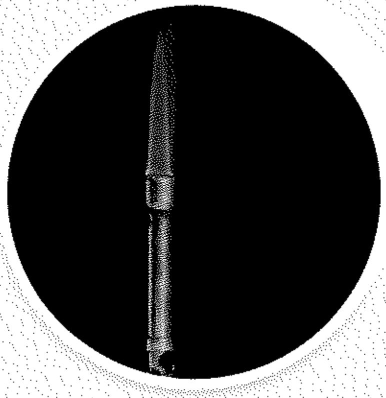
Staying Safe; Being Aware

Before you start any activity or investigation in the lab, read the procedure carefully. Be sure you understand what is involved in each step, including safety precautions. Be aware of what you are doing and what others are doing at all times. Know where safety equipment such as fire extinguishers and eyewash stations are, and how to use them. By following safety guidelines such as the ones listed in Figure 2.5, and by staying alert, you and your classmates create an environment in which you can confidently explore the properties and interactions of matter.

4. Using equipment

- When carrying equipment for an activity or investigation, hold it carefully. Carry only one object at a time.
- When working with electrical equipment, make sure your hands are dry, especially when touching electrical cords, plugs, or sockets. Pull the plug, not the cord.
- Report damaged equipment to your teacher immediately.
- Place electrical cords where people will not trip over them.





5. Working with heat

- If you use a laboratory burner, be sure you understand how to light and use it safely.
- Point the open end of a container being heated away from yourself and others.
- Do not allow a container to boil dry.
- Handle hot objects carefully. Remember that glassware and equipment looks the same hot as it does cold.
- Inform your teacher if you receive a burn. Apply cold water to the burned area immediately.

6. Working with chemicals

- Read and understand all safety labels, including WHMIS symbols.
- Never taste any substances you use in the lab.
- If any part of your body contacts a substance in the lab, inform your teacher. Immediately wash the area thoroughly with cold water. If you get anything in your eyes, wash them immediately and continuously for 15 minutes.
- Handle substances carefully. If you are asked to smell a substance, never smell it directly. Hold the container slightly in front of and beneath your nose, and waft the fumes toward your nostrils.

7. Cleaning up

- Clean up any spills according to your teacher's instruction.
- Clean equipment and glassware before you put it away.
- Dispose of all materials as directed by your teacher. Never discard materials in the sink or garbage unless your teacher directs you to.
- Wash your hands thoroughly after doing an activity or investigation.

Figure 2.5 These are just some of the safety rules to follow in your school laboratory.

Connect to Investigation 2B on pages 98–99

Before you leave this page . . .

1. What is an SDS?
2. List three things you should do before beginning any investigation in the lab.
3. What are the locations of the eyewash stations and fire extinguisher in your classroom?

AT ISSUE Should we use flame-retardant substances?

What's the Issue?

In Canada, many, many household products—from upholstered furniture, electronics, and children's toys to kettles, chairs, and carpet backing—and even our cars contain polybrominated diphenyl ethers (PBDEs). The purpose of these chemicals is to slow or stop fires, and so protect the consumer.

But are we really protected by these chemicals, or do they pose a health risk to us? The David Suzuki Foundation warns that exposure to these chemicals can damage our immune systems, reproductive systems, neurological systems, and more. It's a bit ironic: the very chemicals that are included in products in order to keep us safe from the effects of fire actually expose us to harm when they burn. And scientists are concerned that we're exposed to them at other times too. For example, they are released into the air while they are being manufactured. And when products containing them disintegrate, the toxic chemicals accumulate in household dust. Recently, the Canadian government agreed that PBDEs do pose a risk to people and the environment. It has put in place regulations to prevent their manufacture in Canada and to restrict their use.

Dig Deeper

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

1. Canada has recently restricted the use of PBDEs in new Canadian-made products, but there are still many existing products in Canadian households, including carpets and toys, which contain these PBDEs. Do you think these might pose an ongoing health risk to the public? If so, which part of the population might be most at risk? Explain your answer. Research to find suggestions about what families can do to minimize their exposure.
2. The flammability of children's sleepware has been regulated in Canada since 1971. How have the regulations changed since then? Are the regulations successful in protecting children?
3. What materials might First Peoples have used that have flame-retarding properties? A local Elder or Knowledge Keeper could assist with answers to this question.

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. State whether each of the following is an example of matter. Explain your answer in each case. PA C

- **a)** a brick
- **b)** sunlight
- **c)** the sound of a train
- **d)** air
- **e)** the colour red
- **f)** a text message

2. Classify each of the following as an element, a compound, or a mixture. PA C

- **a)** ocean water
- **b)** gold
- **c)** carbon dioxide
- **d)** a pencil

3. List at least two physical properties of each of the following pure substances. PA C

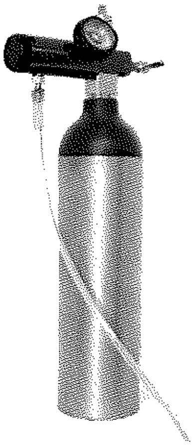
- **a)** oxygen
- **b)** copper
- **c)** carbon (diamond)
- **d)** carbon (coal)

4. When you cook food, its appearance and taste changes. Why does this indicate a chemical reaction is occurring? PA E C

5. What is each of these safety icons telling you? PA C

- **a)** Eye Safety
- **b)** Fire Safety
- **c)** Chemical Safety
- **d)** Disposal Alert

Connecting Ideas



6. Which WHMIS 2015 symbols would you expect to see on a cylinder of oxygen like the one shown here? Explain your answer. (Refer to Safety in Your Science Classroom on pages xiv–xvii.) AI

7. You are about to carry out an investigation involving a laboratory burner. AI

- **a)** Which safety icons would you expect to see in the instructions?
- **b)** What precautions would you take?

Making New Connections

8. Physical and chemical properties define both the uses and hazards associated with materials. PA E AI

- **a)** What does the chemical property of combustibility refer to?
- **b)** List three combustible materials.
- **c)** List three materials that are not combustible.
- **c)** List one application in which a combustible material is needed.
- **d)** List one application in which a material that is not combustible is needed.

9. Early chemists would taste the substances they were working with as a way to identify and describe them. PA E AI C

- **a)** Would you characterize taste as a physical or chemical property? Explain.
- **b)** Why is it essential not to eat or drink anything, even chewing gum, when working in the laboratory?

INVESTIGATION

2-A

STRUCTURED INQUIRY

Safely Observing a Chemical Reaction

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

- 1 mol/L hydrochloric acid can cause burns. Inform your teacher immediately of any spills. If any hydrochloric acid contacts your skin, flush the area with cold water for 15 minutes.

What You Need

- 2.5 g mossy zinc
- large test tube
- 50 mL beaker
- test tube clamp
- 5 mL 1 mol/L hydrochloric acid
- graduated cylinder
- 2 wooden splints
- matches
- ring stand

An important part of investigating matter involves observing what happens when different substances interact. In order to perform lab activities safely, including those that involve potential hazards such as splint tests and acids, it is essential to read and understand the procedure and safety precautions before you start.

One technique for identifying substances is to observe the effect on the substance of a flame or glowing ember. For example, when a flame is brought close to a source of hydrogen, the flame will ignite the hydrogen and produce a loud "pop" sound.

Question

How can a burning splint test be carried out safely to help you identify the element produced when zinc and hydrochloric acid are mixed?

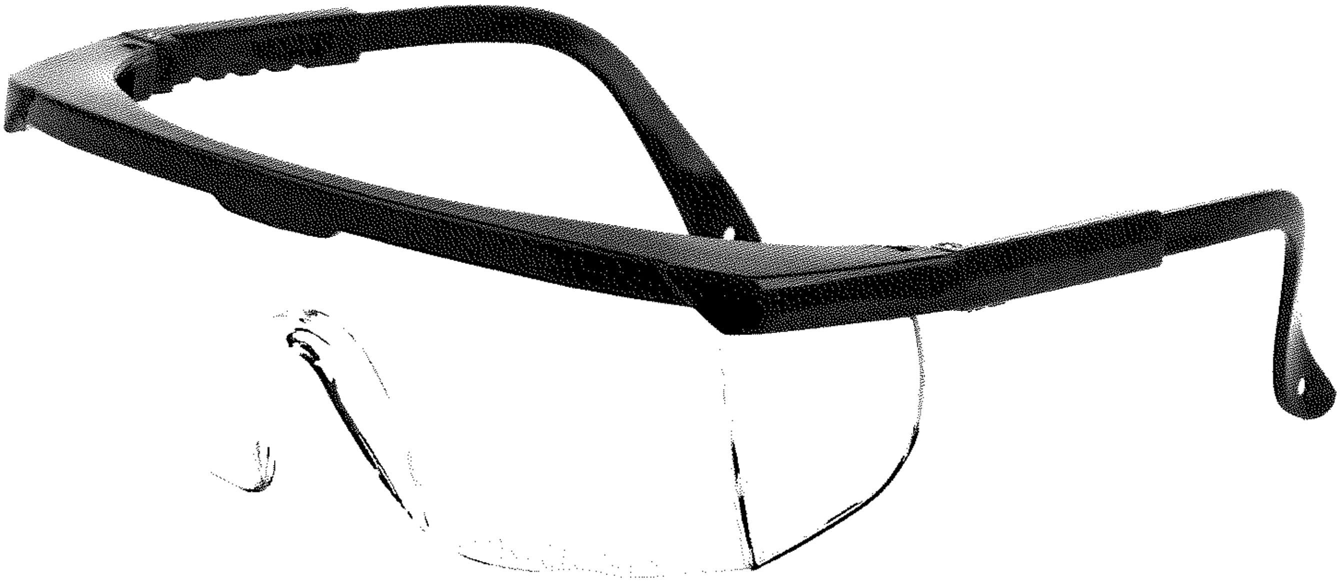
Procedure

1. Work in pairs. Place 2.5 g of mossy zinc in a large test tube.
2. Place the test tube in a clamp and attach the clamp to a ring stand so that the mouth of the test tube is angled up and away from you. Attach the clamp about halfway down the tube.
3. Measure 5 mL of 1 mol/L hydrochloric acid in a graduated cylinder. CAUTION: 1 mol/L hydrochloric acid could cause burns and produce hazardous fumes.
4. Light a wooden splint with a match. Dispose of the match as directed by your teacher. CAUTION: If you are using gloves, do not wear them for this step.
5. Place the burning splint at the mouth of the test tube, then move the burning splint to the mouth of the graduated cylinder. Record your observations.

6. Extinguish the flame and dispose of the splint as directed by your teacher.
7. Carefully pour the hydrochloric acid into the test tube.
8. Wait 2 minutes. Then invert the small beaker over the top of the test tube.
9. Wait 90 seconds. Then repeat step 4.
10. Remove the beaker from the test tube. Then place the burning splint at the mouth of the test tube. Record your observations.

Evaluate and Communicate

1. Describe any changes you observed during the test.
2. What caused the bubbles to form when you added the hydrochloric acid to the zinc metal?
3. Why did you test the zinc metal and hydrochloric acid with the burning splint before mixing them?
4. What happened to the burning splint in step 10? Compare this to what happened in step 5. How do you explain the differences in what you observed?



INVESTIGATION

2-B

STRUCTURED INQUIRY

Explore Safety Data Sheets

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- Safety in Your Science Classroom on pages xiv–xvii
- Internet access
- several copies of an SDS

Under the WHMIS 2015 system, each chemical has a Safety Data Sheet (SDS). The SDS lists information about the properties of the chemical, as well as instructions about how to handle and store it safely. For example, your teacher may use a concentrated hydrochloric acid, such as 37% hydrochloric acid, to make the solutions you use in class. Because it is reactive and corrosive, this acid has many safety precautions associated with its use. A portion of an SDS for concentrated hydrochloric acid is shown below.

A1 Chemical Company

A1 Chemical Company
Safety Data Sheet (SDS)
Version 5.4
Revision Date 05/17/2016
Print Date 07/20/2016

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	Hydrochloric acid 37%
Brand:	A1
Product use:	For research purposes
Supplier:	A1 Chemical Company
Manufacturer:	Acme Chemical Manufacturer
Telephone:	(555) 555-5555

2. HAZARDS IDENTIFICATION

Emergency Overview

WHMIS Classification
E Corrosive Material Corrosive

GHS Classification
Corrosive to metals (Category 1)
Skin corrosion (Category 1B)
Serious eye damage (Category 1)
Specific target organ toxicity – single exposure (Category 3), Respiratory system

GHS Label elements, including precautionary statements

Pictogram:

Signal word: Danger

Question

What is an SDS and how is it meant to be interpreted and used?

Procedure

1. Work in small groups. Each group will be given several copies of the SDS of a particular hazardous material. (If possible, your teacher will also provide a sample of the material for your reference.)
2. Read the procedure and divide up tasks among group members.
3. Research and answer the following questions about SDSs in general.
   - What are the purposes of an SDS?
   - What types of materials are required to have an SDS?
   - How is the information on an SDS categorized?
4. Research and answer the following questions about your SDS.
   - What is the name of your material?
   - Where and how is the material used?
   - What are the chemical and physical properties of your material?
   - What first-aid measures are recommended if one of the following occurs:
     - inhalation
     - skin contact
     - eye contact
     - ingestion
   - What precautions are listed for safe handling and storage?
5. Each member of the group must come up with at least one additional question about your assigned material or about SDSs in general that arose from the research. Do additional research to answer your questions.

Process and Analyze

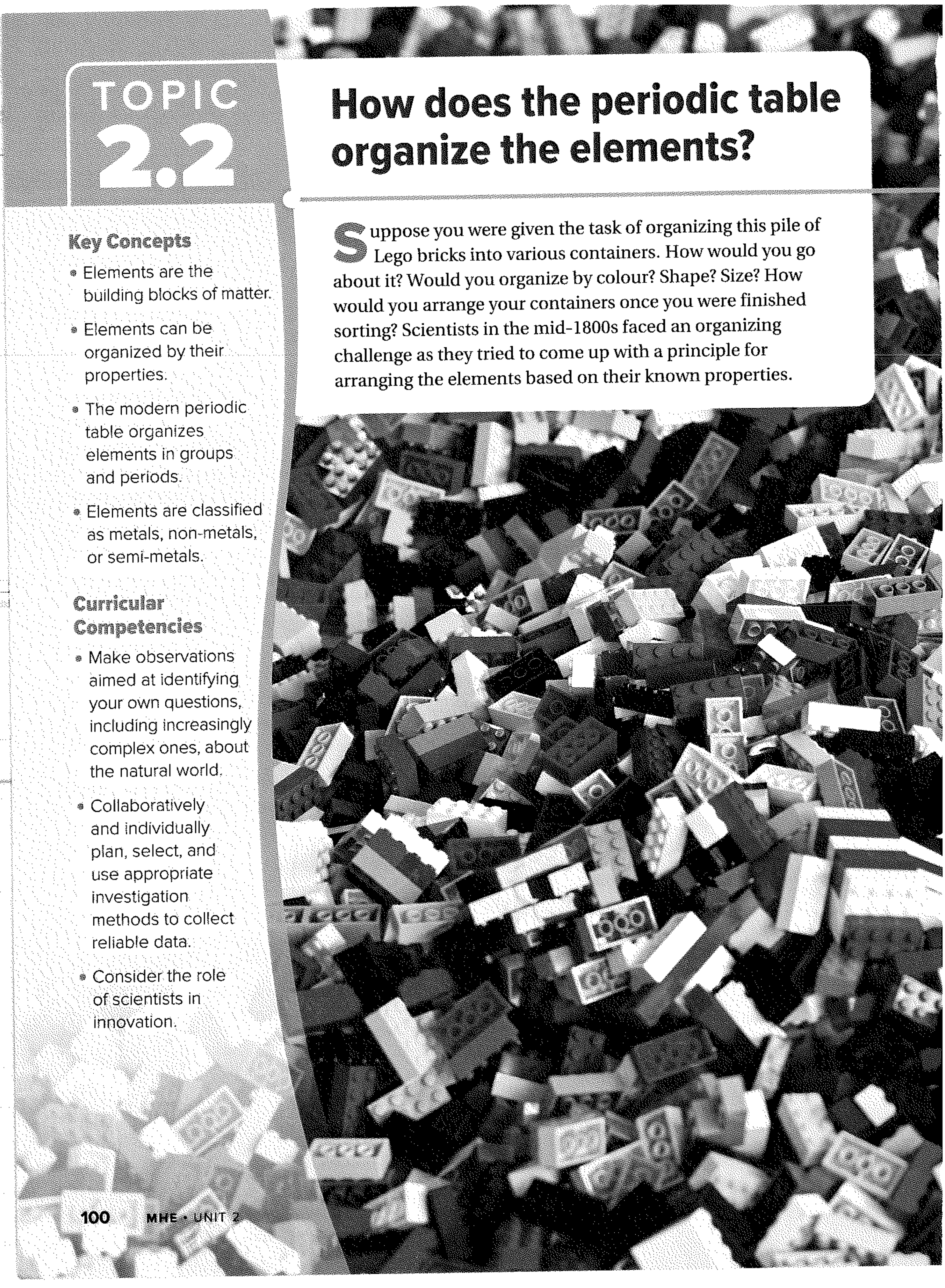
1. Within your group, share the results of your research. How do the chemical and physical properties of your material affect the safety measures listed on the SDS?
2. Which sections on the SDS are most relevant to you as a student in a high school science classroom?

Communicate

3. Give each member of your group a number. For a group of five, for example, give each person a unique number from one to five. Have all the like numbers in the classroom gather in groups. Be sure there is one person from each of the original groups in each new group.
4. In the new groups, take turns sharing what you learned about your assigned material and its SDS.
5. From a First Peoples perspective, safe interactions with the natural world may be seen as part of our reciprocal relationships with the universe. How does understanding and following safety procedures show respect for the interconnectedness of life?

TOPIC 2.2

How does the periodic table organize the elements?



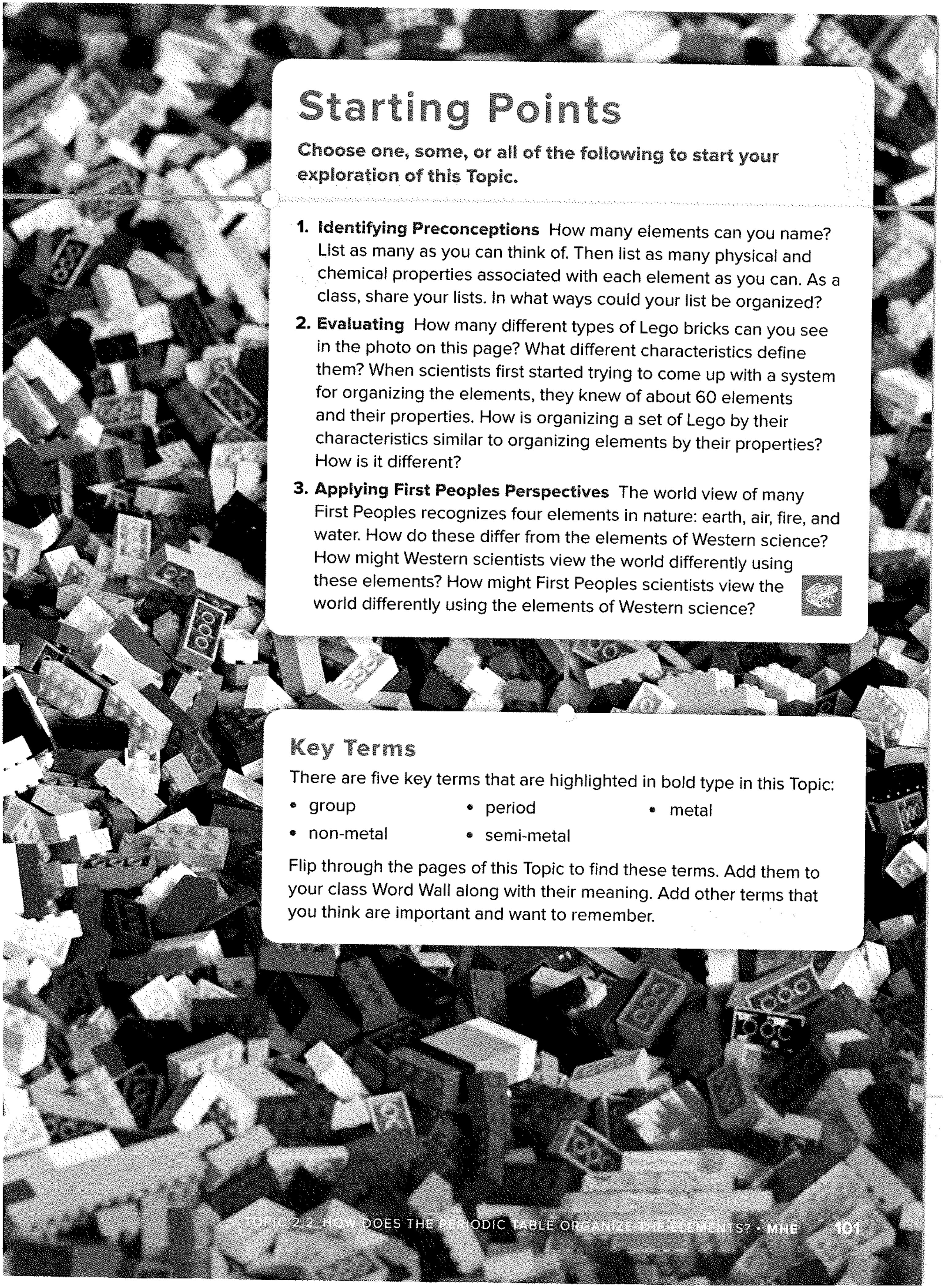
Suppose you were given the task of organizing this pile of Lego bricks into various containers. How would you go about it? Would you organize by colour? Shape? Size? How would you arrange your containers once you were finished sorting? Scientists in the mid-1800s faced an organizing challenge as they tried to come up with a principle for arranging the elements based on their known properties.

Key Concepts

- Elements are the building blocks of matter.
- Elements can be organized by their properties.
- The modern periodic table organizes elements in groups and periods.
- Elements are classified as metals, non-metals, or semi-metals.

Curricular Competencies

- Make observations aimed at identifying your own questions, including increasingly complex ones, about the natural world.
- Collaboratively and individually plan, select, and use appropriate investigation methods to collect reliable data.
- Consider the role of scientists in innovation.



Starting Points

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

1. **Identifying Preconceptions** How many elements can you name? List as many as you can think of. Then list as many physical and chemical properties associated with each element as you can. As a class, share your lists. In what ways could your list be organized?
2. **Evaluating** How many different types of Lego bricks can you see in the photo on this page? What different characteristics define them? When scientists first started trying to come up with a system for organizing the elements, they knew of about 60 elements and their properties. How is organizing a set of Lego by their characteristics similar to organizing elements by their properties? How is it different?
3. **Applying First Peoples Perspectives** The world view of many First Peoples recognizes four elements in nature: earth, air, fire, and water. How do these differ from the elements of Western science? How might Western scientists view the world differently using these elements? How might First Peoples scientists view the world differently using the elements of Western science?

Key Terms

There are five key terms that are highlighted in bold type in this Topic:

- group
- period
- metal
- non-metal
- semi-metal

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

Elements are the building blocks of matter.

Activity

Elements on Brick World

What if you lived in an alternate reality in which the building blocks of matter are Lego bricks, not atoms? Work in groups. Your teacher will give you a set of bricks. Use your set to do the following:

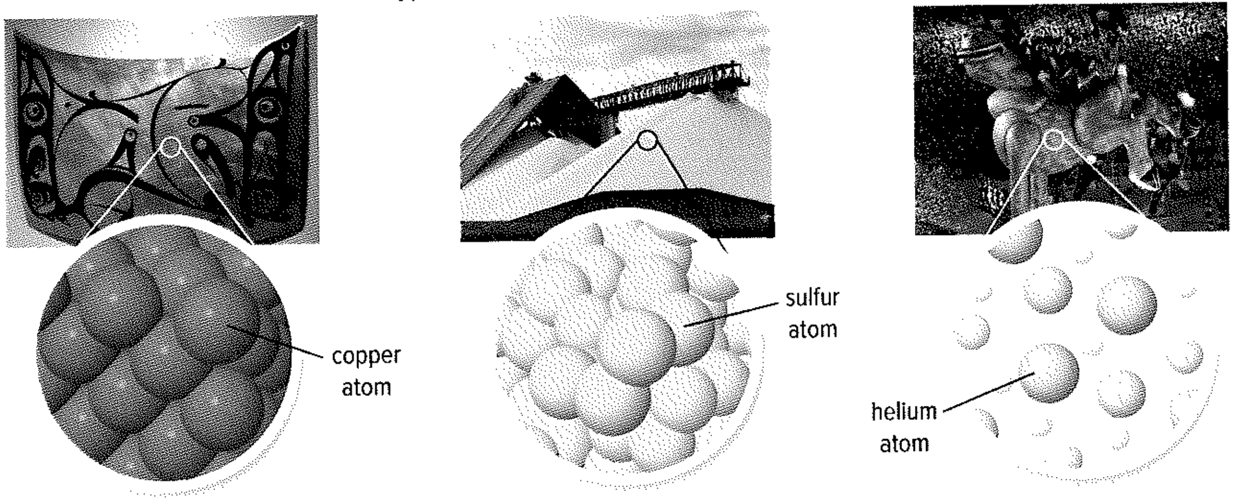
- Make sketches of each "element" and give them names.
- Make models of two different "compounds" using your brick elements.
- Make a model of a mixture that contains two or more brick compounds.

When you are finished, do a gallery walk to see the work of your classmates. What do you notice about the variety of brick elements, compounds, and mixtures?

Connect to Investigation 2C on page 118

Matter can take many different forms, but all forms of matter can be broken down into a fairly small number of basic building blocks—the elements. On Earth, about 90 elements occur naturally. Carbon, silver, and oxygen are examples of naturally occurring elements. There are also a number of elements that do not exist naturally but have been synthesized in laboratories. Three examples of elements with very different properties are shown in **Figure 2.6**.

Figure 2.6 Like all elements, copper, sulfur, and helium are each made up of one type of atom. They cannot be broken down further into different substances.



Copper (Cu) is shiny and malleable. This means it can be hammered into thin sheets such as the copper leaf used on this car hood by B.C. artist Michael Nicoll Yahgulanaas. This piece is part of a series called *Coppers from the Hood*.

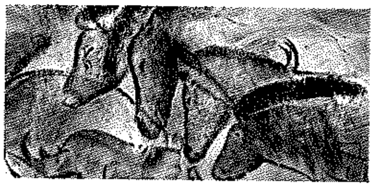
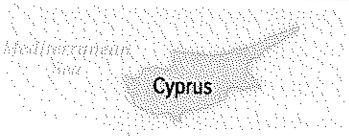
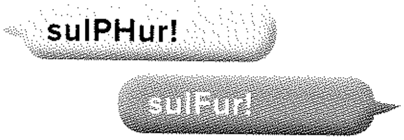
Sulfur (S) is a powdery, bright yellow solid. The piles shown here in Vancouver harbour are awaiting export overseas. Sulfur is used mainly to make sulfuric acid. Sulfuric acid is used to make many industrial products such as fertilizers, detergents, batteries, and medicines.

This giant floating moose was used in the closing ceremonies of the Vancouver 2010 Winter Olympics. To make it float, it was filled with helium (He), which is a colourless, odourless gas that is less dense than air.

Element Names and Symbols

Each element has a unique chemical name and symbol. The chemical symbol is one or two letters. (Synthetic elements that have not yet been named are given placeholder names and three-letter symbols.) The first letter is always capitalized, and the remaining letter or letters, if any, are always lowercase. The names and symbols of the elements are accepted and used by all scientists worldwide in order to standardize the communication of chemical information. Many element names come from an ancient language called Latin. Others are named for countries or continents (polonium, americium) or to honour scientists of note (bohrium, rutherfordium). The symbols and names of some elements are shown in Table 2.2.

Table 2.2 **Symbols and Names of Selected Elements**

Name of Element	Element Symbol	Origin of Symbol or Name
carbon	C	*Carbo* = Latin for coal and charcoal. Carbon in the form of soot and charcoal has been known to humans for many thousands of years. 
copper	Cu	*Cuprum* = Latin for cyprium, meaning metal of Cyprus, an island country near Greece. The ancient Romans obtained much of their copper from mines on Cyprus. 
francium	Fr	*France* = Marguerite Perey discovered this element in France in 1939. 
lead	Pb	*Plumbum* = Latin for lead. This element's name has the same root as "plumbing" because the ancient Romans used lead in their plumbing systems. Unfortunately, lead is toxic and their pipes poisoned their water. 
sulfur	S	*Sulphuium* = Latin for sulfur. In Canada, the United States, and Great Britain, there has been some switching back and forth of the name of this element from sulfur to sulphur. The spelling "sulfur" is now considered standard. 

Before you leave this page . . .

1. How many elements occur naturally on Earth?

2. What distinguishes one element from another?

CONCEPT 2

Elements can be organized by their properties.

Activity

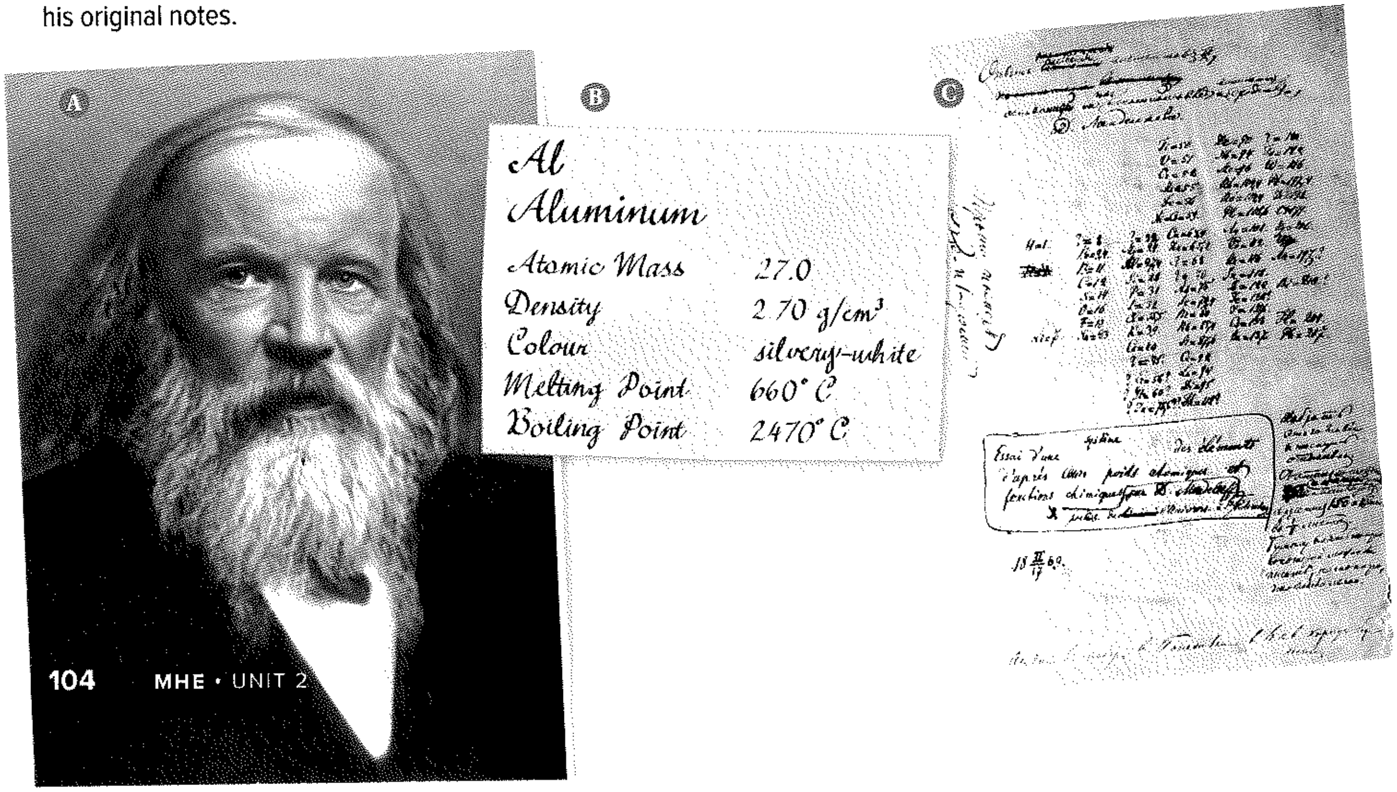
Element Cards

Work in groups. Your teacher will give your group a set of cards. On each card is an element and information about its properties. Your challenge is to arrange the cards in rows and columns in a way that makes sense to you and your team members. When you are finished, explain your reasoning to the rest of the class.

In the mid-1800s, scientists had identified nearly 60 elements, and nobody knew how many more there might be. Scientists needed a classification system that would organize their observations. They were already grouping elements into "families" based on similar properties, but many family relationships were not obvious. What else could a classification system be based on?

By the 1860s, some scientists were trying to sort the known elements according to atomic mass. *Atomic mass* is the average mass of an atom of an element. Among them was a Russian chemist named Dmitri Mendeleev (1834–1907).

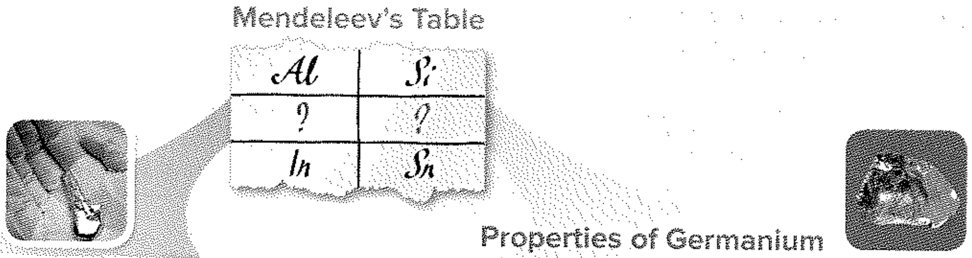
To help him experiment with different ways to organize the elements, Mendeleev made a card for each one. On each of these cards, he put data similar to the data you see in Figure 2.7. He shuffled and reordered the cards, playing a game of "chemical solitaire" to try to make sense of the repeating patterns of properties.



Al
Aluminum

Atomic Mass	27.0
Density	2.70 g/cm³
Colour	silvery-white
Melting Point	660° C
Boiling Point	2470° C

Figure 2.7 Ⓐ Dmitri Mendeleev was a Russian teacher and chemist. He was the youngest of 17 children. Ⓑ Mendeleev wrote the properties of elements on cards like this one so he could rearrange them and compare properties. Ⓒ These are some of his original notes.



Properties of Gallium

Property	Mendeleev's Prediction	Actual Data
Atomic mass	68	69.72
Density (g/cm^3)	6.0	5.904
Melting point (°C)	low	29.78

Properties of Germanium

Property	Mendeleev's Prediction	Actual Data
Atomic mass	72	72.61
Density (g/cm^3)	5.5	5.32
Melting point (°C)	high	947

Figure 2.8 The gaps in Mendeleev's table predicted the existence of yet-to-be-discovered elements. Mendeleev used the properties of other elements in the same families to predict the properties of these elements.

The Predictive Power of Mendeleev's Table

After several months of "chemical solitaire," Mendeleev arrived at an arrangement that organized the elements according to their properties. Like other scientists before him, Mendeleev knew that the properties of elements tended to repeat over regular intervals. Like other scientists, he was ordering the elements by increasing atomic mass. However, Mendeleev realized that he needed to leave gaps in his arrangement—blank spaces predicting the existence of elements not yet found or even suspected by other chemists.

Using these gaps, he was able to accurately predict properties of elements that were not yet known but would be discovered later, including scandium, gallium, and germanium. How did Mendeleev's table make it possible for him to predict the properties of undiscovered elements? Mendeleev noted which families had spaces. He inferred that the missing elements would have properties similar to those of other members of their family. Gallium and germanium, shown in Figure 2.8, are famous for having been discovered after Mendeleev predicted their existence and physical properties.

Extending the Connections

Other Contributors to the Periodic Table

Research to find out how other scientists contributed to the development of the periodic table. Choose one of the following scientists: John Dalton, Alexandre Béguyer de Chancourtois, John Newlands, Julius Lothar Meyer, or Henry Moseley.

Before you leave this page . . .

1. Why did Mendeleev leave gaps in his periodic table?
2. How was Mendeleev able to predict the properties of gallium and germanium?

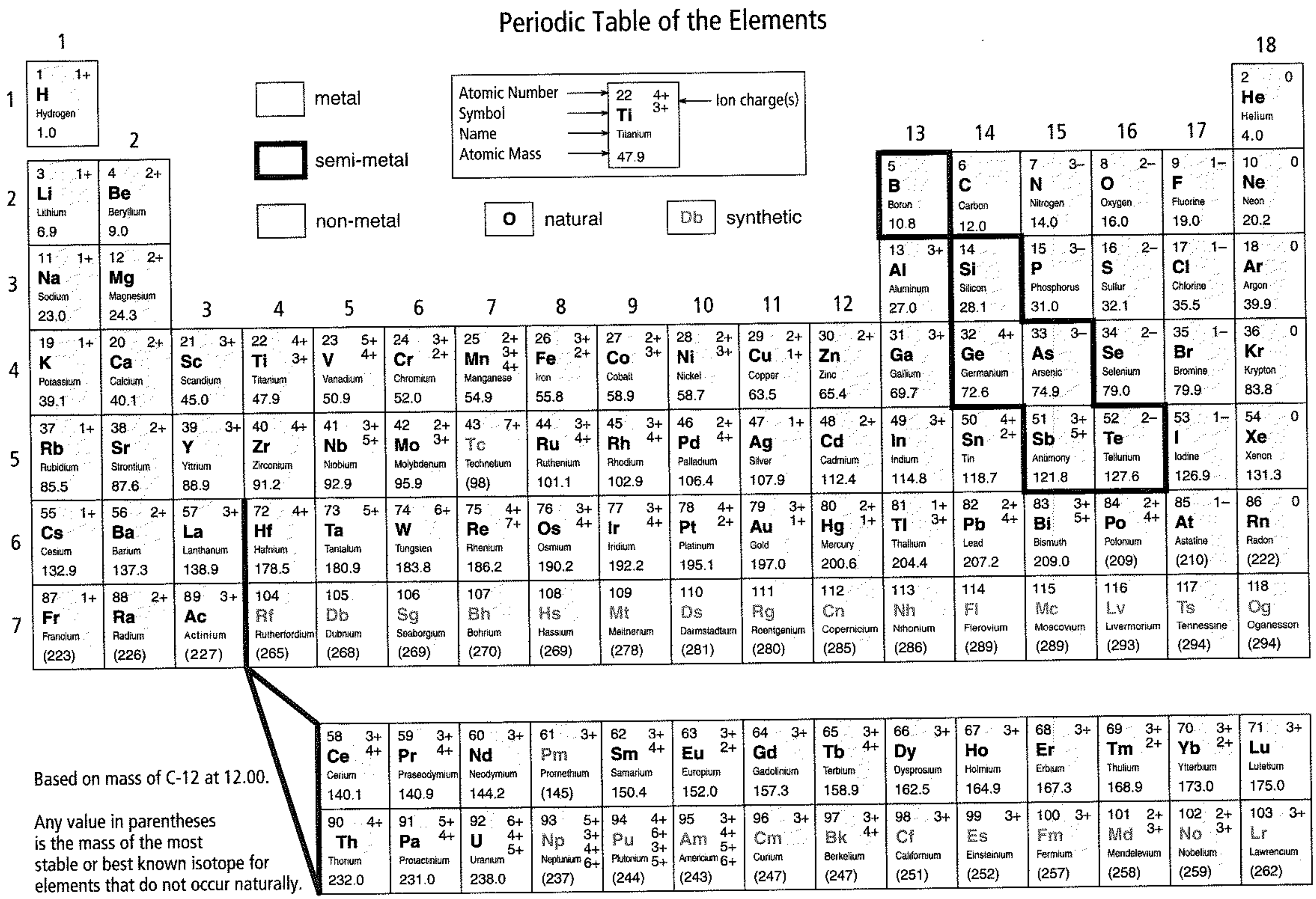


Figure 2.9 The modern periodic table enables the presentation of a wealth of information about each element on a single page.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1+ **H** Hydrogen 1.0																	2 0 **He** Helium 4.0
2	3 1+ **Li** Lithium 6.9	4 2+ **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 3– **N** Nitrogen 14.0	8 2– **O** Oxygen 16.0	9 1– **F** Fluorine 19.0	10 0 **Ne** Neon 20.2
3	11 1+ **Na** Sodium 23.0	12 2+ **Mg** Magnesium 24.3											13 3+ **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 3– **P** Phosphorus 31.0	16 2– **S** Sulfur 32.1	17 1– **Cl** Chlorine 35.5	18 0 **Ar** Argon 39.9
4	19 1+ **K** Potassium 39.1	20 2+ **Ca** Calcium 40.1	21 3+ **Sc** Scandium 45.0	22 4+ 3+ **Ti** Titanium 47.9	23 5+ 4+ **V** Vanadium 50.9	24 3+ 2+ **Cr** Chromium 52.0	25 2+ 3+ 4+ **Mn** Manganese 54.9	26 3+ 2+ **Fe** Iron 55.8	27 2+ 3+ **Co** Cobalt 58.9	28 2+ 3+ **Ni** Nickel 58.7	29 2+ 1+ **Cu** Copper 63.5	30 2+ **Zn** Zinc 65.4	31 3+ **Ga** Gallium 69.7	32 4+ **Ge** Germanium 72.6	33 3– **As** Arsenic 74.9	34 2– **Se** Selenium 79.0	35 1– **Br** Bromine 79.9	36 0 **Kr** Krypton 83.8
5	37 1+ **Rb** Rubidium 85.5	38 2+ **Sr** Strontium 87.6	39 3+ **Y** Yttrium 88.9	40 4+ **Zr** Zirconium 91.2	41 3+ 5+ **Nb** Niobium 92.9	42 2+ 3+ **Mo** Molybdenum 95.9	43 7+ Tc Technetium (98)	44 3+ 4+ **Ru** Ruthenium 101.1	45 3+ 4+ **Rh** Rhodium 102.9	46 2+ 4+ **Pd** Palladium 106.4	47 1+ **Ag** Silver 107.9	48 2+ **Cd** Cadmium 112.4	49 3+ **In** Indium 114.8	50 4+ 2+ **Sn** Tin 118.7	51 3+ 5+ **Sb** Antimony 121.8	52 2– **Te** Tellurium 127.6	53 1– **I** Iodine 126.9	54 0 **Xe** Xenon 131.3
6	55 1+ **Cs** Cesium 132.9	56 2+ **Ba** Barium 137.3	57 3+ **La** Lanthanum 138.9	72 4+ **Hf** Hafnium 178.5	73 5+ **Ta** Tantalum 180.9	74 6+ **W** Tungsten 183.8	75 4+ 7+ **Re** Rhenium 186.2	76 3+ 4+ **Os** Osmium 190.2	77 3+ 4+ **Ir** Iridium 192.2	78 4+ 2+ **Pt** Platinum 195.1	79 3+ 1+ **Au** Gold 197.0	80 2+ 1+ **Hg** Mercury 200.6	81 1+ 3+ **Tl** Thallium 204.4	82 2+ 4+ **Pb** Lead 207.2	83 3+ 5+ **Bi** Bismuth 209.0	84 2+ 4+ **Po** Polonium (209)	85 1– **At** Astatine (210)	86 0 **Rn** Radon (222)
7	87 1+ **Fr** Francium (223)	88 2+ **Ra** Radium (226)	89 3+ **Ac** Actinium (227)	104 Rf Rutherfordium (265)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (269)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (280)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (289)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)

58 3+ 4+ **Ce** Cerium 140.1	59 3+ 4+ **Pr** Praseodymium 140.9	60 3+ **Nd** Neodymium 144.2	61 3+ Pm Promethium (145)	62 3+ 4+ **Sm** Samarium 150.4	63 3+ 2+ **Eu** Europium 152.0	64 3+ **Gd** Gadolinium 157.3	65 3+ 4+ **Tb** Terbium 158.9	66 3+ **Dy** Dysprosium 162.5	67 3+ **Ho** Holmium 164.9	68 3+ **Er** Erbium 167.3	69 3+ 2+ **Tm** Thulium 168.9	70 3+ 2+ **Yb** Ytterbium 173.0	71 3+ **Lu** Lutetium 175.0
90 4+ **Th** Thorium 232.0	91 5+ 4+ **Pa** Protactinium 231.0	92 6+ 4+ 5+ **U** Uranium 238.0	93 5+ 3+ 4+ 6+ Np Neptunium (237)	94 4+ 6+ 3+ 5+ Pu Plutonium (244)	95 3+ 4+ 5+ 6+ Am Americium (243)	96 3+ Cm Curium (247)	97 3+ 4+ Bk Berkelium (247)	98 3+ Cf Californium (251)	99 3+ Es Einsteinium (252)	100 3+ Fm Fermium (257)	101 2+ 3+ Md Mendelevium (258)	102 2+ 3+ No Nobelium (259)	103 3+ Lr Lawrencium (262)

Based on mass of C-12 at 12.00.

Any value in parentheses is the mass of the most stable or best known isotope for elements that do not occur naturally.

CONCEPT 3

The modern periodic table organizes elements in groups and periods.

Activity

Observing the Elements

Turn the page and take a look at the pictorial periodic table shown in Figure 2.11. What patterns do you see among elements of the same group (vertical column) and in the same period (horizontal row)?

Today's periodic table, shown in Figure 2.9 on the left, is strikingly similar to Mendeleev's. The principle behind the order of the elements, though, is different. For the most part, Mendeleev ordered the elements in his table based on increasing atomic mass. But this principle did not work perfectly: he had to place a few elements out of order so that they would appear in the group they seemed to belong to, based on their properties. Later, a scientist called Henry Moseley developed a way to determine the number of positive charges in an atom, which told him the number of protons in the atom. This number is now known as an element's *atomic number*. When arranged according to increasing atomic number, the elements all fit perfectly in the table, with no reordering needed.

Connect to Investigation 2D on page 120

Meet the Modern Periodic Table

The modern periodic table consists of boxes arranged in vertical columns and horizontal rows by increasing atomic number. The box for oxygen is shown in Figure 2.10. Mendeleev called the vertical columns of the periodic table families. Today they are often called **groups** and are numbered 1 through 18. The horizontal rows of the table are called **periods**. Beginning with hydrogen in the first period, there are a total of 7 periods.

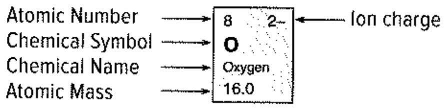


Figure 2.10 A typical box from the periodic table tells you the element's name, symbol, atomic number, and atomic mass. The symbol's font tells you the element's state.

group a vertical column of elements in the periodic table; also called a *family*

period a horizontal row of elements in the periodic table

Before you leave this page . . .

1. What was Moseley's contribution to the periodic table and what problem did it resolve?

2. Give the symbol and atomic number of each of the following elements:

a) manganese

b) magnesium

c) arsenic

d) astatine

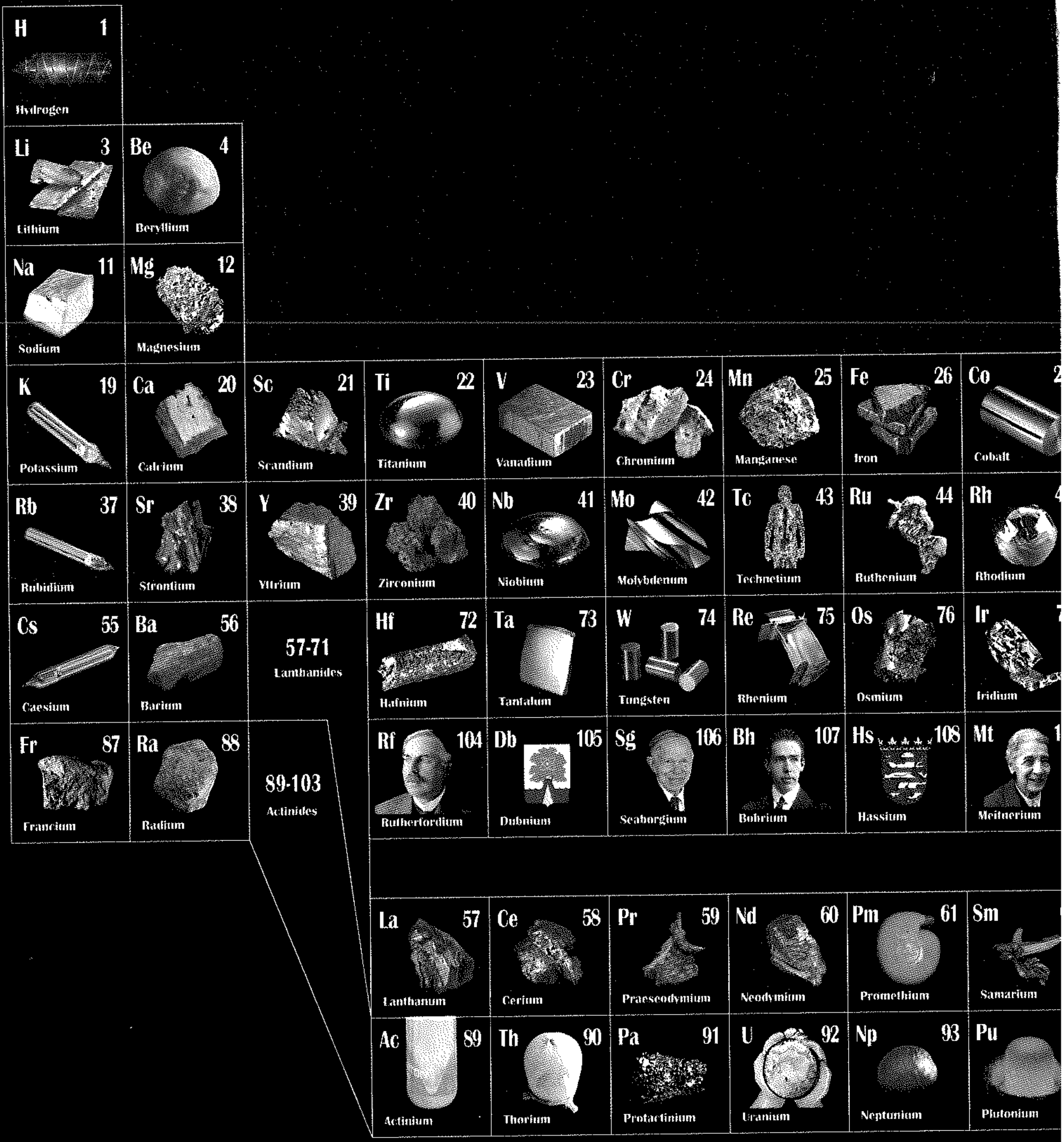
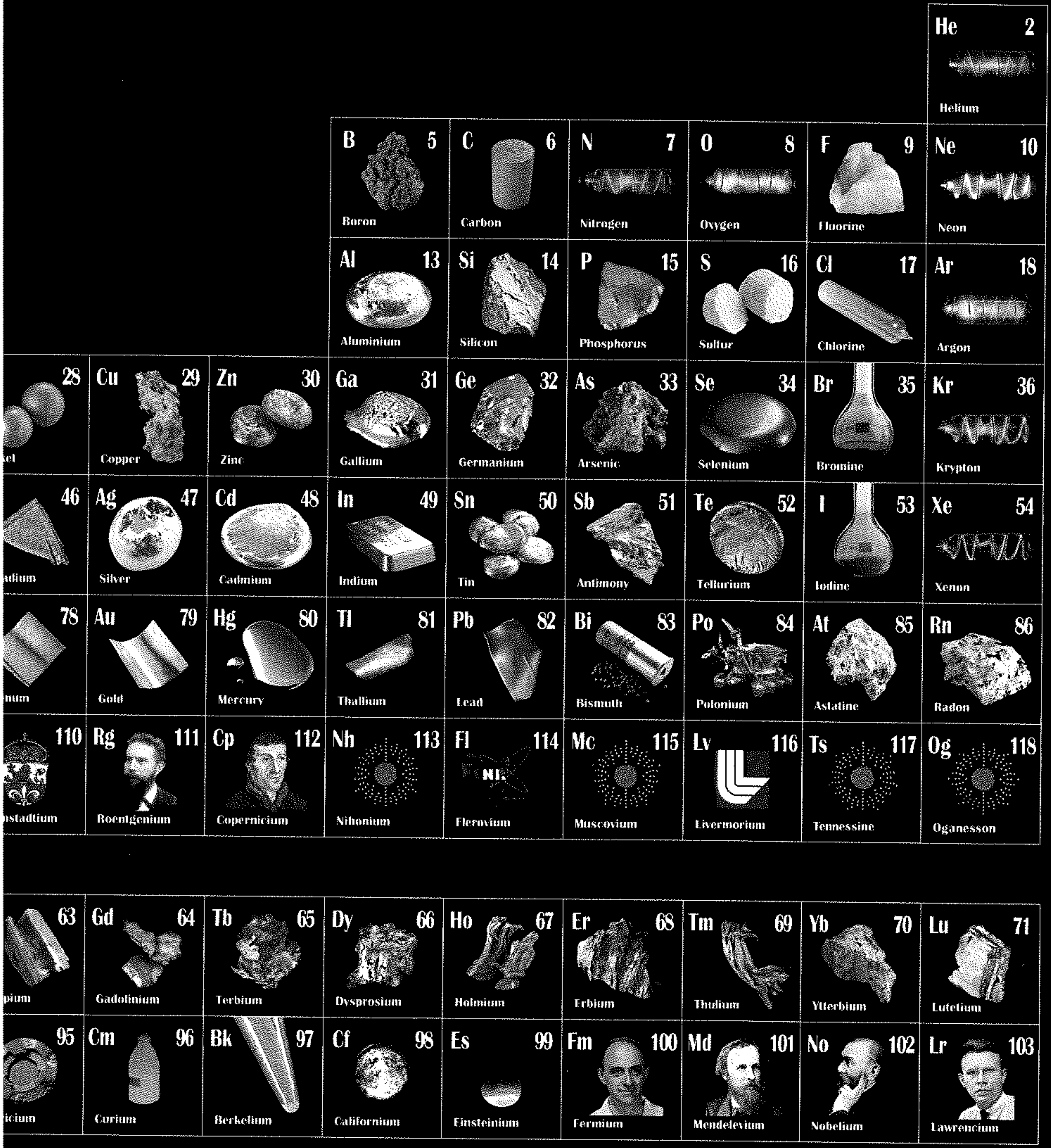


Figure 2.11 This version of the periodic table includes photos of many of the elements.
What property do most of the elements have in common?



								He 2 Helium
			B 5 Boron	C 6 Carbon	N 7 Nitrogen	O 8 Oxygen	F 9 Fluorine	Ne 10 Neon
			Al 13 Aluminium	Si 14 Silicon	P 15 Phosphorus	S 16 Sulfur	Cl 17 Chlorine	Ar 18 Argon
28 el	Cu 29 Copper	Zn 30 Zinc	Ga 31 Gallium	Ge 32 Germanium	As 33 Arsenic	Se 34 Selenium	Br 35 Bromine	Kr 36 Krypton
46 dium	Ag 47 Silver	Cd 48 Cadmium	In 49 Indium	Sn 50 Tin	Sb 51 Antimony	Te 52 Tellurium	I 53 Iodine	Xe 54 Xenon
78 num	Au 79 Gold	Hg 80 Mercury	Tl 81 Thallium	Pb 82 Lead	Bi 83 Bismuth	Po 84 Polonium	At 85 Astatine	Rn 86 Radon
110 nstadtium	Rg 111 Roentgenium	Cp 112 Copernicium	Nh 113 Nihonium	Fl 114 Flerovium	Mc 115 Muscovium	Lv 116 Livermorium	Ts 117 Tennessine	Og 118 Oganesson

63 pium	Gd 64 Gadolinium	Tb 65 Terbium	Dy 66 Dysprosium	Ho 67 Holmium	Er 68 Erbium	Tm 69 Thulium	Yb 70 Ytterbium	Lu 71 Lutetium
95 icium	Cm 96 Curium	Bk 97 Berkelium	Cf 98 Californium	Es 99 Einsteinium	Fm 100 Fermium	Md 101 Mendelevium	No 102 Nobelium	Lr 103 Lawrencium

CONCEPT 4

Elements are classified as metals, non-metals, or semi-metals.

Activity

Comparing Conductivity

One property that is used to describe and classify matter is electrical conductivity. Materials that are electrical conductors allow electric current to move through them. Your teacher will give you an electrical conductivity meter and items to test. Make a table like the one below, and predict whether each item will conduct electric current. Then test your prediction. What do you notice about the materials that conduct electric current?

Item	Prediction	Is it a conductor?

The boxes on the periodic table in Figure 2.9 are shaded to show the three broad categories of elements: metals (blue), non-metals (yellow), and semi-metals (green). These classifications are based on similarities in physical and chemical properties within each category. The elements of Groups 1, 2, and 13 to 18 are called *main-group elements* or *representative elements*. The elements in Groups 3 to 12 are called *transition elements*.

Metals

Most of the elements are metals. The **metals** are found on the left side of the zigzag line on the periodic table and are shaded in blue. Except for 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 thermal energy and electric current. They are also malleable and ductile, which means they can be beaten into sheets or drawn out into wires.

metal typically, an element that is hard, shiny, malleable, ductile, and that conducts electricity and heat; found to the left of the zigzag line on the periodic table

The two rows of metals shown at the bottom of the periodic table are called the *inner transition metals*. They are normally shown below the table to keep it compact. Figure 2.12 shows two important groups of metals: the *alkali metals*, found in Group 1, and *alkaline-earth metals*, found in Group 2. Notice that although hydrogen is shown as part of Group 1, it is not an alkali metal. Figure 2.13 explains why.

Activity

Predict Properties

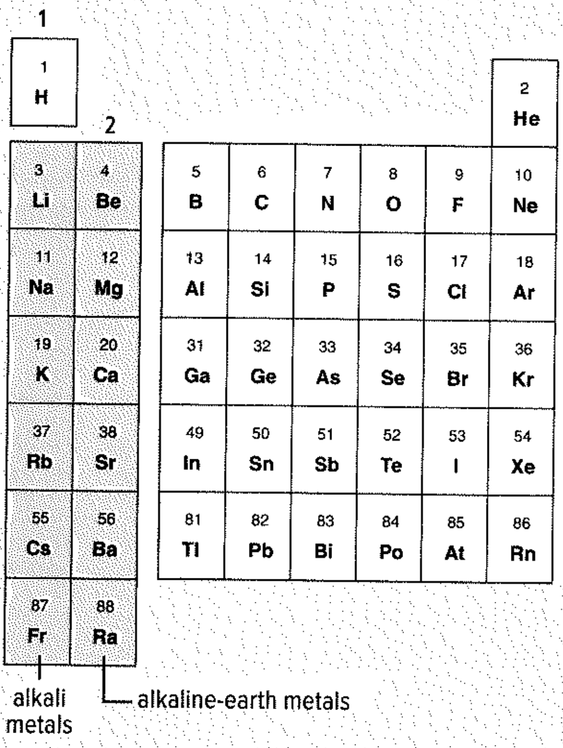
Francium is a rare, unstable alkali metal. It was discovered in 1939, but its existence was predicted by Mendeleev in the 1870s. Use data about the properties of other alkali metals to predict some of francium's properties.

Alkali Metals Data

Element	Melting Point (°C)	Boiling Point (°C)	Atomic radius (pm)
lithium	180.5	1342	152
sodium	97.8	883	186
potassium	63.4	759	227
rubidium	39.3	688	248
cesium	28.4	671	265
francium	?	?	?

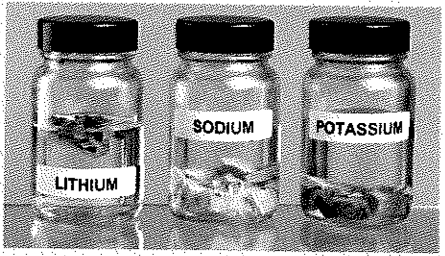
1. Come up with a way to clearly display the trends for each of the properties given in the table that will help you to predict a value for francium.
2. Predict whether francium is a solid, a liquid, or a gas at room temperature. How can you support your prediction?
3. Which of the following atomic radii is most likely to belong to francium: 252 pm, 270 pm, or 283 pm? Explain your prediction.

Figure 2.12 This periodic table has been cropped to show only the main-group elements. **What are some differences and similarities between the alkali metals and the alkaline-earth metals?**



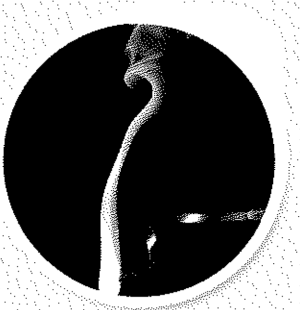
Alkali Metals

The elements of Group 1, except for hydrogen, are known as the alkali metals. They are shiny and soft—soft enough to be cut easily with a butter knife. Alkali metals are highly reactive with many substances, including water and oxygen. This reactivity is why pure alkali metals are stored in a non-reactive liquid such as kerosene or oil.



Alkaline-earth Metals

All of the elements of Group 2 are alkaline-earth metals. They are shiny and soft, but not as soft as the alkali metals. Alkaline-earth metals are also highly reactive, but not as reactive as the alkali metals. For example, magnesium does not need to be stored in a non-reactive liquid, but it burns easily in air when ignited, as shown here.



Non-metals

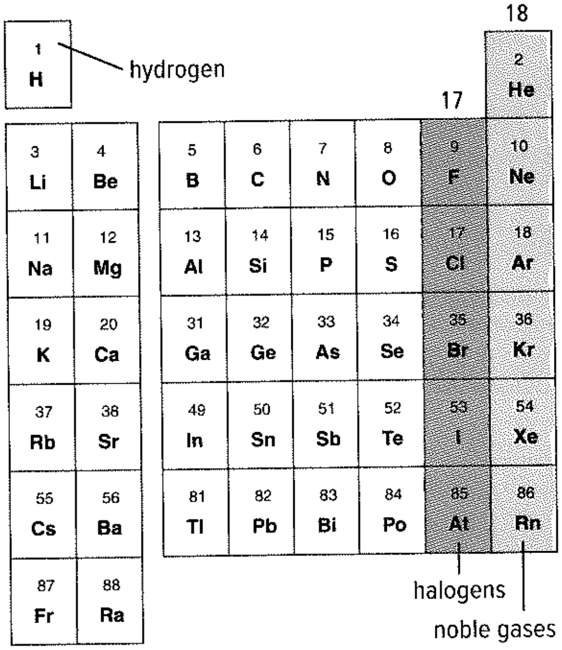
non-metal typically, an element that is not shiny, malleable, or ductile, and is a poor conductor of electric current and heat; found to the right of the zigzag line on the periodic table

The **non-metals** are found on the upper right side of the periodic table. Hydrogen, which is found in the upper left, is also a non-metal. In the periodic table in Figure 2.9, the nonmetals are shaded in yellow. Non-metals are elements that are generally gases or brittle, dull-looking solids. They are poor conductors of heat and electric current. Figure 2.13 shows hydrogen as well as two important groups of non-metals: the *halogens* and the *noble gases*.

Figure 2.13 Halogens, the Group 17 elements, are highly reactive. The defining characteristic of noble gases, the Group 18 elements, is that they are unreactive.

Hydrogen: A Special Case

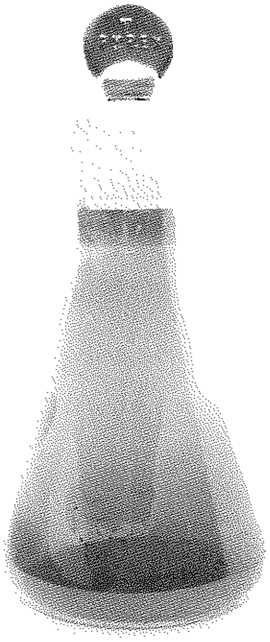
Hydrogen is usually placed on the left side of the periodic table. However, hydrogen is a non-metal, not a metal. The lightest element, hydrogen is a colourless, odourless, tasteless, and highly flammable gas. Hydrogen makes up over 90 percent of the atoms in the universe. On Earth, most hydrogen is found combined with oxygen as part of the compound water.



							18
1 H						17	2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra						

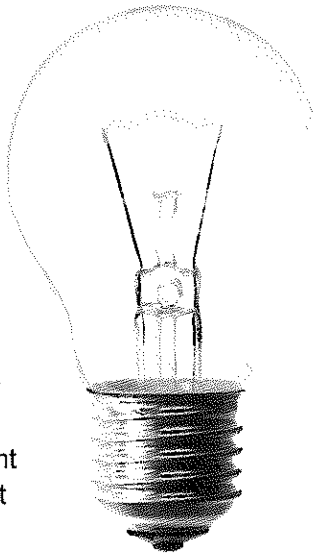
Halogens

The halogens are the elements of Group 17. These non-metals are highly reactive, which means they are usually found in nature as part of compounds. Bromine, shown here, is the only non-metal element that is a liquid at room temperature.



Noble Gases

The noble gases are the elements of Group 18. They are all odourless, colourless gases. They are the least reactive of all of the elements. Helium and neon never form compounds, and the other noble gases form compounds only with great difficulty. Incandescent light bulbs are filled with argon because the argon does not react with the tungsten filament in the bulb.



Semi-metals

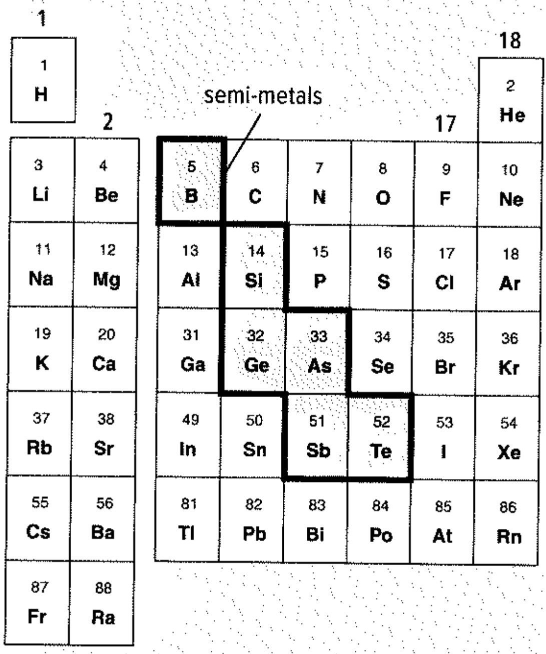
The elements in the green boxes in a staircase shape are called the **semi-metals** or *metalloids*. Semi-metals are the in-between elements—they have physical and chemical properties of both metals and non-metals. For example, like metals, they are shiny solids at room temperature. But semi-metals are brittle and not ductile like non-metals. They also tend to be poor conductors of heat and electric current. Figure 2.14 shows some important applications of semi-metals.

semi-metal an element that shares some properties with metals and some properties with non-metals

Extending the Connections

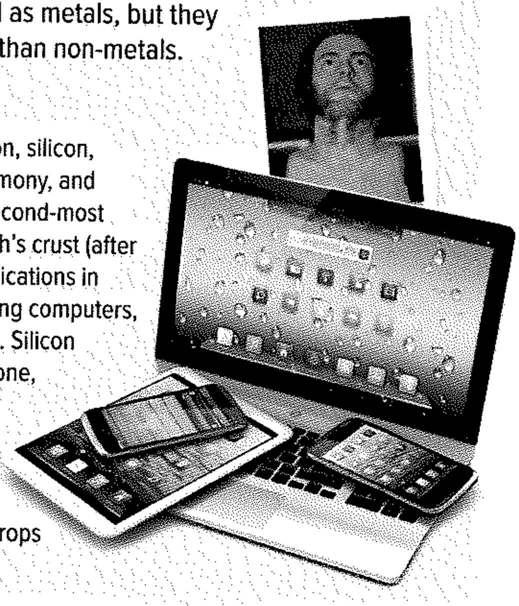
What makes silicon special?

Silicon is so important to the electronics industry that an area near San Francisco that has become a hub of this industry is nicknamed "silicon valley." What properties make silicon so important in the manufacture of electronics? Can other semi-metals be used in similar ways? Research to find out.



1	2					17	18
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra						

Figure 2.14 Semi-metals have some metallic properties and some non-metallic properties. Some of their properties are in-between. For example, semi-metals do not conduct electric current as well as metals, but they are better conductors than non-metals.



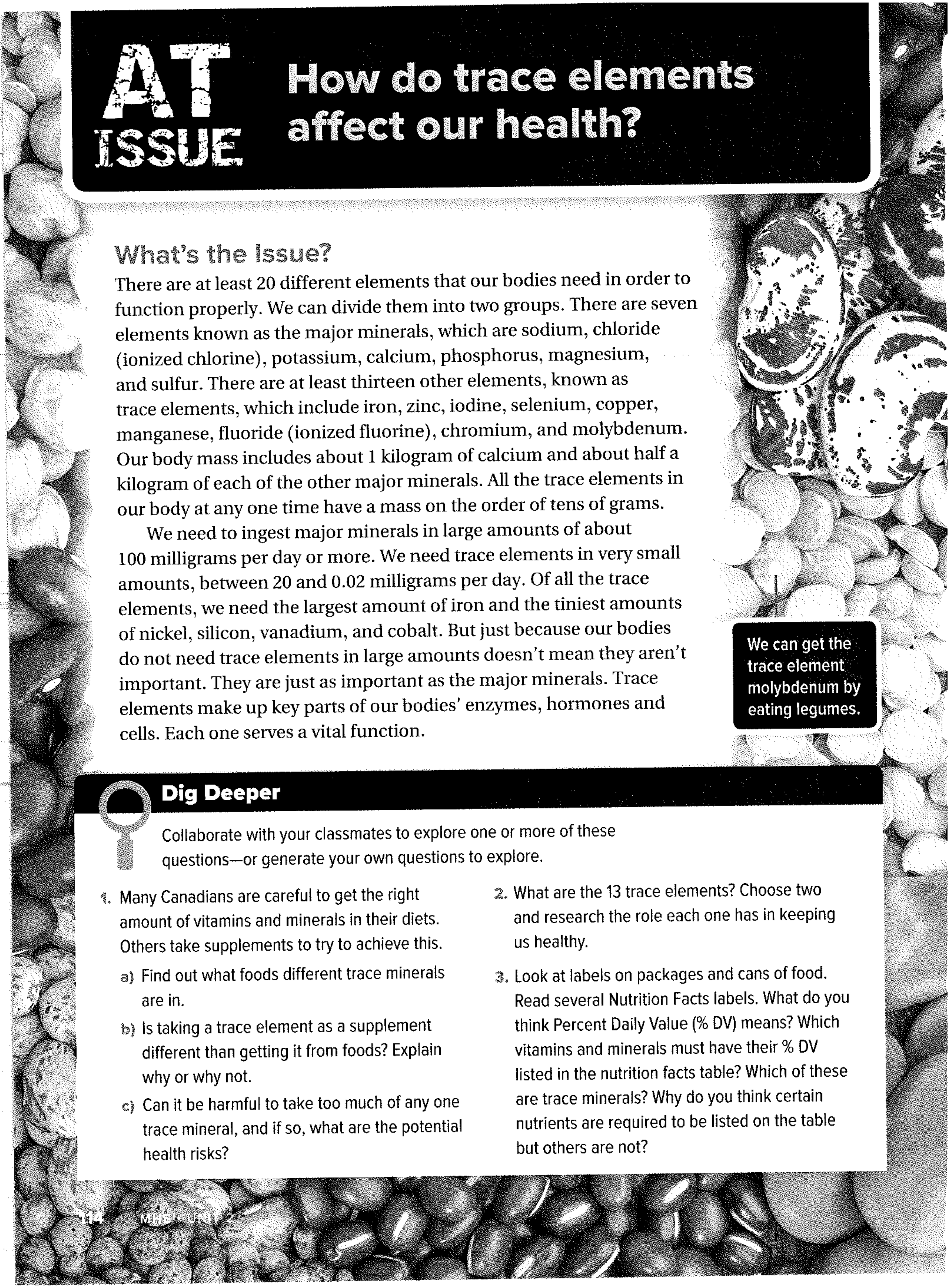
Semi-metals

The semi-metals are boron, silicon, germanium, arsenic, antimony, and tellurium. Silicon is the second-most abundant element in Earth's crust (after oxygen). It has many applications in electronic devices including computers, tablets, and smartphones. Silicon is also used to make silicone, which is part of a huge variety of applications, including car grease, cookware, satellite parts, contact lenses, and film props and prosthetics.

Before you leave this page . . .

1. Make a table to summarize the characteristic properties of metals, non-metals, and semi-metals.
2. What makes hydrogen an unusual element?
3. What characteristics define semi-metals?

AT ISSUE How do trace elements affect our health?



We can get the trace element molybdenum by eating legumes.

What's the Issue?

There are at least 20 different elements that our bodies need in order to function properly. We can divide them into two groups. There are seven elements known as the major minerals, which are sodium, chloride (ionized chlorine), potassium, calcium, phosphorus, magnesium, and sulfur. There are at least thirteen other elements, known as trace elements, which include iron, zinc, iodine, selenium, copper, manganese, fluoride (ionized fluorine), chromium, and molybdenum. Our body mass includes about 1 kilogram of calcium and about half a kilogram of each of the other major minerals. All the trace elements in our body at any one time have a mass on the order of tens of grams.

We need to ingest major minerals in large amounts of about 100 milligrams per day or more. We need trace elements in very small amounts, between 20 and 0.02 milligrams per day. Of all the trace elements, we need the largest amount of iron and the tiniest amounts of nickel, silicon, vanadium, and cobalt. But just because our bodies do not need trace elements in large amounts doesn't mean they aren't important. They are just as important as the major minerals. Trace elements make up key parts of our bodies' enzymes, hormones and cells. Each one serves a vital function.

Dig Deeper

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

1. Many Canadians are careful to get the right amount of vitamins and minerals in their diets. Others take supplements to try to achieve this.
   a) Find out what foods different trace minerals are in.
   b) Is taking a trace element as a supplement different than getting it from foods? Explain why or why not.
   c) Can it be harmful to take too much of any one trace mineral, and if so, what are the potential health risks?
2. What are the 13 trace elements? Choose two and research the role each one has in keeping us healthy.
3. Look at labels on packages and cans of food. Read several Nutrition Facts labels. What do you think Percent Daily Value (% DV) means? Which vitamins and minerals must have their % DV listed in the nutrition facts table? Which of these are trace minerals? Why do you think certain nutrients are required to be listed on the table but others are 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. How is the atomic number of an element related to the structure of an atom of that element? PA C

2. List five pieces of information that are recorded on a typical periodic table. PA

3. Compare and contrast the alkali metals and alkaline-earth metals. PA

4. Classify each of the following elements as a metal, a non-metal, or a semi-metal.

- **a)** silicon, Si
- **b)** antimony, Sb
- **c)** krypton, Kr
- **d)** mercury, Hg
- **e)** nitrogen, N
- **f)** cesium, Cs
- **g)** lead, Pb

5. Make a Venn diagram to compare physical properties of metals and non-metals. PA C

6. Which group on the periodic table has elements in all three states of matter? Give examples. PA C

7. Describe where on the periodic table you find the following: PA C

- **a)** metals
- **b)** non-metals
- **c)** semi-metals

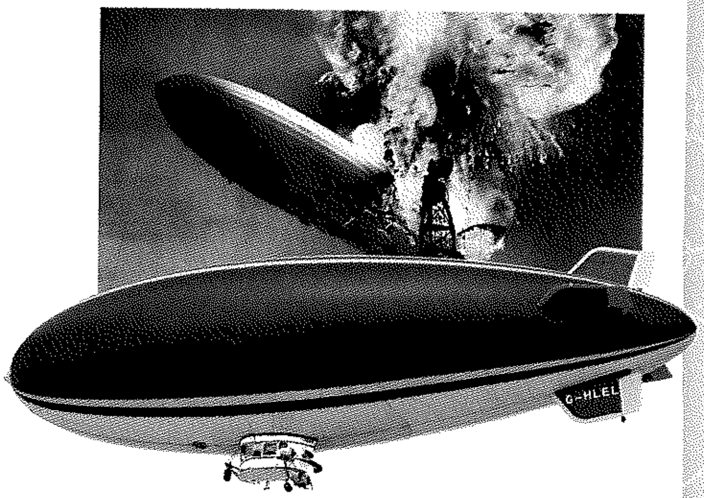
Connecting Ideas

8. Anishnabae Elder Betty McKenna has said that "we contain all those little bits and pieces that's out there. We have calcium, we have salt, we have iron, we have copper, zinc and potassium.... [We] go from the universe right down to Mother Earth and that's us." How does this quote relate to what you have learned about the elements? E C

Making New Connections

9. In the past, gold rushes in British Columbia and elsewhere saw large numbers of everyday people travelling long distances, hoping to find veins of pure gold. Gold is somewhat unusual among metals—most have to be extracted from compounds and are not found in their elemental form, as gold is. What does this tell you about the reactivity of gold? E C

10. On May 6, 1937, a passenger airship called the *Hindenburg* caught fire and crashed, killing nearly half of its passengers as well as one person on the ground. The airship was filled with hydrogen gas. Although people disagree about the sequence of events that led to the disaster, the combustibility of the hydrogen likely contributed. PA E AI



- **a)** What property of hydrogen would have led to its use in airships?
- **b)** Helium is the gas used today for airships. What property of helium makes it more suitable for use in airships than hydrogen?

TAKE Action

Make a Difference

Campaign to Reduce E-waste

Electronics are all around us: our computers, cellphones, electronic readers, tablets … It's difficult to imagine a world without them. Every year more and more electronic equipment and batteries are produced for our use. What this also means, of course, is that every year large amounts of electronics are being discarded as waste. Worldwide, this electronic waste (or e-waste) is skyrocketing. In Canada alone, in 2002, we produced over 11 million tonnes of electronic waste. Ten years later, this number had climbed to 14.3 million tonnes produced in a year.

Is e-waste garbage?

E-waste includes batteries and electrical and electronic equipment such as cameras, microwaves, printers, radios, speakers, and telephones. But just because we call it "waste," it doesn't mean it should be treated as garbage to be lugged away to the landfill site.

Electronic devices contain metals and other elements such as lead, cadmium, barium, chromium, mercury, and arsenic that can be harmful. For example, when chromium exists in compounds as the ion chromium(VI), it can easily be absorbed into our bodies, where it can cause permanent eye injury and even DNA damage over time.

How do these substances come to be absorbed into human bodies? Worldwide, large amounts of e-waste are still dumped into regular landfill sites where it breaks down and the hazardous substances are permitted to leach into the soil or water. In some places, people burn the e-waste to extract metals for resale. Toxins can become airborne, or may be left behind in the ash. The land, water, and air become polluted, and plants, fish, and other animals, including humans, can be harmed or killed by taking them in.

Diverting e-waste from landfills

What's the alternative? Instead of being thrown away, many intact electronics can be repaired or re-used. In addition, many parts of electronic equipment can be recycled to make new parts. Or, the materials making up the equipment—

including glass, steel, plastic, aluminum, and copper—can be recycled. People can dispose of them at special recycling centres so they can be directed to this purpose. Recycling helps to conserve natural resources. It also saves the energy that would have been required to produce new equipment.

There are several regulated programs for e-waste in Canada that allow us to dispose of our e-waste safely. Many jurisdictions offer e-waste pick-up days from specific locations or provide collection sites. Specialized recyclers take them away for safe processing.

Planning for Your Campaign

Your task is to run a campaign to educate your fellow students and their families about the importance of reducing e-waste—and motivate them to take part. Research successful campaigns. Think about how to target and influence your specific local audience. Questions to consider when developing your campaign can include the following:

- Will you work on your campaign alone or would it be more effective to get one or more partners? How will you do that? How will you agree on your roles?
- How can you ensure that your target audience connects with your campaign? Should you focus on one or two specific types of electronics that they use primarily? If so, how can you find out what these are?
- How can you convince your target audience that this issue is important? What information do you need to investigate and learn about?
- Many successful campaigns use posters, slogans, videos, or websites. How will you communicate your message?
- What catchy title and graphics can you use?
- How can you evaluate the success of your campaign?

Write out your plan and, with your teacher's approval, carry it out.

Analyze and Evaluate

1. How successful was your plan? How well did your evaluation plans help you to determine its success?
2. What did you learn that could help you to improve your campaign?

Apply and Innovate

3. Suppose other schools in your province learn of your successful campaign and want to do something similar. They have asked you for advice. Write a short bullet-point list of tips and strategies. Don't be afraid to inform them of areas where you were less successful; you can use what you learned to help guide them toward success.

INVESTIGATION

2-C

GUIDED INQUIRY

Skills and Strategies

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

What You Need

- Internet access
- print sources of information on your element
- other materials to be determined by your plan, such as posterboard, markers, other art supplies, a smartphone for recording video

Present an Element at ElementCon

As a world-renowned expert on a particular element, you have been invited to present information about that element at ElementCon—an annual convention for fans of the periodic table.

Question

What can you learn about the history, properties, and applications of an element?

Procedure

1. Your teacher will assign you an element. Use print and online resources to find out all about your element. Be sure to answer the following questions as you research:
   a) What is the name, symbol, and number of the element? What are the origins of its name and symbol?
   b) When and how was the element first discovered?
   c) What are the physical and chemical properties of the element, including the following, if applicable:
      - melting and boiling point
      - density
      - state at room temperature
      - colour
      - texture
      - hardness or softness
      - odour
   d) Where on the periodic table is your element found? Is it a metal, a non-metal, or a semi-metal?
   e) What features define an atom of your element?
   f) Where is the element found?
      - Where in the world and in the universe is it found?
      - Can it be found pure or is it always in compounds?
      - What types of compounds does it form?
      - How can the element be isolated from its compounds?
   g) How is the element used today and how was it used in the past? What is the economic importance of the element in Canada or elsewhere in the world?

2. Take notes to record the information you find. Record the sources of information you used.

Process and Analyze

1. Did you find conflicting information as you researched? Give one example. How did you decide which source to use?
2. Evaluate the sources you used. Were they
   - trustworthy? Explain how you know.
   - current? Explain how you know.

Apply and Communicate

3. Make a plan to decide how you will present your findings at your "booth" at the ElementCon. You may use one or more of the following ideas to present the information you found.
   - Put up an informative poster with tables and images.
   - Use storytelling to creatively reveal properties and other information about your element.
   - Make a display showing a model of an atom of your element.
   - Create a comic book in which your element is the superhero, with powers and weaknesses related to its chemical and physical properties.
   - Write a clickbait-style "Which element are you?" quiz for classmates to try that has questions relating to the properties of your element that distinguish it from others.
   - Collect and display items that contain your element or that relate to your element in some other way.
   - Make a video in which you explain why your element is interesting, unique, and important.
   - Make a video re-creating the discovery of your element.
   - Create a slide show with photos, text, and music relating to your element.
4. Have your teacher approve your plan before you design your booth. On ElementCon day, your teacher will divide the class in half. Half the class will visit booths, while the other half will present. Then the groups will switch.

INVESTIGATION
2-D

STRUCTURED INQUIRY

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Never eat or drink anything in the laboratory.

What You Need

- a selection of elements and information cards—these elements will include a variety of solid, liquid, and gaseous elements from different families of the periodic table

Meet the Elements

Most of the matter we interact with every day is in the form of compounds and mixtures. In this investigation, you will observe a number of elements in uncombined form.

Question

How can we distinguish among elements by observing some of their physical and chemical properties?

Procedure

1. Your teacher will give a list of the elements you will be observing. Use this list to prepare a table like the one opposite. (Alternatively, your teacher may provide a table for you to fill out.) Be sure to leave plenty of room for observations.
2. Observe the elements as directed by your teacher. Record properties provided on the information cards. Your teacher may demonstrate additional properties.

Process and Analyze

1. Where within any period do you find the following:
   - **a)** the most dense metals
   - **b)** the most reactive metals
2. Where within any group do you find the following:
   - **a)** the most dense elements
   - **b)** the most reactive elements
3. Many of the elements you examined were metals.
   - **a)** List four properties that most metal elements have in common.
   - **b)** List the elements that are exceptions to the properties you listed above, and explain why.
   - **c)** List the elements that are magnetic.
4. List the elements that conducted electric current. Were they all metals?

Symbol	Element Name	State	Colour	Additional Properties (lustre, malleability, density, conductivity, magnetism)	Group
H					
Li					
Na					

Communicate and Question

5. Summarize your findings about metals and non-metals.

6. What questions do you have about the elements or a specific element as a result of this investigation? Come up with at least three questions. Choose one and do Internet research to find the answer.

TOPIC 2.3

How can atomic theory explain patterns in the periodic table?

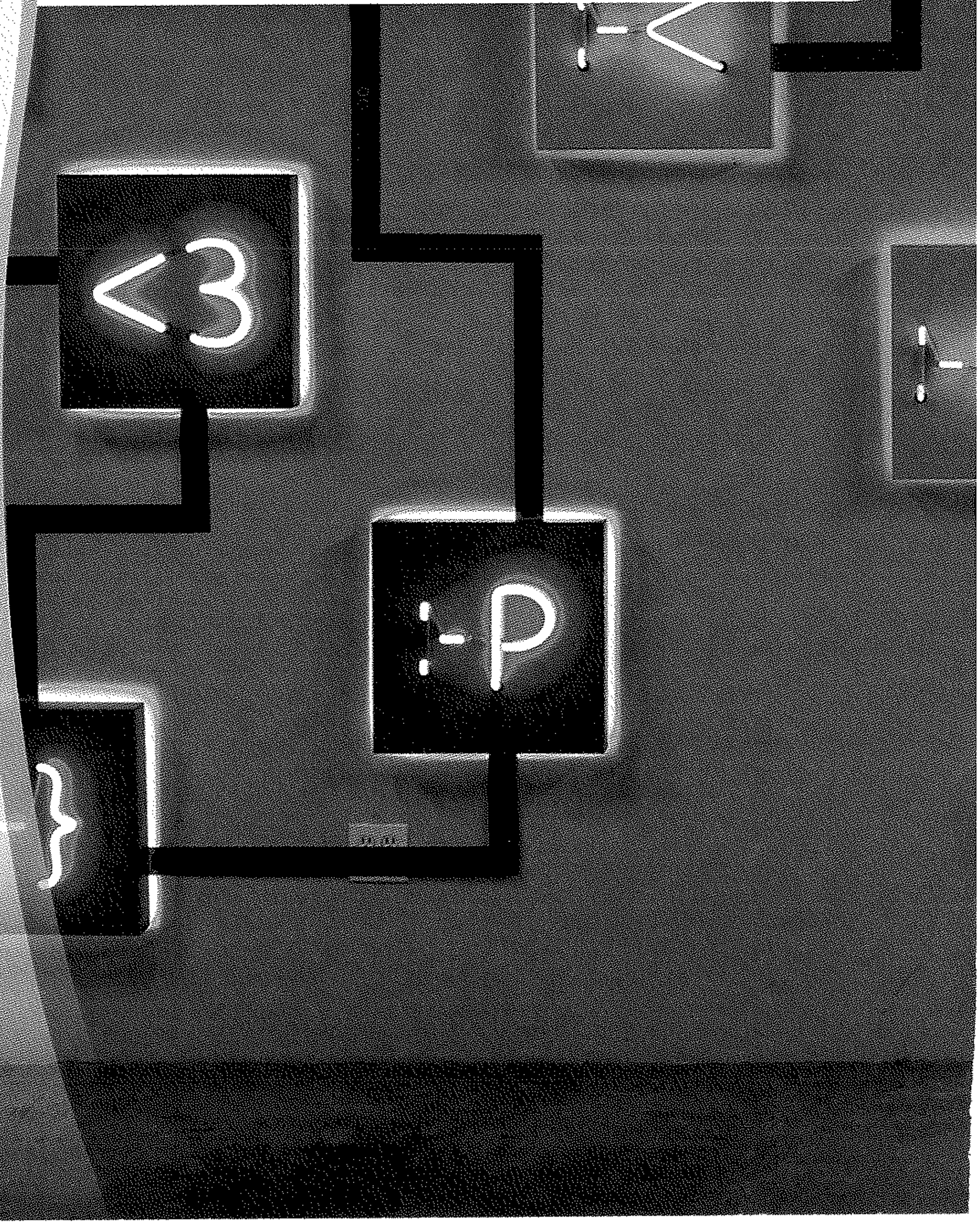
This playful sculpture by artist Lisa Schulte is called *A Conversation*. Schulte used neon and argon lights to create a trail of emojis that tell a story. In contrast to the increasingly strong emotional "reactions" portrayed here, noble gases such as neon and argon are inert—they do not undergo chemical reactions. The inertness of noble gases is one example of a pattern revealed by the periodic table. But what causes these patterns?

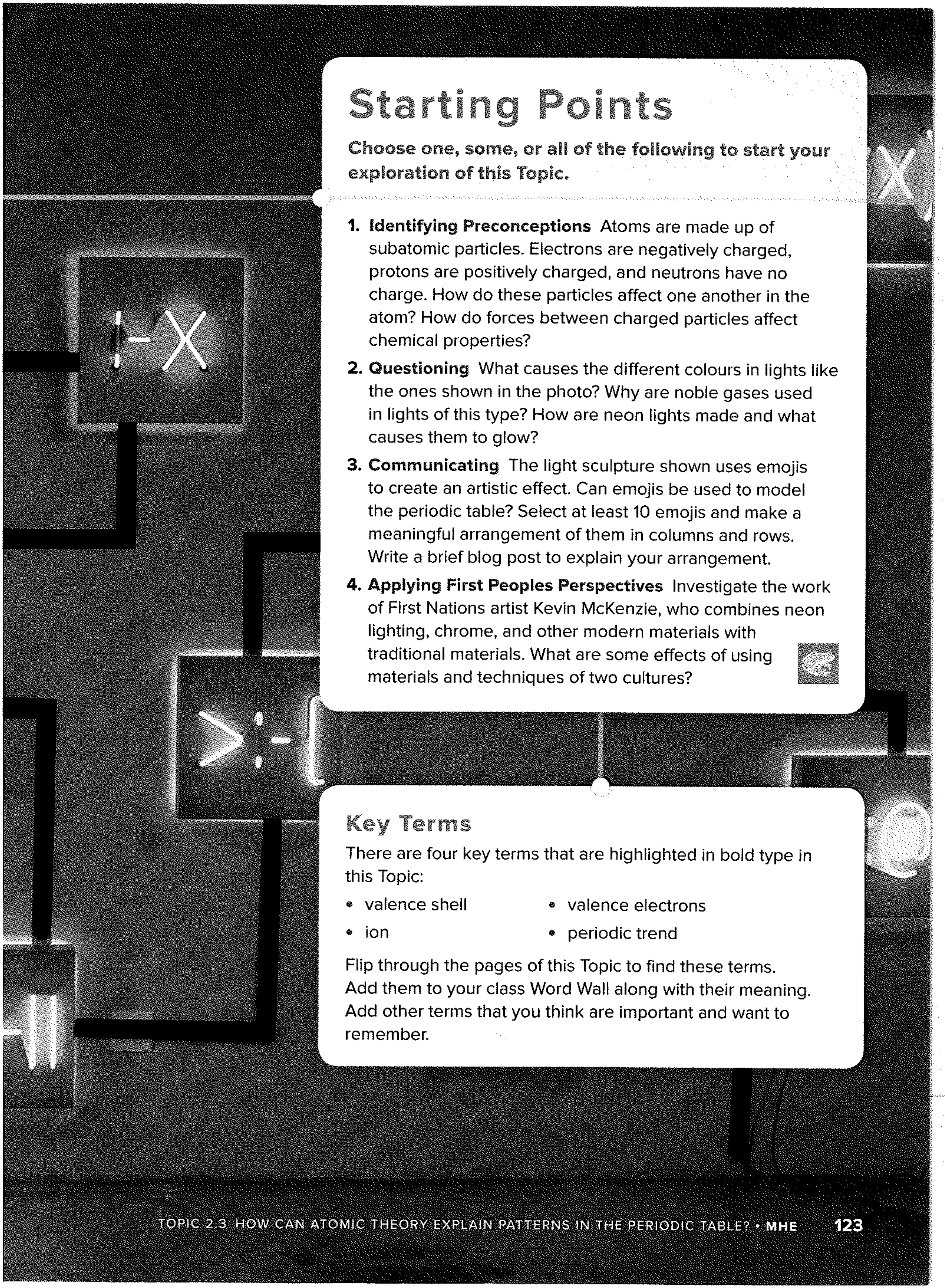
Key Concepts

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.

Curricular Competencies

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables (dependent and independent) and identifying inconsistencies.
- Construct, analyze, and interpret graphs, models, and/or diagrams.
- Formulate physical or mental theoretical models to describe a phenomenon.





Starting Points

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

1. **Identifying Preconceptions** Atoms are made up of subatomic particles. Electrons are negatively charged, protons are positively charged, and neutrons have no charge. How do these particles affect one another in the atom? How do forces between charged particles affect chemical properties?
2. **Questioning** What causes the different colours in lights like the ones shown in the photo? Why are noble gases used in lights of this type? How are neon lights made and what causes them to glow?
3. **Communicating** The light sculpture shown uses emojis to create an artistic effect. Can emojis be used to model the periodic table? Select at least 10 emojis and make a meaningful arrangement of them in columns and rows. Write a brief blog post to explain your arrangement.
4. **Applying First Peoples Perspectives** Investigate the work of First Nations artist Kevin McKenzie, who combines neon lighting, chrome, and other modern materials with traditional materials. What are some effects of using materials and techniques of two cultures?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- valence shell
- ion
- valence electrons
- periodic trend

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

The structure of atoms can be represented using simple diagrams.

Activity

What do you know about atoms?

In your notebook, and without referring to your textbook, draw a diagram of a helium atom. What information did you provide about the atom in your diagram?

Mendeleev arranged elements in his periodic table based on the physical and chemical properties of different elements. Metals appear on the left side of the zigzag line, and non-metals appear on the right. Elements in the same families share similar properties. But why is this the case? What characteristic of elements causes their properties to repeat in this predictable way? To find the answer, we need to consider the structure of the atom.

Key Features of Atomic Structure

Recall that the atom is the smallest unit of an element that has the properties of that element. For example, an atom of carbon is represented in Figure 2.15. Each atom has a tiny, dense nucleus containing neutrons and protons. (A hydrogen nucleus has a single proton only.) The nucleus is surrounded by electrons, which exist in specific electron energy shells. Most of the mass of an atom is in the nucleus. Table 2.3 summarizes key characteristics of protons, neutrons, and electrons.

Figure 2.15 Every carbon atom has six positively charged protons in its nucleus and six negatively charged electrons surrounding the nucleus. (Most carbon atoms have six neutrons, but some have seven or eight.)

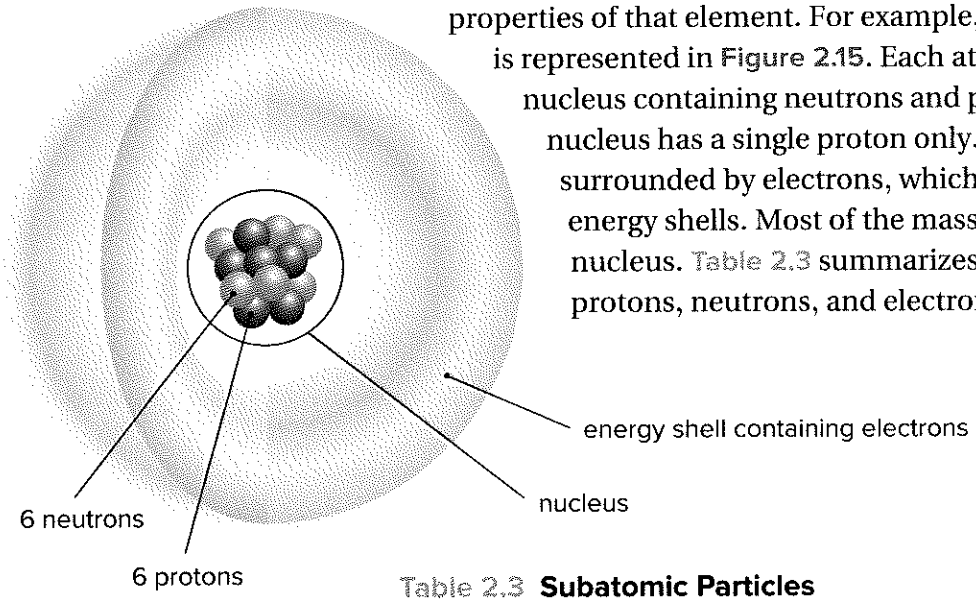


Table 2.3 **Subatomic Particles**

Name	Relative Mass	Electric Charge	Symbol	Location in Atom
proton	1836	+	p^+	nucleus
neutron	1837	0	n^0	nucleus
electron	1	–	e^-	electron energy shells surrounding the nucleus

Bohr Diagrams Are a Useful Way to Model Atoms

It is useful to be able to represent atoms in a simplified, two-dimensional way that provides information about their structure. Bohr diagrams represent the electron arrangements of atoms using the "energy shell" concept of Bohr's model of the atom. As shown in Figure 2.16, a Bohr diagram shows how many electrons occupy each specific energy level or shell. The number of electrons that can occupy each energy shell changes as you move outward from the nucleus. The first energy shell can have a maximum of two electrons. The second and third energy shells can have a maximum of eight electrons. (This is true for the first 20 elements, after which things become more complex.) The outermost occupied shell of an atom is called a **valence shell**. Electrons in the valence shell are called **valence electrons**.

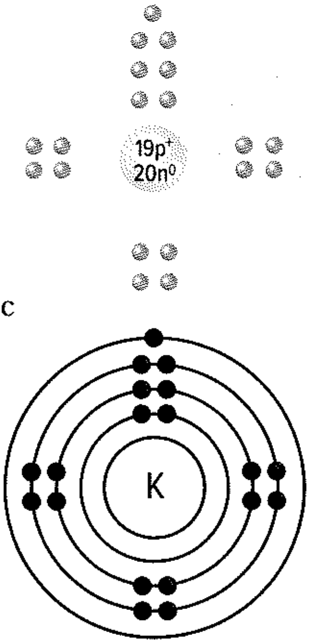


Figure 2.16 Both of these Bohr diagrams represent an atom of potassium. **What is one drawback and one advantage of each diagram?**

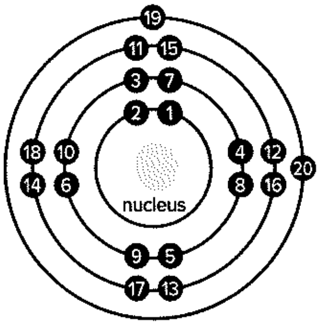
valence shell the outermost occupied energy shell of an atom

valence electrons the electrons in the outermost occupied energy shell of an atom

Activity

Model Bohr Atoms

Your teacher will assign you a number from one to 20. Using a pie plate, a marker, construction paper, pom-poms, and glue, create a Bohr diagram for the element that corresponds to your number. For example, if you are number 6, your element is carbon.



1. Glue a construction paper circle "nucleus" in the centre of your pie plate. Write the symbol for your element on the circle.
2. Examine the diagram on the right to see in what order you will place the pom-pom "electrons" and how many shells will be occupied. (For a neutral atom, number of electrons = atomic number.)
3. Draw circles on the pie plate to represent the occupied energy shells for your atom. Then glue on pom-poms to represent your electrons.
4. Display your model. In your notebook, use the models to help you draw Bohr diagrams for each of the first 20 elements.

Before you leave this page . . .

1. Draw a diagram of an atom, labelling protons, electrons, and neutrons.
2. List how many electrons can be found in the first and second energy shells.

CONCEPT 2

Elements in chemical groups have similar electron arrangements.

Activity

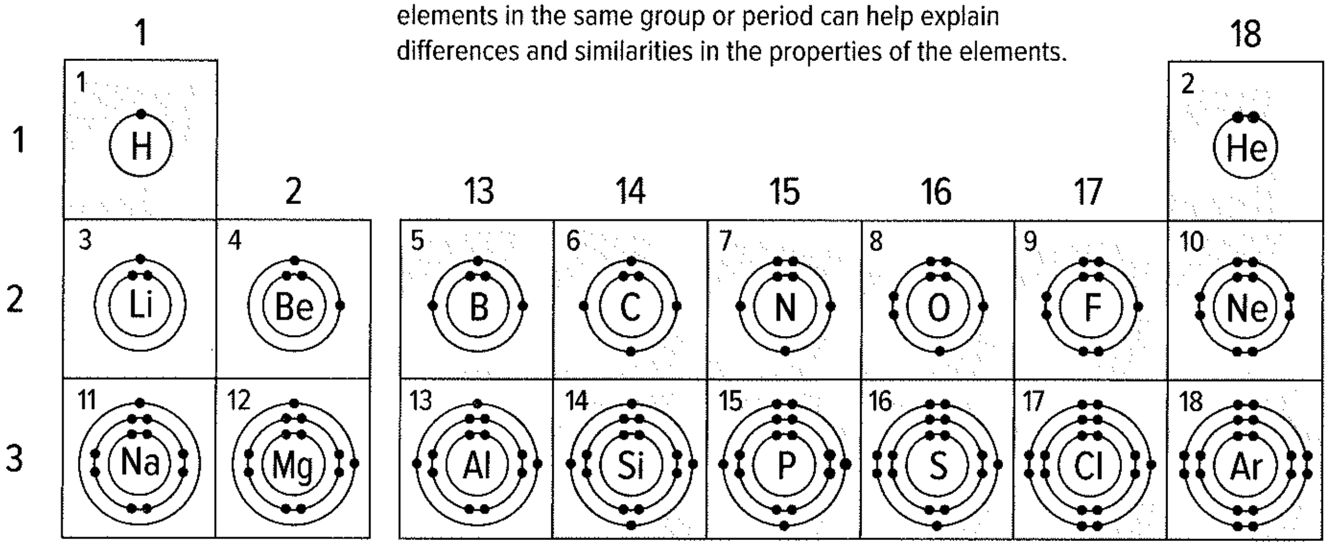
Valence Electrons and Group Numbers

Examine Figure 2.17. How do the valence electrons in each group relate to the group number?

Figure 2.17 shows Bohr diagrams for elements in the first three periods of the periodic table. If you look carefully at the electron arrangements, you will see that two key patterns emerge:

1. *Atoms in the same group have the same number of valence electrons.* Each element in Group 1 has one valence electron, and each element in Group 2 has two valence electrons. The elements in Groups 13 to 18 have 3, 4, 5, 6, 7, and 8 valence electrons, respectively. An exception is helium. Helium has only two valence electrons, but the other noble gases have eight.
2. *Atoms in the same period have the same number of occupied energy shells.* The two elements in the first period, hydrogen and helium, have only one occupied energy shell. The eight elements in the second period have two occupied energy shells. The eight elements in the third period have three.

Figure 2.17 Analyzing the electron arrangements of elements in the same group or period can help explain differences and similarities in the properties of the elements.



Noble Gas Stability: A Full Valence Shell

During a chemical reaction, atoms gain, lose, or share valence electrons with other atoms. Noble gases are special among the elements, because they all have full valence shells. This feature makes them unusually stable. Their atoms do not tend to gain, lose, or share electrons with other elements— for the most part, they are unreactive. As you can see in Figure 2.18, helium has two electrons, which is the maximum number of electrons for the first energy shell. The other noble gases have eight electrons in their valence shells.

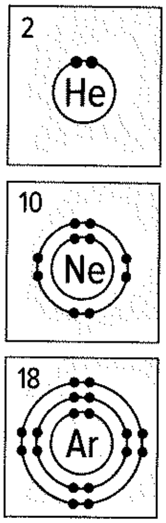


Figure 2.18 The noble gases have full valence shells.

How Other Elements Achieve Full Valence Shells

One way that atoms of elements other than the noble gases can achieve a full valence shell is by gaining or losing electrons during chemical reactions. When a neutral atom gains or loses an electron, it becomes charged—it becomes an **ion**. When an atom loses an electron, it becomes a positively charged ion. When an atom gains an electron, it becomes a negatively charged ion.

ion an atom with a positive or negative charge

The reactivity of an element is linked to how close it is to having a full valence shell. For this reason, the most reactive elements are those of Groups 1 and 17. The atoms of these elements are only one electron away from having a full set of valence electrons. As shown in Figure 2.19, Group 1 atoms can give up an electron, exposing the full energy shell underneath. Group 17 atoms can gain an electron, completing their valence shell.

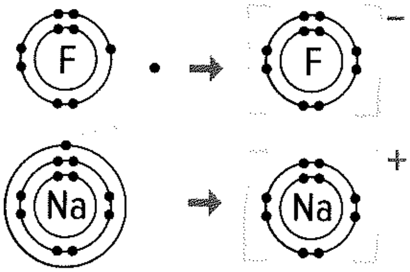


Figure 2.19 If a fluorine atom gains an electron, forming the ion F^-, it will have the same electron arrangement as neon, including a full valence shell. A sodium atom can have the same electron arrangement as neon by losing an electron and forming the ion Na^+.

Extending the Connections

A Noble Gas is Hard to Find

When Mendeleev developed his periodic table, he did not include a column for the noble gases, because they had not yet been discovered. Which noble gas was found first and how was it discovered? Who realized where the noble gases should be placed on the periodic table? Do research to find out.

Before you leave this page . . .

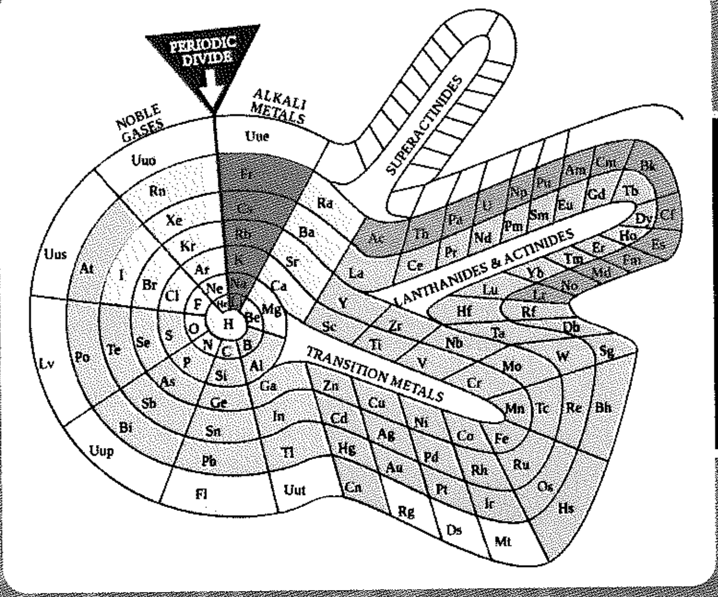
1. Explain why metals tend to lose electrons and non-metals tend to gain them.
2. Use diagrams to compare the electron arrangements of a chloride ion, a potassium ion, and an argon atom.

AT ISSUE

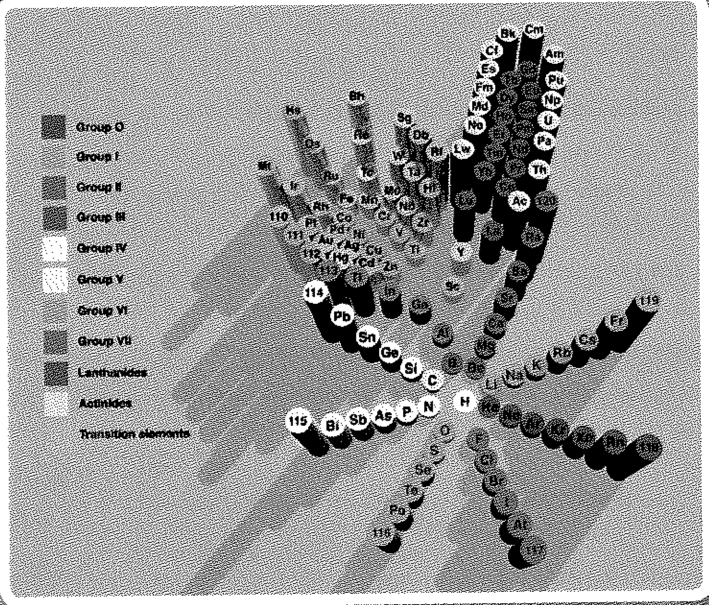
How can the periodic table be represented in a different form?

What's the Issue?

The modern periodic table that you have been learning about is organized in columns and rows according to the atomic numbers of the elements. When the elements are arranged in order of increasing atomic number, a periodic pattern in the properties of the elements emerges.

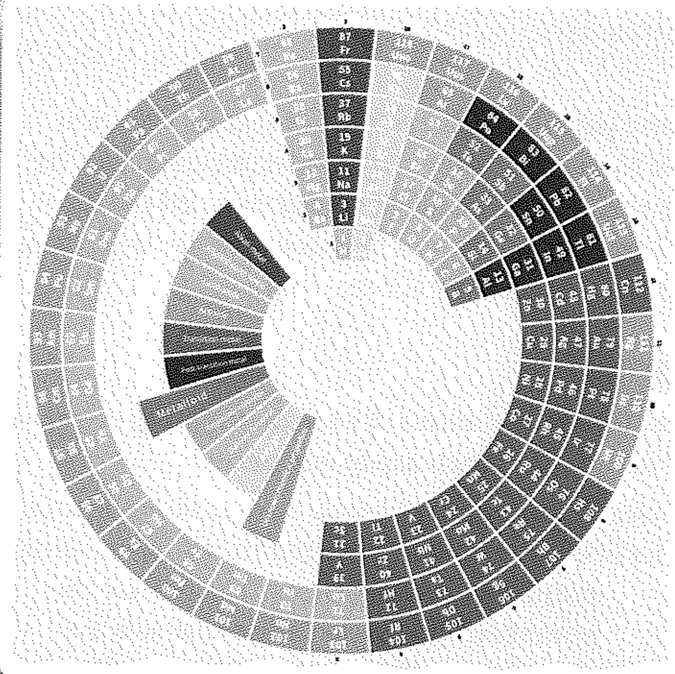


Dr. Theodor Benfey designed this spiral periodic table in 1964. One of his aims was to show the continuity of the elements and remove the apparent "jump" from one period to the next that occurs in the traditional periodic table.



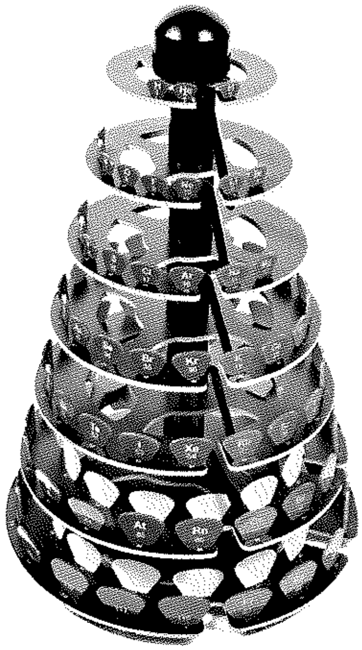
In this three-dimensional digital periodic table, the heights of the columns represent the magnitude of the atomic numbers of the elements.

But is that the only way that all the elements could be organized? Many people have argued no—and have developed their own versions of the periodic table. In fact, since the early 1900s more than 300 versions of the periodic table have been developed. Some tables have been developed purely for creative reasons. Others have been developed to show different types of information or relationships between elements and their properties that the standard version of the periodic table does not show.



Like Dr. Benfey's spiral table, this circular periodic table emphasizes the continuity between periods. However, its shape is simpler and it uses only colour-coding to show the groups.

This three-dimensional periodic spiral was designed in 1977 by Dr. Hinsdale Bernard. The connected platforms represent the periods, and the elements are colour-coded to show what part of the table they belong to.



Dig Deeper

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

1. What key pieces of information do you think should be in a periodic table?
2. Choose one of the periodic tables shown on these pages to learn more about, or choose another table to research, such as an online interactive table. Why did the designer of your chosen table choose to present it that way? What other questions do you have about the table? Perform research to find the answers to your questions.

CONCEPT 3

The periodic table shows how properties of elements change in predictable ways.

Activity

On Trend

What does the term *trend* mean to you? Write a brief definition. How have you seen the term used in the news media and on social media? How is your life influenced or affected by trends?

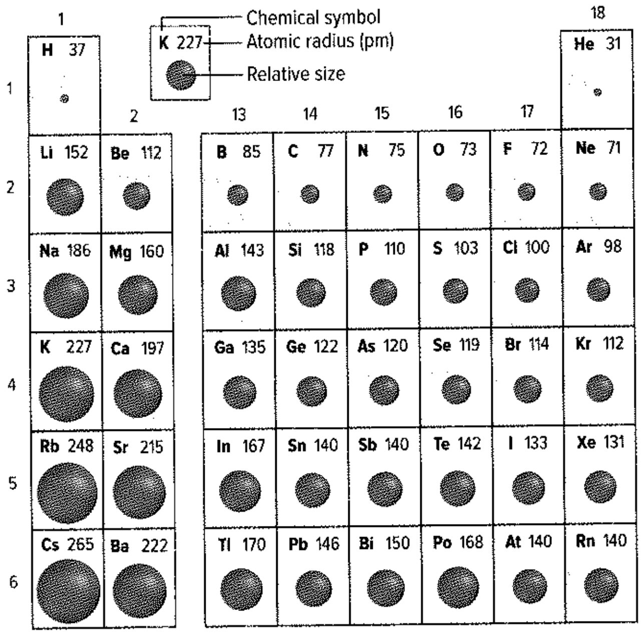
periodic trend a regular variation in the properties of elements based on their atomic structure

In chemistry, the term **periodic trend** refers to a regular variation in the properties of elements based on their atomic structure. The periodic table is a powerful tool for analyzing such trends because it can help you see and compare variations in groups and periods. One trend that can be analyzed in this way is atomic size.

Atomic Size Trends

Figure 2.20 compares the sizes of atoms of each main-group element. Observe the sizes of the atoms in each group and period.

1. *Atomic size increases moving down a group.* As you move down a group in the periodic table, elements have atoms with increasing numbers of energy shells. The greater the number of shells, the farther the valence electrons are from the nucleus, and therefore the larger the atom is.
2. *Atomic size decreases moving left to right across a period.* Elements have increasing numbers of electrons in their valence shells as you move left to right across a period. And yet the atomic size *decreases*. Why? As you move from left to right in a period, the number of occupied valence shells stays the same, but the number of protons in the nucleus increases. The attraction between each valence electron and the nucleus increases because a greater positive charge on the nucleus pulls more strongly on the negatively charged electrons. As a result, the valence electrons are pulled more tightly towards the nucleus.



	1	2	13	14	15	16	17	18
1	H 37							He 31
2	Li 152	Be 112	B 85	C 77	N 75	O 73	F 72	Ne 71
3	Na 186	Mg 160	Al 143	Si 118	P 110	S 103	Cl 100	Ar 98
4	K 227	Ca 197	Ga 135	Ge 122	As 120	Se 119	Br 114	Kr 112
5	Rb 248	Sr 215	In 167	Sn 140	Sb 140	Te 142	I 133	Xe 131
6	Cs 265	Ba 222	Tl 170	Pb 146	Bi 150	Po 168	At 140	Rn 140

Figure 2.20 Atomic size is represented here by the sizes of the spheres. The number under each element is the radius of the atom in picometres (pm). One picometre is equal to 1/1 000 000 000 000 m.

Metal Reactivity and Atom Size

Figure 2.21 compares what happens when potassium and sodium are added to water. As you can see, the reaction is more vigorous and violent for the potassium. In other words, potassium is more reactive than sodium. Why is this the case? They are both in Group 1, and both have one valence electron. The difference is that a potassium atom is larger than a sodium atom. A potassium atom's valence electron is farther away from the nucleus than the sodium atom's valence electron. As a result, the pull of the nucleus is weaker, and the electron is easier to remove. That is what makes potassium more reactive.

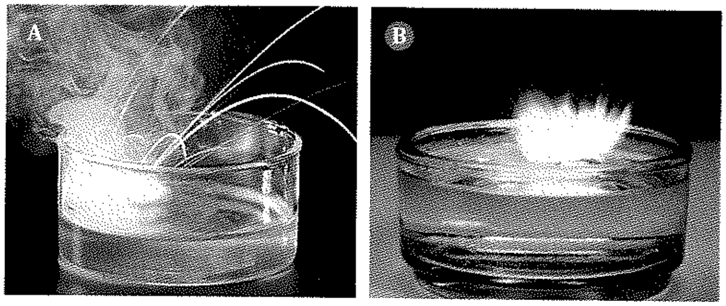
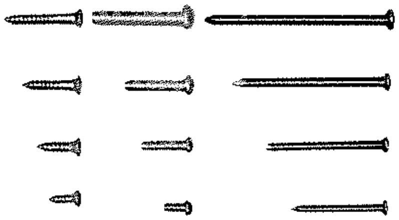


Figure 2.21 Potassium Ⓐ is more reactive than sodium Ⓑ because less energy is needed to remove the valence electron from potassium.

Activity

Recognizing Trends

The periodic table makes it easy to see trends in atomic properties such as atomic size. Can you use a similar arrangement to reveal trends in the characteristics of everyday objects?



1. Obtain a sample of fasteners, including nails, bolts, and screws.
2. Measure the length of each nail with a ruler.
3. Use a balance to measure the mass of each nail.
4. Place the nails in a series from smallest to largest.
5. Continue to arrange a series of screws and a series of bolts that also correspond to the series of nails created in Step 4.
6. Make a table listing the length and mass of each fastener according to its position.
7. Describe the following:
   a) the trend in mass as you go from left to right across each row
   b) the trend in mass as you go down each column of the table
8. Analyze your organization of the fasteners, and explain any other trends that you find in the table.
9. Describe how you could make a similar "periodic table" of another type of familiar item.

Before you leave this page . . .

1. Explain why atoms get larger down a group on the periodic table.
2. Explain why atoms get smaller from left to right across a period on the periodic table.
3. Explain why an alkali metal is more reactive than an alkaline-earth metal in the same period.

AT ISSUE

Who decides a new element's name?

What's the Issue?

When Mendeleev first published his periodic table, would he have been surprised to learn that scientists are still updating this ultimate source of chemical information 150 years later? Today, all of the elements that occur naturally have been discovered. Therefore, the discovery of new elements involves making them in laboratories and analyzing complex results to confirm their existence. Who decides when a new element has been made and what to call it?

The International Union of Pure and Applied Chemistry, or IUPAC for short, is the international scientific organization that is in charge of naming chemical elements, as well as other chemicals. They are also in charge of confirming that new elements have actually been synthesized. In 2016, IUPAC confirmed that the new elements numbered 113, 115, 117, and 118 actually existed, and assigned these elements temporary names that were added to the periodic table. The seventh row of the periodic table was completed when these four elements were assigned official names and symbols as shown below.

Newly Synthesized Elements

Element Number	Name	Symbol
113	nihonium	Nh
115	moscovium	Mc
117	tennessine	Ts
118	oganesson	Og

Dig Deeper

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

1. According to IUPAC, what are the rules for naming new elements? What were the reasons behind the names for new elements 113, 115, 117, and 118? What were the temporary names given to these elements before their official names were decided?
2. IUPAC announced the four new names in June 2016. They then waited 5 months to allow for both scientific and non-scientific people to review the names. Why did IUPAC do this?
3. Choose a synthetic element and find out how it was made. How does IUPAC confirm the synthesis of a new element? Why are multiple results required to make this decision?
4. Does the naming of these last four elements mean that scientists are finished making new elements and that the periodic table is complete? Explain your answer.

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. What is a periodic trend? PA C

2. Compare the number of protons and electrons in each of the following: PA C

a) a positively charged ion

b) a negatively charged ion

c) a neutral atom

3. Why are the noble gases so stable? PA C

4. What is the relationship between reactivity among elements (other than the noble gases) and the number of valence electrons? PA

5. Describe and explain the periodic trends relating to atomic sizes. PA C

6. Which of the following pairs of metals would you expect to be more reactive? Briefly explain your answers. QP PA C

a) potassium or calcium?

b) rubidium or potassium?

7. How many valence electrons do atoms in the following groups have? (If there are exceptions to the rule, state them.) PA

a) Group 1

b) Group 2

c) Group 17

d) Group 18

Connecting Ideas

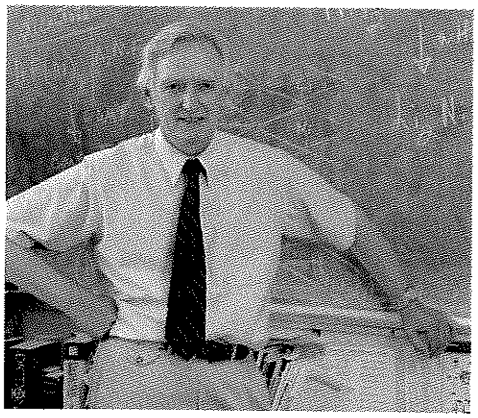
8. Do you expect a calcium ion, Ca^{2+}, to be larger or smaller than a calcium atom? Explain your answer. QP PA C

9. The noble gases were not identified until after Mendeleev first published his periodic table. Use your knowledge of noble gases to infer why it took so long to discover them. E C

Making New Connections

10. Fluorine is the most reactive of the halogens. It is more reactive than chlorine, which is just below it. Bromine is less reactive than chlorine. How would you summarize and explain this trend? PA AI C

11. Neil Bartlett, shown below, was a chemist and a teacher at the University of British Columbia who specialized in the chemistry of the element fluorine. Bartlett is celebrated as the first chemist to succeed in getting a noble gas to react and form a compound. PA E AI C



a) Bartlett was working on getting the noble gas xenon to react with fluorine. He eventually succeeded in making a number of compounds of xenon and fluorine. Why do you think fluorine was a good choice of element to work with in trying to get noble gases to react? **Hint:** Refer to Question 10.

b) What features of xenon made it a good choice of noble gas for Bartlett to use in his attempts to get a noble gas to react? Research to find out.

c) What effect did Bartlett's discovery have? Research to find out.

INVESTIGATION

2-E

STRUCTURED INQUIRY

Reactivity Trends in the Periodic Table

Periodic trends include both physical and chemical properties of elements. In this investigation, find out if (and how) the reactivity of metals relates to their position on the periodic table.

Question

Is there a relationship between the reactivity of a metal and its position in the periodic table?

Procedure

1. Read the Procedure steps and design a table to record your observations.
2. Put 10 mL of water into each of the three test tubes. Add one metal to each test tube. Record your observations.
3. When the reactions stop, dispose of the liquid as directed by your teacher. You will use the magnesium and aluminum metals again for the next step.
4. Add 10 mL of HCl to the remaining magnesium and aluminum samples. Record your observations and indicate the relative reactivity of each metal. CAUTION: Be very careful when working with the hydrochloric acid. Acid can burn skin. If you spill any of the acid solution on your hands, rinse it off immediately with cold water and inform your teacher.
5. Clean up your work area and dispose of materials as directed by your teacher.

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing
- Communicating

Safety

- Hydrochloric acid can burn skin.
- Clean up any spills and inform your teacher immediately.
- Do not handle calcium with your bare hands.

What You Need

- water
- 3 test tubes
- test-tube rack
- aluminum
- pea-sized piece of calcium
- 1 cm strip magnesium ribbon
- 1 mol/L hydrochloric acid

Analyze and Interpret

1. Compare the reactivities of magnesium and calcium. Use evidence to support your comparison.
2. Compare the reactivities of magnesium and aluminum. Use evidence to support your comparison.
3. Which of the three metals was the most reactive? Which metal was the least reactive?

Conclude and Communicate

4. Draw Bohr diagrams for magnesium, calcium, and aluminum. Does your understanding of atomic structure support yuor observations from this investigation? Justify your response.

Apply and Innovate

5. What other metals could you test in this way?
   - a) Suggest two or three additional metals that you could test.
   - b) Write a procedure for testing the reactivity of the metals. Include safety precautions.
   - c) With your teacher's permission, carry out your procedure.
   - d) Make a brief digital slide show to compare and analyze the findings of your own investigation together with your results from Investigation 2-E.
6. What other questions do you have about the different reactivities of elements as a result of carrying out this investigation?
   - a) Choose one question to investigate.
   - b) Conduct research to help you come up with a procedure for investigating your question in the laboratory.
   - c) Write a procedure for investigating your question.
   - d) With your teacher's permission, carry out your procedure.
   - e) Write a brief report to describe your investigation and your results.

TOPIC 2.4

How do elements combine to form compounds?

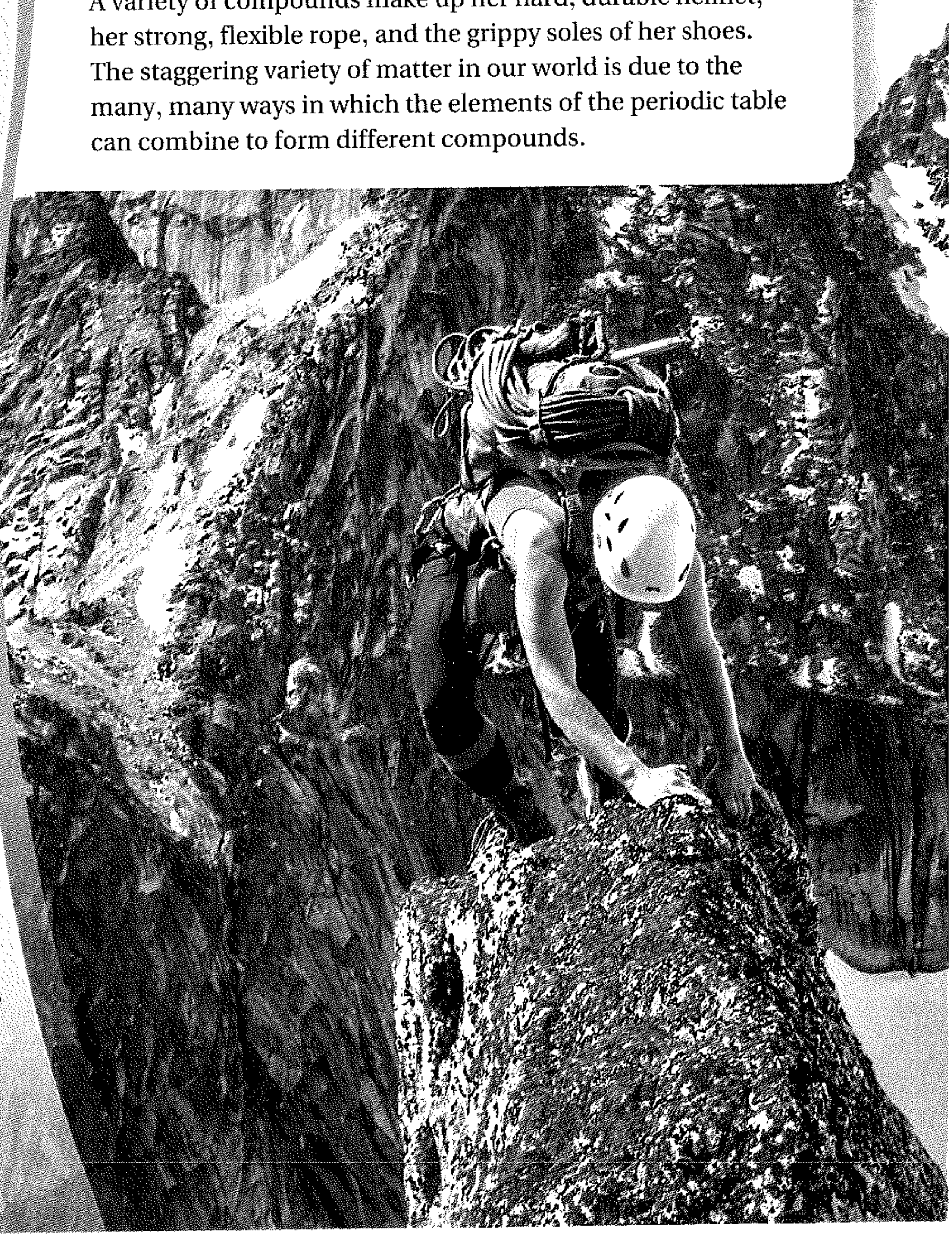
Key Concepts

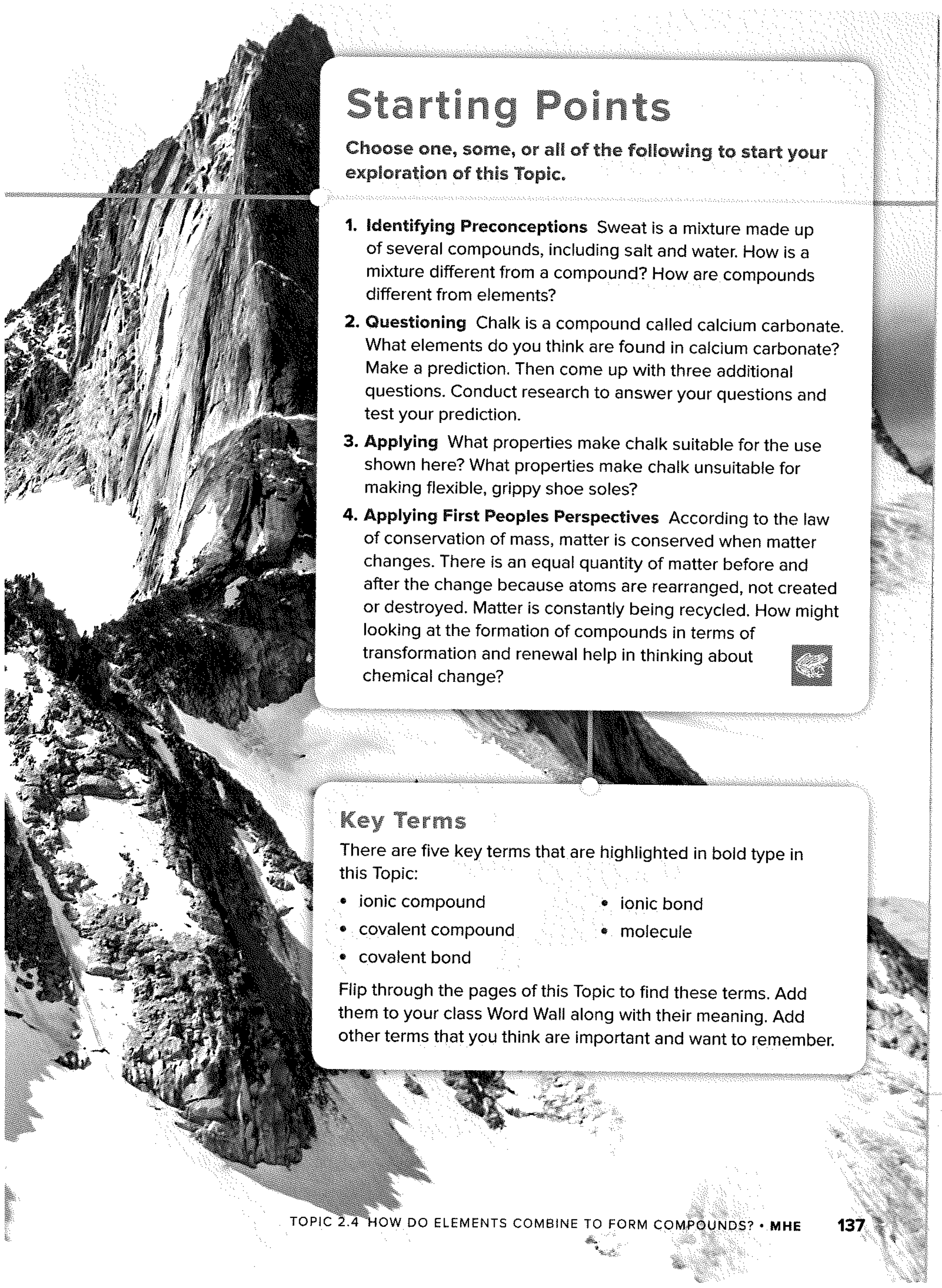
- Compounds account for the huge variety of matter on Earth.
- Ionic compounds are made of ions.
- Covalent compounds are made of molecules.
- Covalent bonding also occurs in elements and network solids.

Curricular Competencies

- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data.
- Apply First Peoples perspectives and knowledge, other ways of knowing, and local knowledge as sources of information.
- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions.

This climber depends on chalk—a white, powdery compound—to absorb the sweat from her hands and improve her grip on the rock. The sweat itself is mainly the compound salt, also called sodium chloride, dissolved in another compound, water. The climber breathes deeply to stay focussed, and the mixture that is her exhaled breath includes gaseous water, along with carbon dioxide, another compound. A variety of compounds make up her hard, durable helmet, her strong, flexible rope, and the grippy soles of her shoes. The staggering variety of matter in our world is due to the many, many ways in which the elements of the periodic table can combine to form different compounds.





Starting Points

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

1. **Identifying Preconceptions** Sweat is a mixture made up of several compounds, including salt and water. How is a mixture different from a compound? How are compounds different from elements?
2. **Questioning** Chalk is a compound called calcium carbonate. What elements do you think are found in calcium carbonate? Make a prediction. Then come up with three additional questions. Conduct research to answer your questions and test your prediction.
3. **Applying** What properties make chalk suitable for the use shown here? What properties make chalk unsuitable for making flexible, grippy shoe soles?
4. **Applying First Peoples Perspectives** According to the law of conservation of mass, matter is conserved when matter changes. There is an equal quantity of matter before and after the change because atoms are rearranged, not created or destroyed. Matter is constantly being recycled. How might looking at the formation of compounds in terms of transformation and renewal help in thinking about chemical change?

Key Terms

There are five key terms that are highlighted in bold type in this Topic:

- ionic compound
- covalent compound
- covalent bond
- ionic bond
- molecule

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

Compounds account for the huge variety of matter on Earth.

Activity

What is it made of?

For each of the following familiar compounds, list as many properties as you can. Then list properties of the elements that make up the compounds.

- table salt, or sodium chloride (made of sodium and chlorine)
- water (made of hydrogen and oxygen)
- carbon dioxide (made of carbon and oxygen)
- sugar, or sucrose (made of carbon, hydrogen, and oxygen)

Can you get clues about the properties of compounds from the properties of the elements that make them up? Explain your answer.

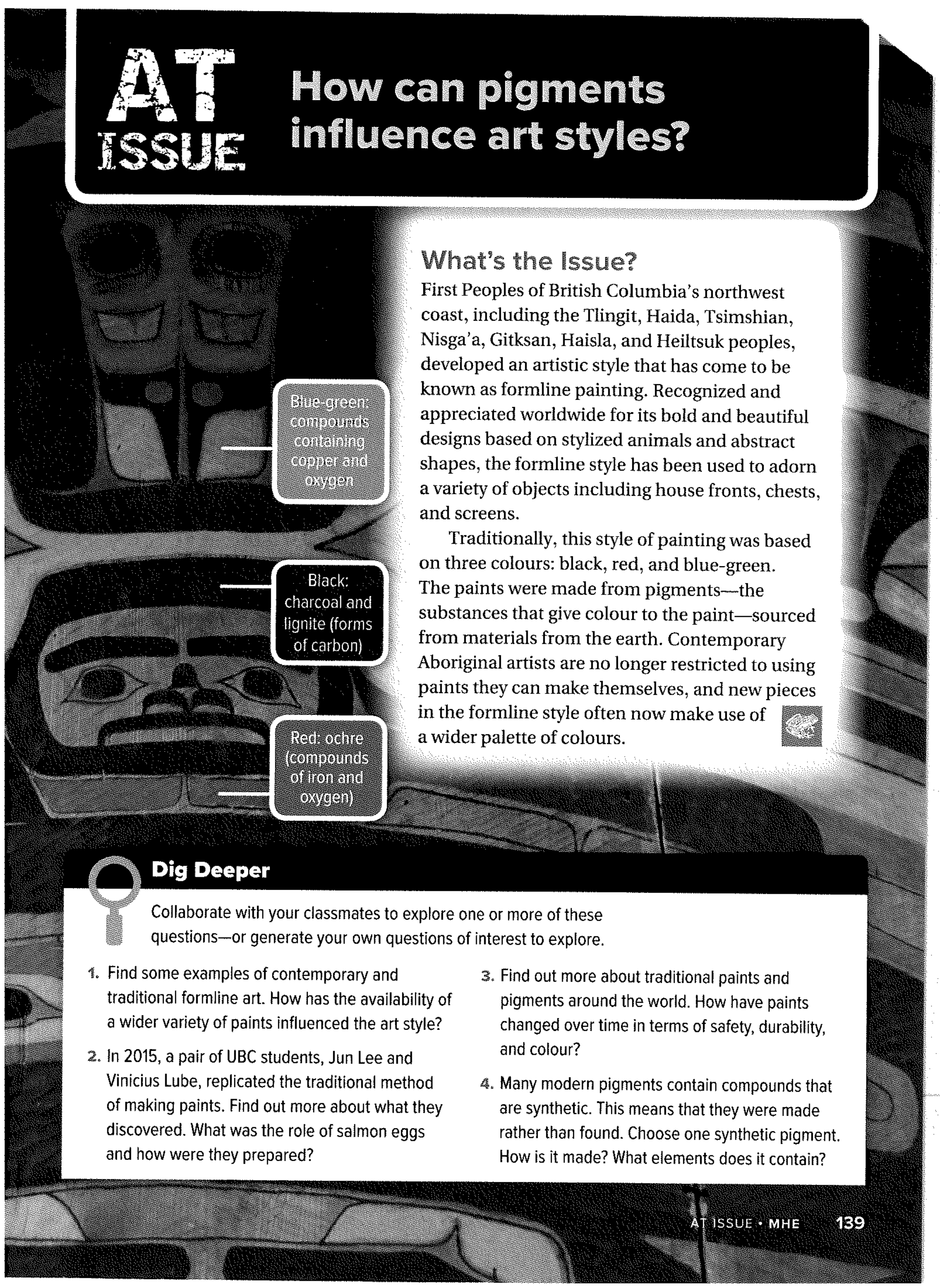
All of the compounds that exist on Earth are built from the elements of the periodic table. The periodic table lists 118 elements, and only 80 of these commonly form compounds. Yet there are 10 million known compounds—and scientists estimate that there could be billions of possible compounds. Figure 2.22 shows just a few examples. The variety of ways in which elements chemically combine to form compounds accounts for the astonishing variety of matter.

Figure 2.22 Hydrogen and carbon alone can be combined in millions of ways to make compounds with very different properties. The plastic bag, candle wax, gasoline, and acetylene gas used in the torch are all made up of compounds containing hydrogen and carbon.

Before you leave this page . . .

1. Distinguish between elements and compounds.
2. Compare the number of elements with the number of compounds on Earth.

AT ISSUE How can pigments influence art styles?



What's the Issue?

First Peoples of British Columbia's northwest coast, including the Tlingit, Haida, Tsimshian, Nisga'a, Gitksan, Haisla, and Heiltsuk peoples, developed an artistic style that has come to be known as formline painting. Recognized and appreciated worldwide for its bold and beautiful designs based on stylized animals and abstract shapes, the formline style has been used to adorn a variety of objects including house fronts, chests, and screens.

Traditionally, this style of painting was based on three colours: black, red, and blue-green. The paints were made from pigments—the substances that give colour to the paint—sourced from materials from the earth. Contemporary Aboriginal artists are no longer restricted to using paints they can make themselves, and new pieces in the formline style often now make use of a wider palette of colours.

Dig Deeper

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

1. Find some examples of contemporary and traditional formline art. How has the availability of a wider variety of paints influenced the art style?
2. In 2015, a pair of UBC students, Jun Lee and Vinicius Lube, replicated the traditional method of making paints. Find out more about what they discovered. What was the role of salmon eggs and how were they prepared?
3. Find out more about traditional paints and pigments around the world. How have paints changed over time in terms of safety, durability, and colour?
4. Many modern pigments contain compounds that are synthetic. This means that they were made rather than found. Choose one synthetic pigment. How is it made? What elements does it contain?

CONCEPT 2

Ionic compounds are made of ions.

Activity

Salt or Sugar?

Your teacher has a sample of salt and a sample of sugar. Without tasting them, how can you tell which is which? As a class, based on prior knowledge of these two compounds, come up with a test or tests you could conduct to distinguish between the two. With the help of volunteers, your teacher will conduct the tests and record the results. Which properties of salt and sugar are you testing for? What do you think accounts for the differences between salt and sugar?

ionic compound a compound made of oppositely charged ions

ionic bond a strong attraction that forms between oppositely charged ions

Compounds made of ions are called **ionic compounds**. Ionic compounds consist of regular arrangements of negatively charged ions and positively charged ions. The ions are held together with **ionic bonds**, which is the name for the attraction between oppositely charged ions. Ionic bonds are very strong.

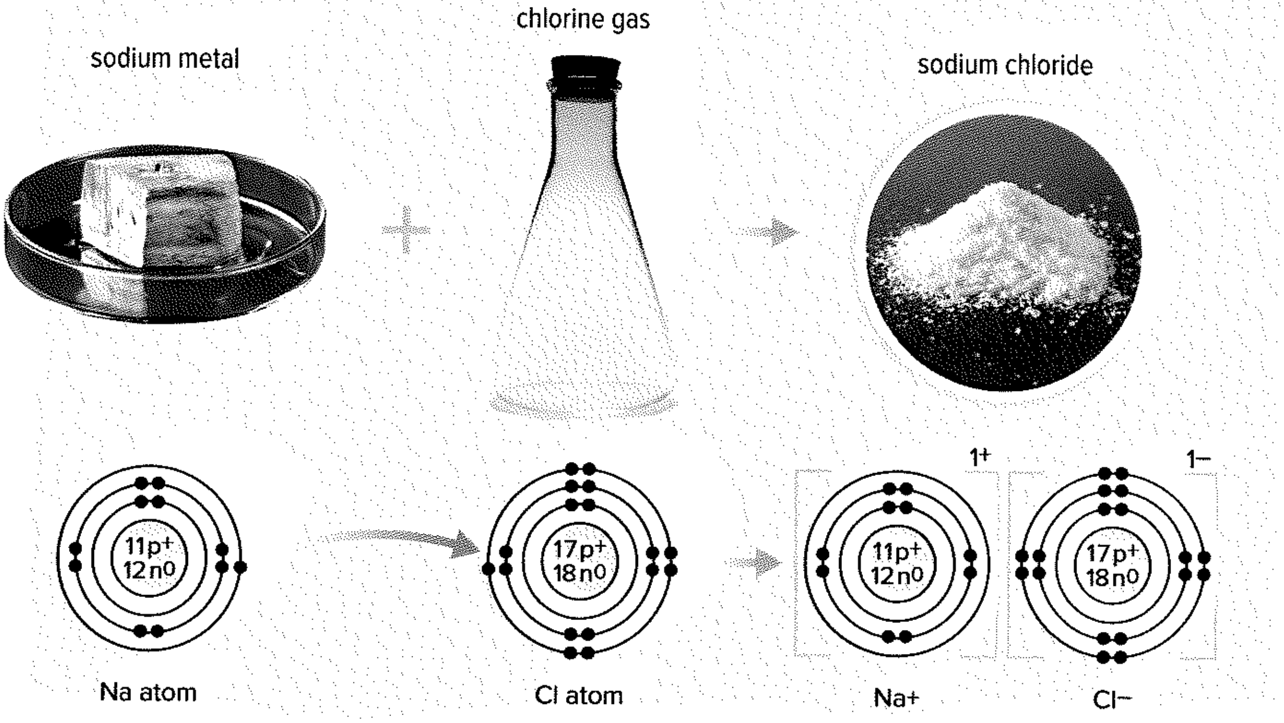
Formation of Ionic Compounds

The simplest types of ionic compounds are made up of two elements: a metal and a non-metal. Ionic compounds containing just two elements are called *binary ionic compounds*. These types of ionic compounds form when atoms of the metal element each lose one or more electrons to atoms of the non-metal element. For example, table salt—sodium chloride—forms when sodium atoms each transfer one electron to chlorine atoms. Each sodium atom becomes positively charged, a positive ion: Na^+. Each chlorine atom becomes negatively charged, a negative ion: Cl^-. This is what happens when sodium metal reacts with chlorine gas to form sodium chloride, as shown in Figure 2.23.

Why do ionic compounds form? In binary ionic compounds, neutral atoms of metals transfer the electrons in their valence shells to neutral atoms of non-metals. This transfer results in full valence shells for the oppositely charged ions that are formed. The stability of a full valence shell is what drives the formation of compounds.

To analyze what happens when ionic compounds form, recall what you have learned about the electron arrangements of elements in the different groups of the periodic table. How can atoms of alkali metals or halogens achieve full valence shells? Explore these questions in the Activity on the next page.

Figure 2.23 A sodium atom loses one electron to a chlorine atom, forming a sodium ion, Na^+, and a chloride ion, Cl^-. These ions are strongly attracted to each other. **What do you notice about the valence shells of the sodium ion and the chloride ion?**



Activity

Patterns in Ion Formation

Examine the periodic table to learn how elements in various groups form ions.

11 1+
Na
sodium
23.0

1. Take a look at the periodic table. Notice that many of the element cells have one or more charges listed in the upper right-hand corner. What are these charges?
2. Look at the groups (vertical columns) of the periodic table. What patterns in ion charges do you notice?
3. What ions are formed by the atoms of elements from Groups 1, 2, 16, 17, and 18? Make generalizations for each group.
4. Think about what you know about the electron arrangement for atoms of each element. How would you explain the patterns in ion formation that you have noticed?
5. Many elements of the periodic table have ion charges listed. What do these charges mean? Do these elements always exist as ions? Explain your answer.

The Structure of Ionic Compounds

Ionic compounds consist of positive and negative ions arranged in regular repeating patterns called *lattices*. The cube-shaped, or *cubic*, structure of sodium chloride is an example of a lattice. Notice the cubic shape of the sodium chloride crystals in the magnified image in Figure 2.24. This shape reflects the underlying lattice structure of the ionic compound.

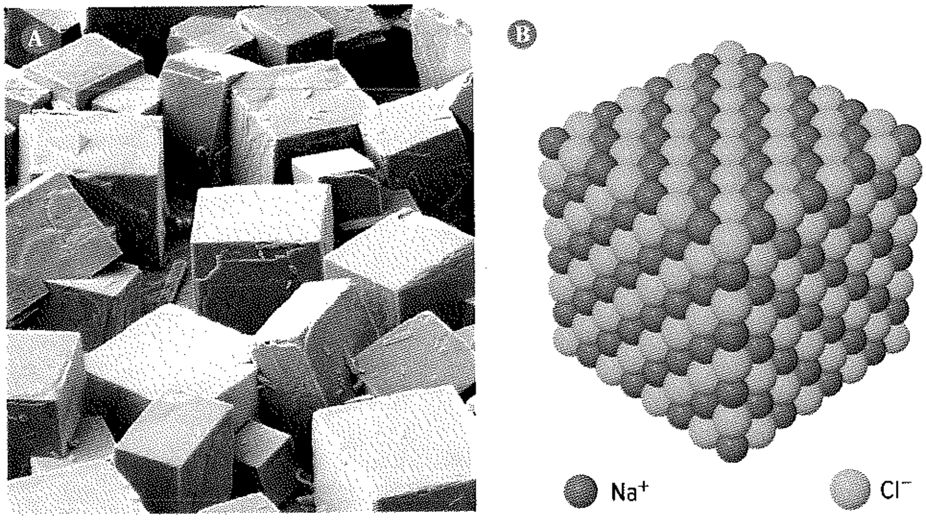


Figure 2.24 Ⓐ This image shows the cubic structure of sodium chloride crystals. Each crystal contains millions and millions of sodium ions and chloride ions. Ⓑ Sodium chloride crystals consist of sodium and chloride ions arranged in a repeating pattern. **Sodium chloride is made of charged particles, but the compound overall has no charge. Why?**

Properties of Ionic Compounds

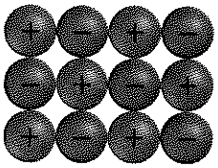
Although ionic compounds have a wide variety of properties, they all have high melting points. They tend to be hard and brittle, breaking along sharp lines. In addition, they are good conductors of electric current when melted or dissolved. These characteristics can all be explained by the structure of ionic compounds.

What are some typical properties of ionic compounds? Ionic compounds ...

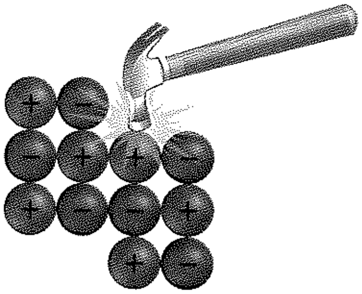
- *Have high melting points:* To melt an ionic compound requires overcoming the strong electrostatic forces holding the ions together in the lattice structure of the solid—the ionic bonds. Because these bonds are so strong, a great deal of energy is required to break them. As a result, ionic compounds tend to melt only at very, very high temperatures. For example, the melting point of sodium chloride is 801°C.

- *Are hard and brittle:* Because of the strength of ionic bonds, ionic solids are very hard. But when enough force is applied, the ions will shift out of alignment. This causes ions with the same charge to be close together. The resulting repulsive force pushes the solid apart, as shown in Figure 2.25.
- *Conduct electric current when liquid or dissolved:* Ionic compounds are not electrical conductors in the solid state, as shown in Figure 2.26. Even though they are made of ions, those ions are held rigidly in place, and charged particles that can move are required to conduct an electric current. Ionic compounds dissolved in water or melted ionic compounds do, however, conduct electric current. In those forms, the ions in an ionic compound are free to move and can therefore conduct electric current.

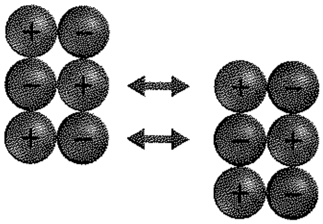
Figure 2.25 When a force strong enough to overcome the strong forces of attraction between oppositely charged ions is applied, ions with like charges come close together. They repel one another and the solid cracks.



Undisturbed ionic crystal

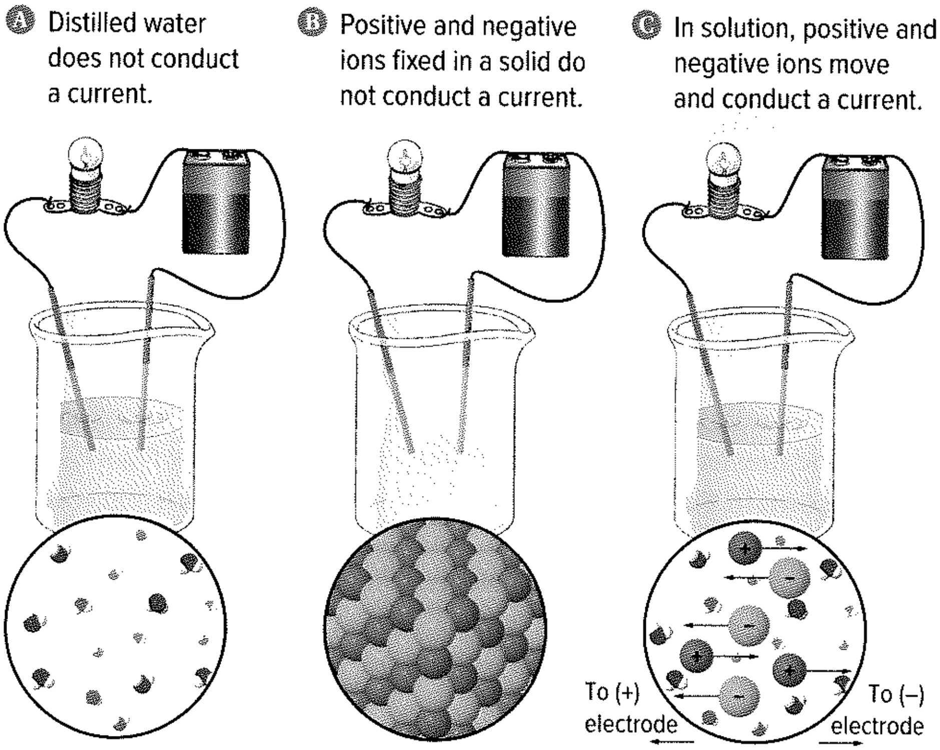


Applied force realigns particles.



Forces of repulsion break crystal apart.

Figure 2.26 Electric current is the flow of charged particles. In solid form, ionic compounds do not conduct electric current because the ions are held tightly in place. But when dissolved in water, ionic compounds are good conductors because the ions are free to move around.



Ⓐ Distilled water does not conduct a current.

Ⓑ Positive and negative ions fixed in a solid do not conduct a current.

Ⓒ In solution, positive and negative ions move and conduct a current.

Before you leave this page . . .

1. What is an ionic bond?
2. Describe the formation of sodium chloride from sodium and chlorine.
3. Binary ionic compounds form when which two types of elements react?
4. When do ionic compounds conduct electric current? Explain.

CONCEPT 3

Covalent compounds are made of molecules.

Activity

Model a Compound

Your teacher will assign you an ionic or covalent compound. Research the structure of the compound. Is it made of molecules? ions? How are they arranged? Then plan how you will make your model. You may choose to use a modelling kit, craft supplies, computer software, beadwork, or collage, for example. Your model should communicate something meaningful about the structure of your compound. Display your model along with a brief description of your compound.

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

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

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

Water, sugar, and carbon dioxide may seem like very different substances. Water is a clear, colourless liquid at room temperature, while sugar is a white solid and carbon dioxide is a colourless gas. But they are all composed of neutral atoms of non-metal elements joined together as molecules. A **molecule** is a particle made up of two or more neutral atoms bonded together by covalent bonds. Unlike ionic bonds, which form when atoms transfer electrons and become ions, **covalent bonds** form when atoms *share* electrons. Covalent bonds and ionic bonds are similar, however, in that they are both very strong. Compounds that form when atoms of two or more elements form covalent bonds are called **covalent compounds**. A molecule of water, a covalent compound, consists of two hydrogen atoms and one oxygen atom bonded together as shown in Figure 2.27.

As shown in Figure 2.28, a covalent bond is similar in some ways to a never-ending tug of war. Each team (atom) tries to pull the rope (shared electrons) toward itself. Neither side wins, and the bond is the rope that connects them. Figure 2.29 on the next page shows some examples of covalent compounds and the molecules that make them up.

Figure 2.27 Water molecules consist of two hydrogen atoms bonded to one oxygen atom.

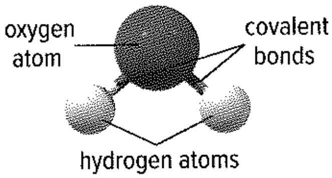
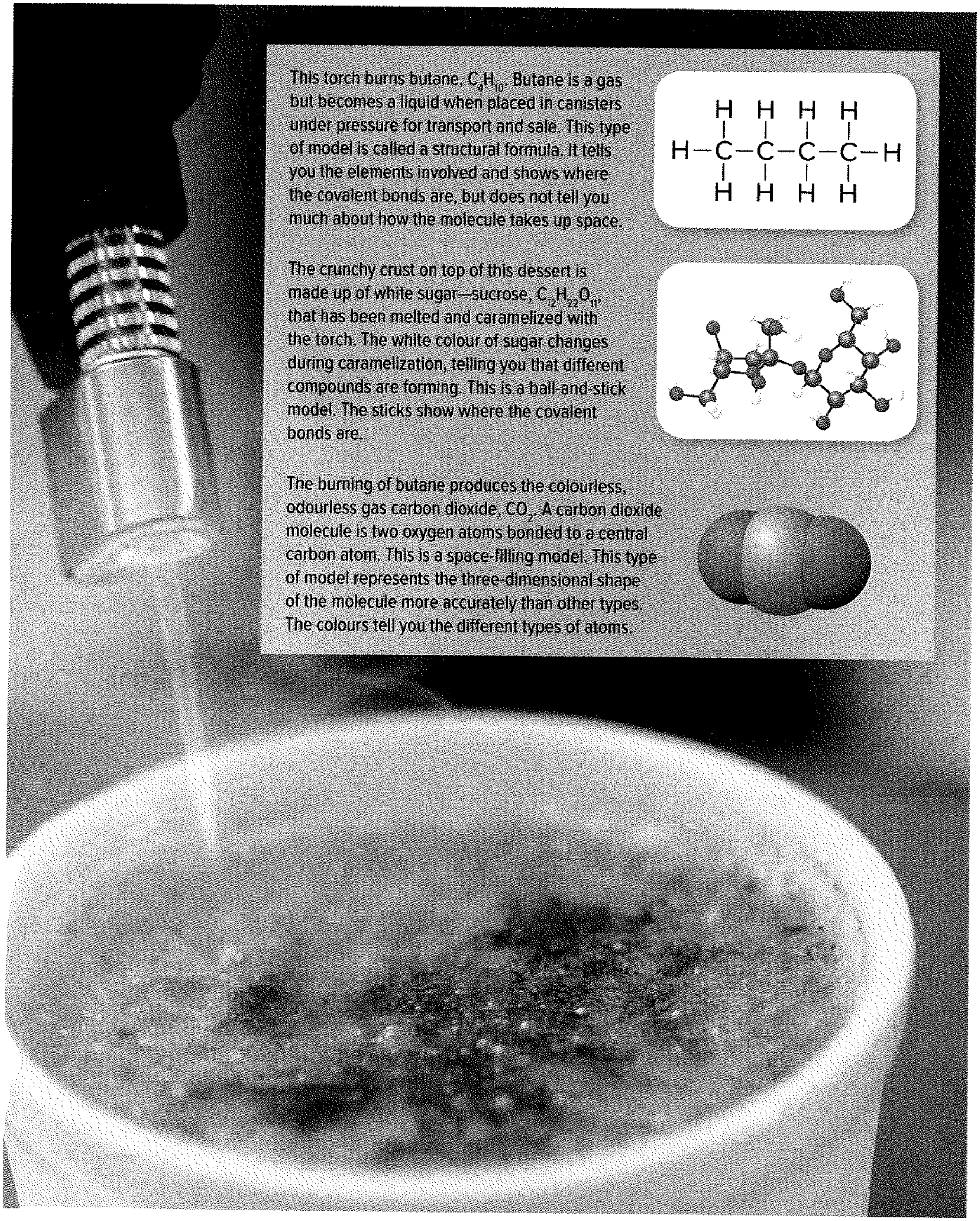


Figure 2.28 A covalent bond is like a tug-of-war in which both atoms attract the shared electrons.

Figure 2.29 Several examples of covalent compounds and the molecules that make them up are shown here using three different types of models. **Which type of model do you find most helpful for understanding the structure of molecules? Explain.**



This torch burns butane, C_4H_{10}. Butane is a gas but becomes a liquid when placed in canisters under pressure for transport and sale. This type of model is called a structural formula. It tells you the elements involved and shows where the covalent bonds are, but does not tell you much about how the molecule takes up space.

The crunchy crust on top of this dessert is made up of white sugar—sucrose, $C_{12}H_{22}O_{11}$, that has been melted and caramelized with the torch. The white colour of sugar changes during caramelization, telling you that different compounds are forming. This is a ball-and-stick model. The sticks show where the covalent bonds are.

The burning of butane produces the colourless, odourless gas carbon dioxide, CO_2. A carbon dioxide molecule is two oxygen atoms bonded to a central carbon atom. This is a space-filling model. This type of model represents the three-dimensional shape of the molecule more accurately than other types. The colours tell you the different types of atoms.

Achieving Stability by Sharing Electrons

The formation of a covalent compound is based on the same principle as the formation of an ionic compound: namely, the stability that is associated with a full valence shell. Instead of transferring electrons, however, non-metals in covalent compounds achieve a full valence shell by sharing electrons. Figure 2.30 shows how electrons are shared in a molecule of water. Notice that the hydrogen atoms achieve a full valence shell of two electrons, while the oxygen atom achieves a full valence shell of eight electrons. A covalent bond is the result of a single pair of shared electrons. Table 2.4 compares how different types of elements achieve stability in compounds.

Figure 2.30 Each hydrogen atom contributes a single electron to the shared pair of electrons in its covalent bond with oxygen.

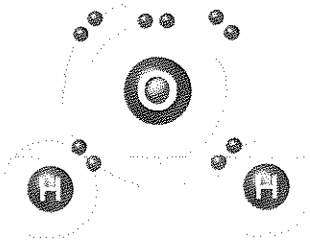
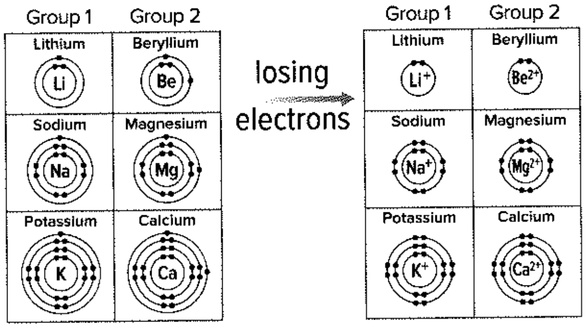
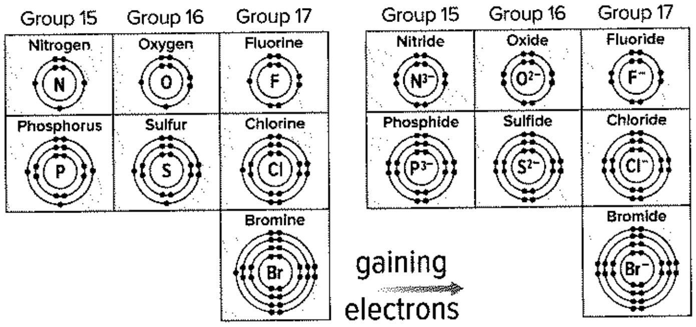
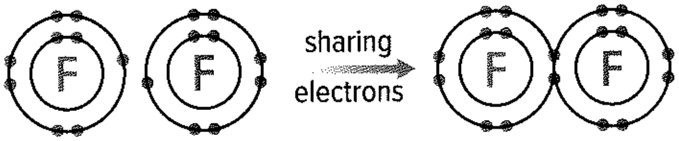


Table 2.4 **Three Ways That Atoms Become Stable**

1. Metals may lose electrons to form positive ions. The charge on the Group 1 metal ions is 1+ because they have lost one electron. The Group 2 metal ions have a charge of 2+, and the Group 3 metal ions have a charge of 3+.		Metals atoms can lose electrons to achieve a full valence shell. They form positive ions because they lose electrons but retain the same number of protons in the nucleus.
2. Non-metals may gain electrons to form negative ions. The charge on the Group 17 non-metal ions is 1− because they have gained one electron. The Group 16 non-metal ions have a charge of 2−, and the Group 15 nonmetal ions have a charge of 3−.		Non-metal atoms can gain electrons to achieve a full valence shell. They form negative ions because they gain electrons. Non-metal ion names end in "-ide."
3. Non-metals may share electrons.		Non-metal atoms can share electrons with other non-metal atoms to achieve a full valence shell.

Properties of Covalent Compounds

Connect to Investigation 2-F on pages 152–153

Covalent compounds have widely varying properties. The plastic casing of a ballpoint pen, the components of gasoline, the strongly scented compounds in a banana, and the carbon dioxide that we exhale with every breath are all covalent compounds. But there are some properties that many covalent compounds share, due to their structure at the molecular level. Covalent compounds ...

- *Have low melting points:* Although the forces that hold atoms together in molecules are very strong, the bonds that attract one molecule to another in a covalent compound are relatively weak, as modelled in Figure 2.31. When you melt or vaporize a covalent compound, you need to supply enough energy to overcome the attraction between the molecules. Because this attraction is weak, most covalent compounds boil and melt at relatively low temperatures.
- *Are relatively soft:* The weakness of the forces between molecules also explains the relative softness of covalent compounds. Compared with ions in ionic compounds, it is easier for molecules to shift and move relative to one another.
- *Are poor conductors:* Unlike ionic compounds, covalent compounds do not have free electrons or ions, and they are relatively poor conductors of electric current and heat. Figure 2.32 shows an application of this property.

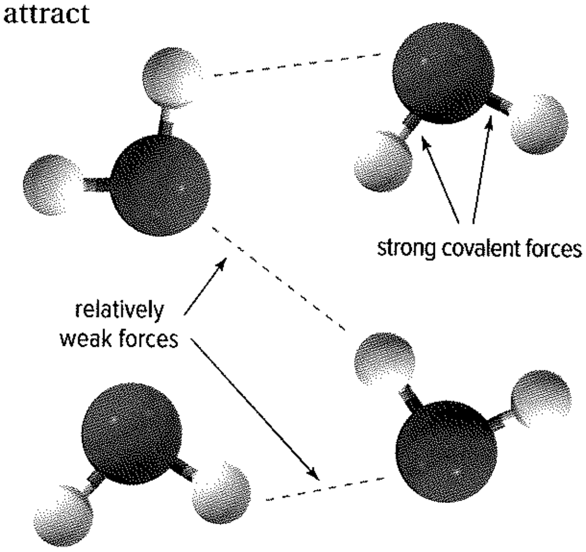


Figure 2.31 The forces that hold atoms together in molecules—covalent bonds—are very strong. Compared with these strong covalent bonds, the forces that hold one molecule to another in a liquid or solid are weak.

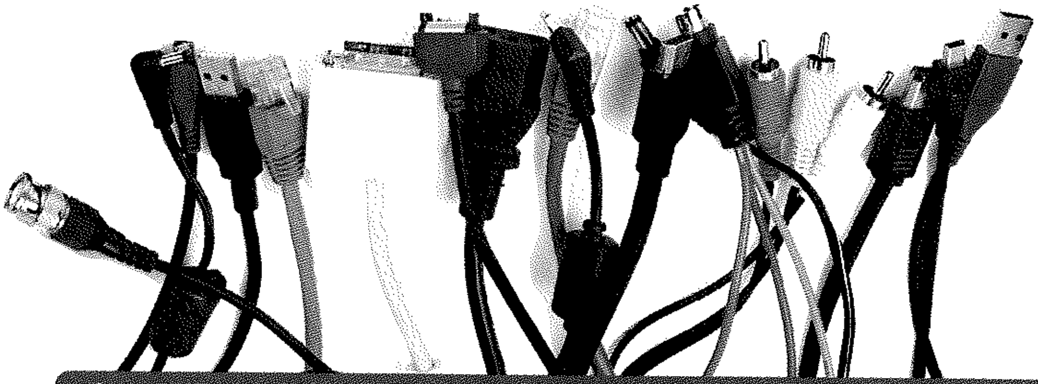


Figure 2.32 Covalent compounds are poor conductors of electric current. This makes them useful as insulating covers for computer cables. **Why is it important that covers for electrical wires not conduct electric current?**

Before you leave this page . . .

1. What type of bond is formed when two non-metal atoms share electrons?
2. What is a molecule?
3. Why do covalent compounds tend to have low melting points?

CONCEPT 4

Covalent bonding also occurs in elements and network solids.

Activity

Dare to Pair

What common items can you think of that come in pairs? Write or sketch as many as you can in one minute. Keep these in mind as you learn about paired atoms in molecules on this page. Which images will help you remember what you learn?

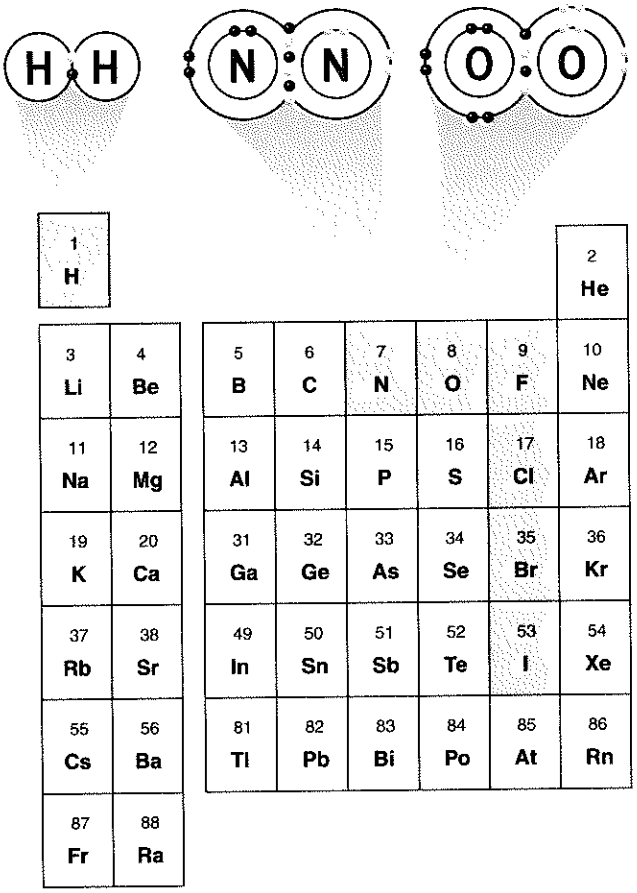


Figure 2.33 Seven of the elements exist as diatomic molecules under normal conditions: H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2. Bohr diagrams of hydrogen, nitrogen, and oxygen are shown as examples.

Compounds are not the only place where covalent bonds exist. Some elements in their natural form are made up of molecules held together with covalent bonds. Hydrogen, H_2, and all of the common halogens are diatomic molecules when they are isolated as pure elements under normal conditions (F_2, Cl_2, Br_2, I_2). Atoms of these elements share one electron in a covalent bond. Oxygen and nitrogen also exist as diatomic molecules. As shown in Figure 2.33, two oxygen atoms share two pairs of electrons to form two covalent bonds: a *double bond*. Two nitrogen atoms share three pairs of electrons to form three covalent bonds: a *triple bond*.

Atoms of the element sulfur also form molecules. In solid form the molecules have eight sulfur atoms each, S_8. In gaseous form sulfur exists as diatomic molecules, S_2.

Network Solids

Some compounds and non-metal elements contain covalent bonds that connect their atoms in one large network. Essentially, these substances consist of one giant molecule. Compounds or elements that are bonded in this way are called *network solids*. Silicon dioxide, SiO_2, is an example of a compound network solid. You can see the structure of silicon dioxide in Figure 2.34.

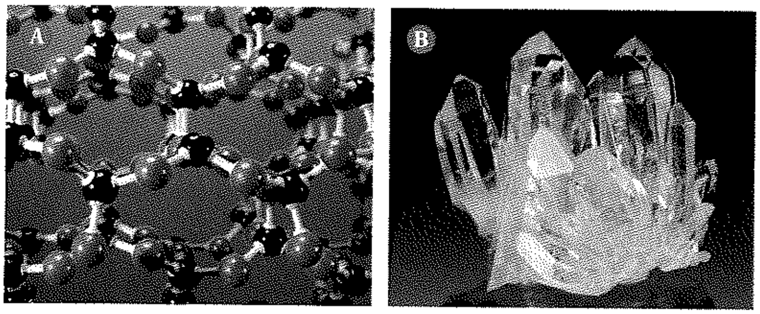
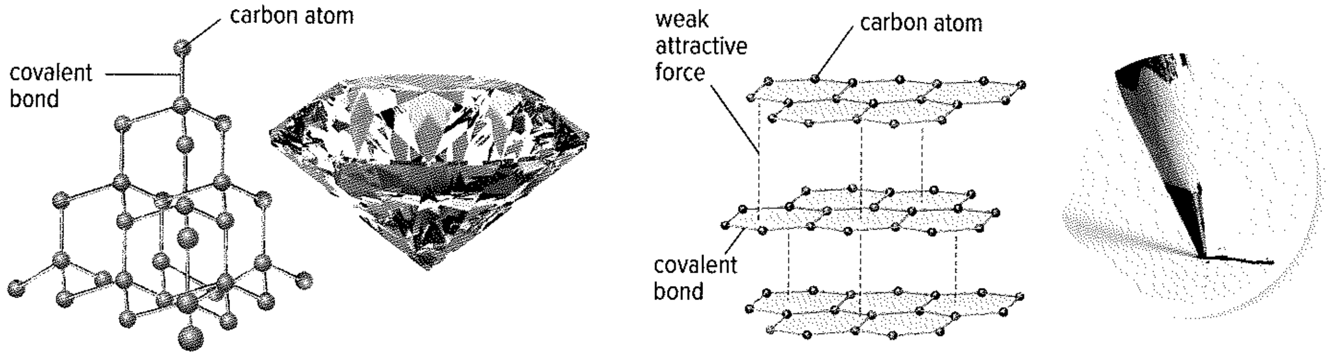


Figure 2.34 Ⓐ Silicon dioxide, quartz, is a network solid. Its atoms are bonded into a regular, repeating structure by covalent bonds. This model shows a small part of the structure. In real quartz crystals like the ones shown in Ⓑ, billions of atoms are bonded together in this same repeating structure, forming one giant molecule.

Carbon in the form of diamond is an example of an element that is a network solid. Carbon comes in a number of different forms, including diamond, graphite, and coal. As you can see in Figure 2.35, each carbon atom in a diamond crystal is bonded to four other carbon atoms by covalent bonds, forming an extremely strong three-dimensional structure. In graphite, each carbon atom forms covalent bonds with three other carbon atoms, forming sheets. These sheets are only weakly attracted to one another and can slide past one another. This is why graphite is a good material to use for pencils: as you write on paper, layers of graphite slide off the pencil tip and onto the page.

Figure 2.35 Diamond and graphite both contain covalent bonds but have very different properties due to their structure. **Think about the properties of coal, another form of carbon. How do you think it is structured? Make a prediction, then research to find out.**



Diamond

In a diamond, carbon atoms bond to one another in a three-dimensional network. Because of the strength of the bonds in three dimensions, diamond is an extremely hard material.

Graphite

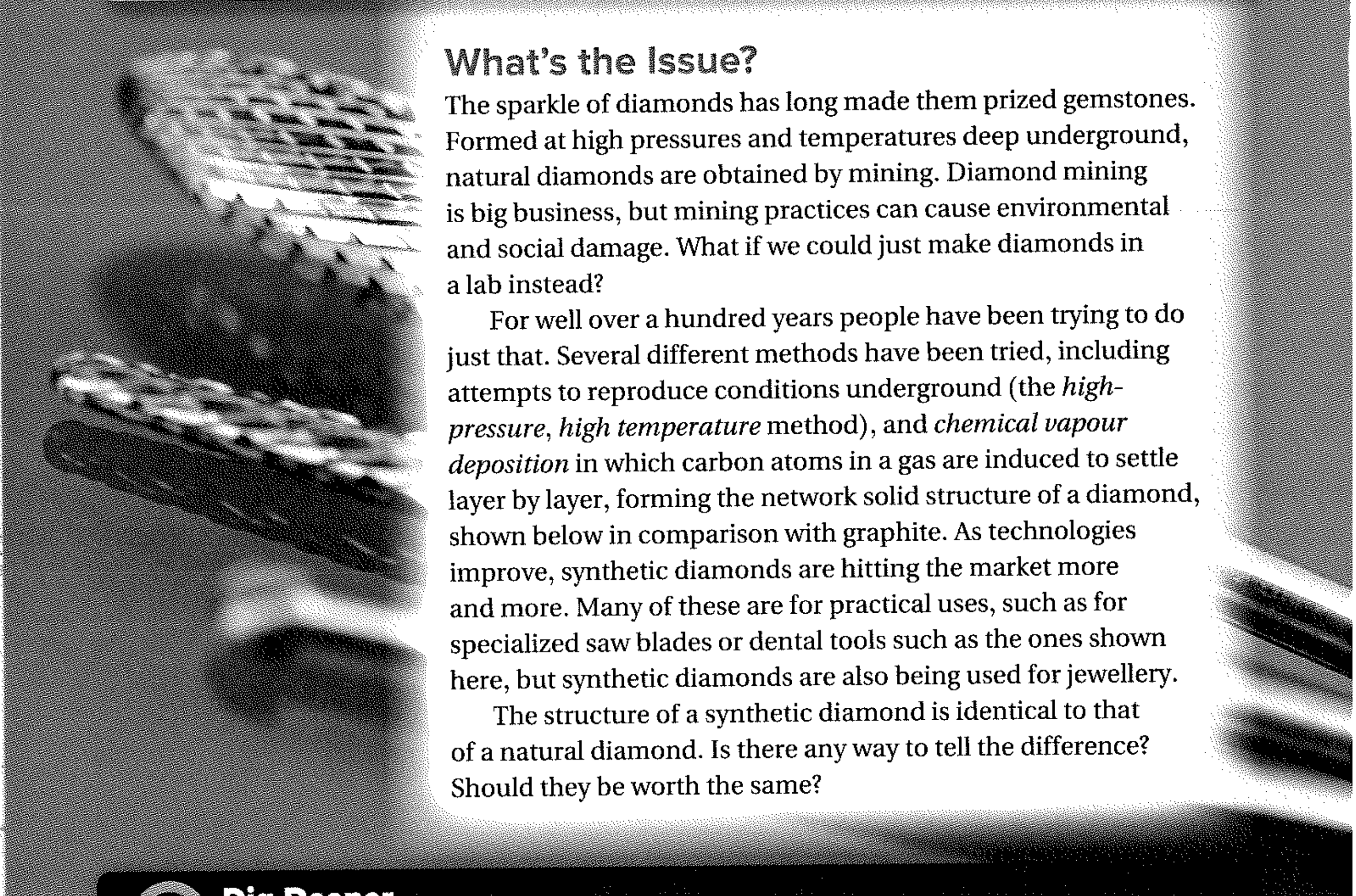
Graphite is made up of carbon atoms that are each bonded to three other carbon atoms, forming flat sheets. The sheets can slide past one another relatively easily.

Before you leave this page . . .

1. Describe a molecule of hydrogen.
2. Why does neon gas consist of individual, unbonded neon atoms while chlorine exists as diatomic chlorine molecules?
3. What is a network solid?

AT ISSUE

Is a synthetic diamond a real diamond?



What's the Issue?

The sparkle of diamonds has long made them prized gemstones. Formed at high pressures and temperatures deep underground, natural diamonds are obtained by mining. Diamond mining is big business, but mining practices can cause environmental and social damage. What if we could just make diamonds in a lab instead?

For well over a hundred years people have been trying to do just that. Several different methods have been tried, including attempts to reproduce conditions underground (the *high-pressure, high temperature* method), and *chemical vapour deposition* in which carbon atoms in a gas are induced to settle layer by layer, forming the network solid structure of a diamond, shown below in comparison with graphite. As technologies improve, synthetic diamonds are hitting the market more and more. Many of these are for practical uses, such as for specialized saw blades or dental tools such as the ones shown here, but synthetic diamonds are also being used for jewellery.

The structure of a synthetic diamond is identical to that of a natural diamond. Is there any way to tell the difference? Should they be worth the same?

Dig Deeper

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

1. Is there any difference between natural and synthetic diamonds? Can jewellers tell the difference? Why would people want to know which kind of diamond they are getting? Research to explore and discuss natural and synthetic diamonds from a seller, and consumer's points of view.
2. What are some of the social and environmental problems that traditional diamond mines cause? How do different diamond mines compare in terms of their social and environmental impact?
3. What is the difference between a synthetic diamond and a simulated diamond? Give examples of simulated diamonds and explain the difference in their structure. Why are simulated diamonds less costly to buy than real diamonds?
4. Graphite and diamond are two forms of carbon, but they are not the only ones. Carbon can also exist in the form of graphene, fullerene, and nanotubes. Choose one of these and research its structure, how it is made, and its applications.

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. In ionic compounds, Group 1 metals exist as ions with charges of 1+, while Group 2 metals exist as ions with charges of 2+. Why is this? PA C

2. Briefly describe the structure of a crystal of sodium chloride, NaCl. PA C

3. Iodine, I_2, reacts with potassium, K, to form potassium iodide, KI. PA C

- **a)** What type of compound is formed? How do you know?
- **b)** Describe what is happening to the atoms of potassium and iodine and their electrons during bonding.

4. Someone on the news is talking about the compound magnesium chloride, $MgCl_2$, and refers to "molecules of magnesium chloride." What is wrong with this phrase? E C

5. At room temperature, many covalent compounds exist as liquids or gases, while ionic compounds are all solids. Why is this? PA C

6. Seven elements exist as diatomic molecules. PA C

- **a)** List the seven elements.
- **b)** Why do the halogens exist as diatomic molecules while the noble gases do not?

7. Classify each of the following compounds as ionic or covalent. Briefly explain your answers. PA C

- **a)** lithium fluoride, LiF
- **b)** nitrogen triiodide, NI_3
- **c)** bromine dioxide, BrO_2
- **d)** barium iodide, BaI_2

Connecting Ideas

8. Copy and complete the following table to show the differences between ionic and covalent compounds. Give your table a title. E C

Characteristic	Ionic Compounds	Covalent Compounds
Melting point		
Hardness		
Conductivity		
Types of elements		
Description of bonding		
Three examples		

Making New Connections

9. The conductivity of samples of deionized water, tap water, and ocean water were tested. The results are given below. The higher the value, the higher the conductivity. (Deionized water is water from which ions have been removed.) AI C

Conductivity of Water Samples

Sample	Conductivity
Deionized water	0.000 006
Tap water	0.005–0.05
Ocean water	5

- **a)** Which sample conducts electric current the best? The worst?
- **b)** Use your knowledge of covalent and ionic compounds to explain these results.

INVESTIGATION
2-F

STRUCTURED INQUIRY

Properties of Ionic and Covalent Compounds

Physical properties such as hardness and melting point can help you classify compounds as ionic or covalent. In this investigation, test six different compounds to determine whether they are ionic or covalent.

Question

How can you use properties to classify compounds as ionic or covalent?

Procedure

1. Label six test tubes A to F. Place samples of six different compounds in the test tubes. Use enough of each compound to fill the rounded bottom of the test tube.
2. Prepare a table like the one shown. It should take up one full page so you have enough space for all your observations. Give your table a title.

Substance	**A**	**B**	**C**	**D**	**E**	**F**
Crush / Hardness						
Melting						
Solubility						
Conductivity						
Total Score						

3. Perform the following tests on each compound. At each test step, analyze all the compounds before moving on to the next test. If a substance responds like a covalent compound, record a score of one (1). If a substance responds like an ionic compound, record a score of zero (0). Also record short, descriptive observations for each test in your table.
4. When you are finished, clean up and dispose of materials as directed by your teacher.

Skills and Strategies

- Planning and conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Review safety rules for working with a hot plate before you begin.

What You Need

- 6 test tubes with stoppers
- 6 samples of compounds
- glass plate or watch glass
- scoop
- plastic water bottle
- hot plate or laboratory burner
- distilled water
- conductivity tester
- tongs

Crush/Hardness Test

Place one or two grains of the compound on a glass plate or watch glass. Press on the compound with a scoop or another metal tool. Ionic compounds withstand considerable force and then crush suddenly into a gritty powder (score 0). Solid molecular compounds are often more flexible and crush like wax or plastic (score 1).

Solubility Test

Each test tube should still contain most of the original substance. Add 10 mL of distilled water to each of the test tubes. Stopper each test tube. Keeping your fingers on the stopper and test tube, gently shake or swirl the water and substance together. Many ionic compounds will dissolve in water, although there are exceptions (score 0). Many molecular solids are insoluble in water (score 1), although again there are exceptions.

Melting Test

Your teacher will use a hot plate or laboratory burner to test whether the compounds will melt. Observe carefully. Among the compounds that do melt, compare the time it took. Do any compounds vaporize? Ionic compounds do not melt except at very high temperatures (score 0). Many covalent compounds melt at relatively low temperatures (score 1).

Conductivity Test

Use a conductivity tester to test the conductivity of the solution in each test tube. When ionic compounds dissolve, the resulting solution will conduct electric current (score 0). When molecular compounds dissolve, the resulting solution will usually not conduct electric current (score 1). Make sure that you clean the probes of the conductivity tester between readings.

Process and Analyze

1. Add up the scores for each compound. A low score, near 0, indicates that a compound is ionic. A high score, near 5, indicates that the compound is covalent. What patterns do you see?
2. If a compound has a score of 2 or 3, use your descriptive observations to help you decide whether it is ionic or covalent.

Evaluate and Communicate

3. Summarize your classification of each substance, including a rationale for each decision.
4. What was the purpose of assigning a number to each test? Did the numbers have any scientific meaning?
5. If you could perform only two tests to identify ionic and covalent compounds, which two tests would you choose? Explain your thinking. If these tests are more important than the others for classifying, how could you reflect that in the scoring system if you were to perform the investigation again?
6. Your teacher will tell you the names and formulas of the compounds. What do the names and formulas tell you, if anything, about the compounds?
7. Examine the element symbols in the chemical formulas. What do you notice about the elements that are in the formulas for the ionic compounds compared to the elements that are in the formulas for the covalent compounds?

TOPIC 2.5

How do we name and write formulas for compounds?

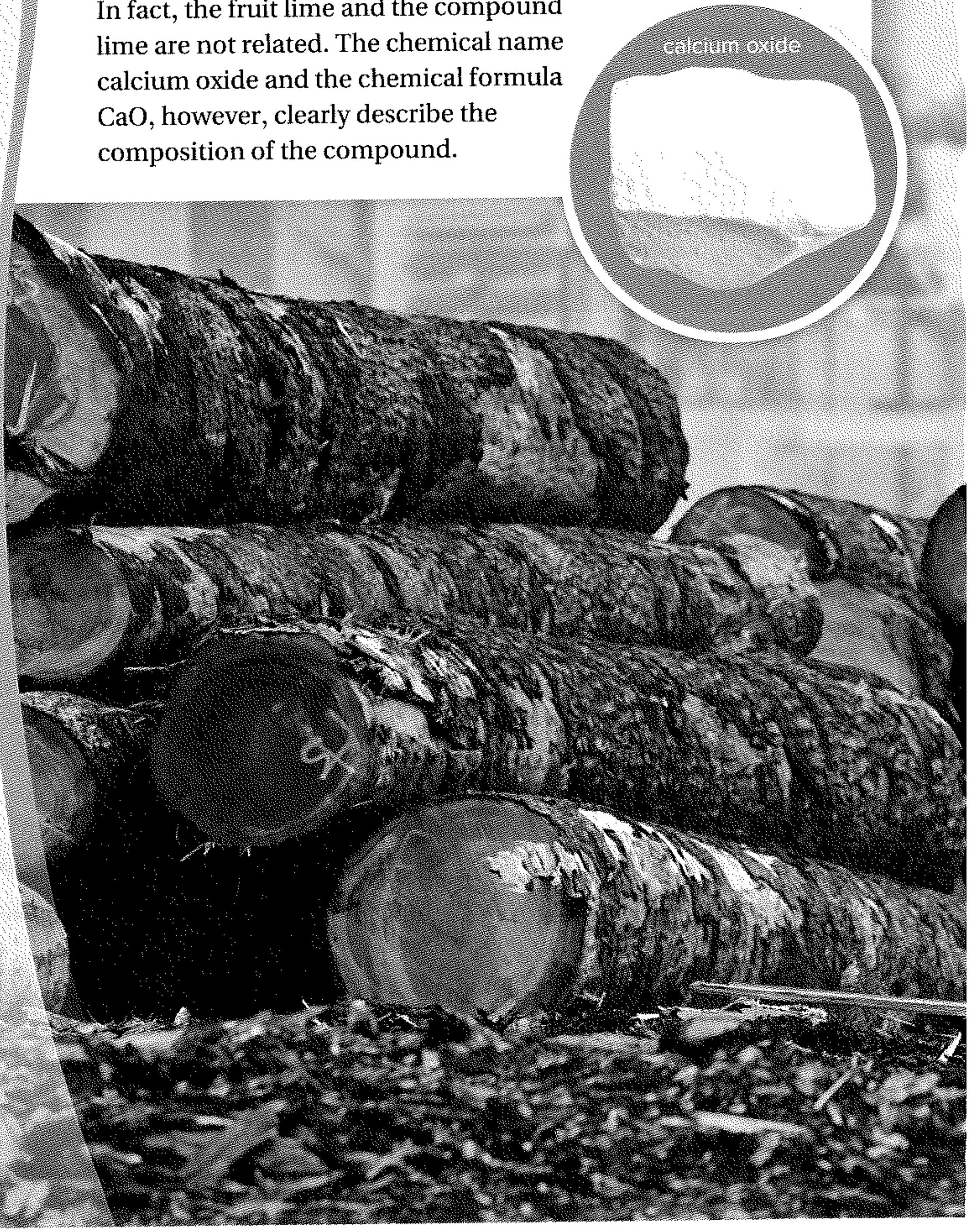
Key Concepts

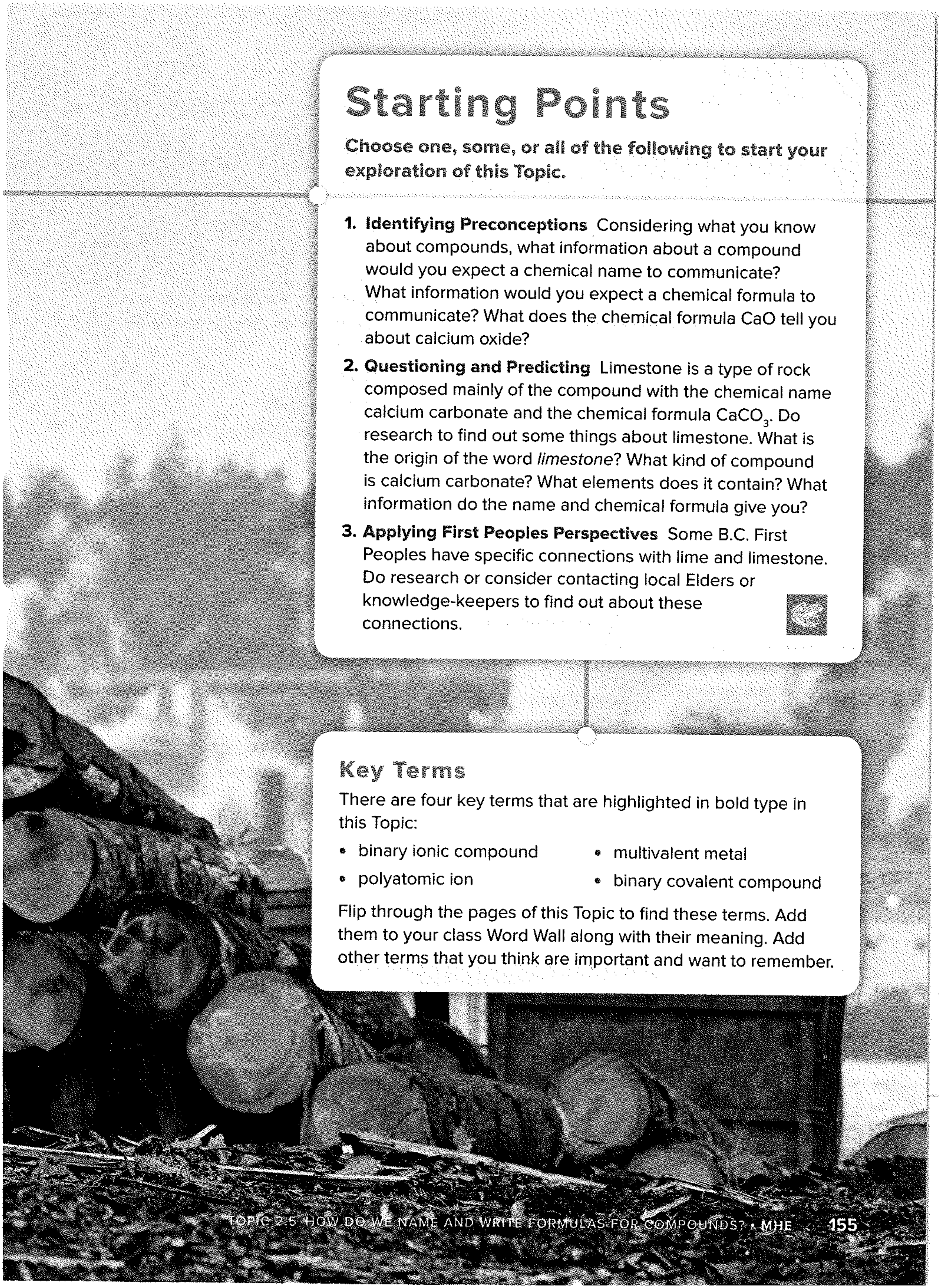
- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.

Curricular Competencies

- Transfer and apply learning to new situations
- Generate and introduce new or refined ideas when problem solving
- Contribute to finding solutions to problems at a local and/or global level through inquiry

What comes to mind when you hear the word *lime*? You may have pictured a small green citrus fruit. But lime is also the common name for a hugely important chemical with a broad variety of applications in farming, the food industry, and pulp and paper manufacturing, to name just a few. Chemists working with the compound lime know that it is an ionic compound composed of calcium and oxygen, but the name *lime*, its common name, does not communicate that. In fact, the fruit lime and the compound lime are not related. The chemical name calcium oxide and the chemical formula CaO, however, clearly describe the composition of the compound.





Starting Points

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

1. **Identifying Preconceptions** Considering what you know about compounds, what information about a compound would you expect a chemical name to communicate? What information would you expect a chemical formula to communicate? What does the chemical formula CaO tell you about calcium oxide?
2. **Questioning and Predicting** Limestone is a type of rock composed mainly of the compound with the chemical name calcium carbonate and the chemical formula $CaCO_3$. Do research to find out some things about limestone. What is the origin of the word *limestone*? What kind of compound is calcium carbonate? What elements does it contain? What information do the name and chemical formula give you?
3. **Applying First Peoples Perspectives** Some B.C. First Peoples have specific connections with lime and limestone. Do research or consider contacting local Elders or knowledge-keepers to find out about these connections.

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- binary ionic compound
- polyatomic ion
- multivalent metal
- binary covalent compound

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

The chemical name of an ionic compound communicates its composition.

Activity

Names in Everyday Life

Names are important in every part of our lives. Write a few sentences to explain the importance of names in each of the following aspects of your life. Why are clear, unique names important in each case?

- Getting around: streets, cities, towns, landmarks
- Communicating: conversation, social media, messaging
- Consuming: product and brand names; names of medications; names of books, songs, and movies

The large bulging mass around the person's neck in Figure 2.36 is called a goitre. These growths are caused by iodine deficiency. Goitres are uncommon today in developed countries because compounds containing the iodide ion, such as potassium iodide, KI, are added to our table salt. Before iodized table salt, goitres were common in Europe, but they were never common among coastal Aboriginal peoples of British Columbia. Why not? Traditional foods of coastal peoples include seaweed, a rich source of iodine. Potassium iodide is an example of a binary ionic compound. In chemistry, *binary* means "composed of two elements." **Binary ionic compounds** are composed of ions of one metal element and ions of one non-metal element joined by ionic bonds.

binary ionic compound a compound made up of ions of one metal element and ions of one non-metal element

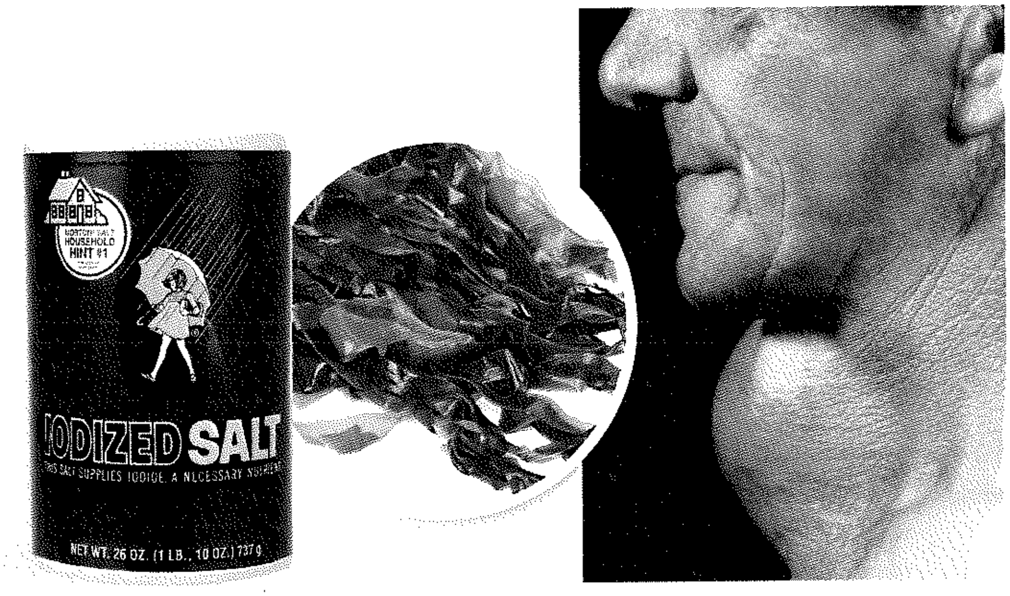


Figure 2.36 When a person does not take in enough iodine, their thyroid gland swells in an attempt to absorb as much iodine as possible, resulting in a goitre. To prevent iodine deficiency, iodine is added to table salt in the form of compounds containing the iodide ion, such as potassium iodide. Seaweed contains other compounds that include the iodide ion.

Names of Binary Ionic Compounds

The name of a binary ionic compound comes from the names of its elements, as described below.

- The first part of *potassium iodide* names the positive ion, potassium, K^+. The positive ion is always a metal in a binary ionic compound. The positively charged metal ion is always named first. Its name is the same as the name of its element.
- The second part of *potassium iodide* names the negative ion, iodide, I^-. The negative ion in a binary ionic compound is always a non-metal. The name of the negative ion in a binary ionic compound always ends with the suffix *-ide*. The negative ion of iodine is iodide.

Common negative ions of non-metals are shown in Table 2.5. The periodic table also lists ion charges.

Table 2.5 **Ions of Non-Metals**

Element	Ion	Symbol	Group
fluorine	fluoride	F^-	17
chlorine	chloride	Cl^-	17
bromine	bromide	Br^-	17
iodine	iodide	I^-	17
oxygen	oxide	O^{2-}	16
sulfur	sulfide	S^{2-}	16
selenium	selenide	Se^{2-}	16
nitrogen	nitride	N^{3-}	15
phosphorus	phosphide	P^{3-}	15

Extending the Connections

Where do the naming rules come from?

The international system for naming chemicals is maintained by the International Union of Pure and Applied Chemistry (IUPAC). Research to find out more about IUPAC, its history, its systems, and its members.

Before you leave this page . . .

1. Each of the following pairs of elements react to form a binary ionic compound. What is the name of the compound in each case?

a) lithium and oxygen

b) calcium and fluorine

c) magnesium and sulfur

d) rubidium and bromine

2. What is the difference between the name of a non-metal element and the name of the negative ion it forms?

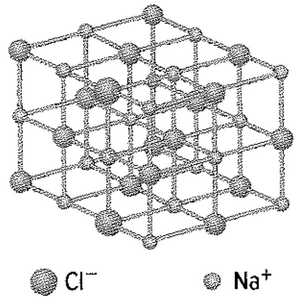
CONCEPT 2

You can determine the formula of an ionic compound from its name.

Activity

Ion Ratios

This diagram represents a crystal of sodium chloride. How does the structure of sodium chloride relate to its chemical formula? Follow these steps to find out:



1. Count the total number of ions of each element.
2. Compare the total number of positive ions with the total number of negative ions.
3. What is the ratio of positive ions to negative ions for each compound?
4. The chemical formula of sodium chloride is NaCl. The chemical formula of calcium chloride, another ionic compound, is $CaCl_2$. What ratio of ions would you expect to see in calcium chloride?

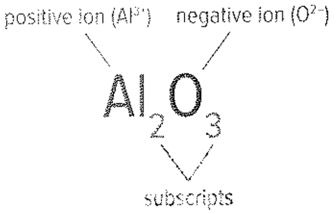


Figure 2.37 Formulas for ionic compounds are always written with the positive ion first and the negative ion second. In binary ionic compounds, the positive ion is a metal ion and the negative ion is a non-metal ion.

The chemical formula of a binary ionic compound contains element symbols to identify each ion. The positively charged metal ion comes first and the negatively charged non-metal ion comes second, as shown in Figure 2.37. Some formulas have small numbers, called subscripts, written to the right of one or both symbols. The subscripts indicate the ratio of each type of ion in the compound. If no subscript is shown, you assume the number to be 1. For example, the formula Ag_2O means Ag_2O_1. The chemical formula for an ionic compound represents the smallest repeating part of the crystal lattice. This unit is called the *formula unit* for that compound. Examine Figure 2.38 to see some examples of chemical formulas of binary ionic compounds, and their meanings.

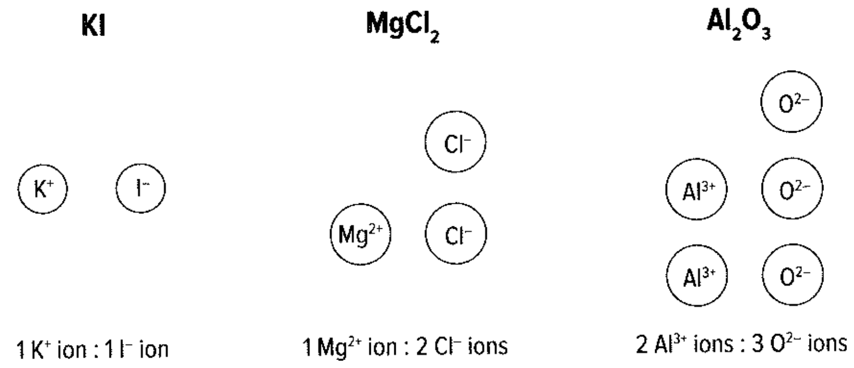


Figure 2.38 The subscripts in chemical formulas of ionic compounds tell you the ratio of the ions in the compound.

Writing Formulas of Ionic Compounds

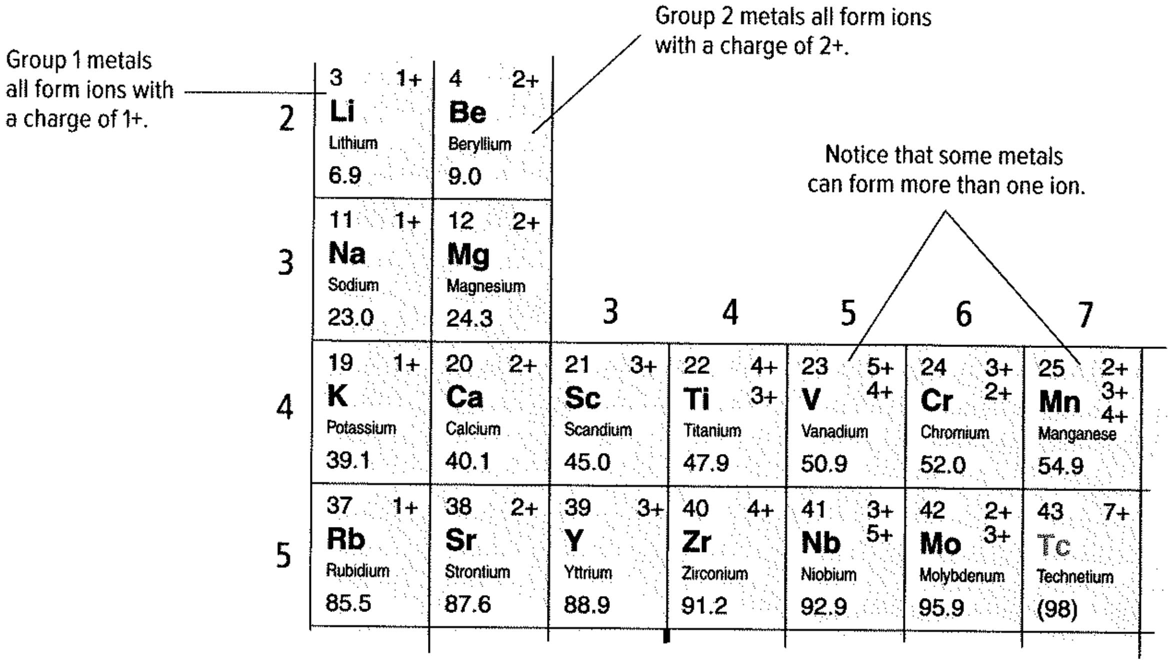
Although an ionic compound is made up of ions, overall the compound is electrically neutral—it has no charge. So the positive charges on the metal ions must balance the negative charges on the non-metal ions. For example, in aluminum oxide, there are two aluminum ions, Al^{3+}, and three oxide ions, O^{2-}. What is the total charge?

Charge from Al^{3+} ions	**Charge from Cl^{-} ions**
There are 2 aluminum ions in the formula, each with a charge of 3+. 2 × (3+) = 6+	There are 3 oxide ions in the formula, each with a charge of 2−. 3 × (2−) = 6−

Total charge: (6+) + (6−) = 0

When writing the formula of a binary ionic compound, you first need to determine the charges on the ions. Table 2.5 lists the ions of non-metals. For metals that form only one type of ion, all you need to do to figure out the ion charge is to look at the periodic table, as shown in Figure 2.39. (You can find the charges for non-metal ions on the periodic table, too.) Once you know the charges, you can figure out the formula.

Figure 2.39 The periodic table lists the charges of ions commonly formed by the various elements.



			3	4	5	6	7
2	3 1+ **Li** Lithium 6.9	4 2+ **Be** Beryllium 9.0					
3	11 1+ **Na** Sodium 23.0	12 2+ **Mg** Magnesium 24.3					
4	19 1+ **K** Potassium 39.1	20 2+ **Ca** Calcium 40.1	21 3+ **Sc** Scandium 45.0	22 4+ 3+ **Ti** Titanium 47.9	23 5+ 4+ **V** Vanadium 50.9	24 3+ 2+ **Cr** Chromium 52.0	25 2+ 3+ 4+ **Mn** Manganese 54.9
5	37 1+ **Rb** Rubidium 85.5	38 2+ **Sr** Strontium 87.6	39 3+ **Y** Yttrium 88.9	40 4+ **Zr** Zirconium 91.2	41 3+ 5+ **Nb** Niobium 92.9	42 2+ 3+ **Mo** Molybdenum 95.9	43 7+ Tc Technetium (98)

Sample Problem

Writing the Formulas of Ionic Compounds

What are the chemical formulas of each of these compounds?

a) calcium chloride

b) aluminum sulfide

Solutions

a) calcium chloride

1. Identify each ion and its charge.

Calcium is a Group 2 metal, so its ion charge is 2+: Ca^{2+}

Chlorine is a Group 17 non-metal, so its ion charge is 1−: Cl^{-}

2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two chloride ions are needed to balance the positive charge on a calcium ion.

Charge from Ca^{2+}	Charge from Cl^{-}
A calcium ion has a charge of 2+. $1 \times (2+) = 2+$	A chloride ion has a charge of 1−. Therefore, two chloride ions are needed to balance the charge of one calcium ion. $2 \times (1-) = 2-$

3. Use subscripts to write the formula. Remember to write the metal ion first. Do not include a subscript if the subscript would be "1."

The formula for calcium chloride is $CaCl_2$.

b) aluminum sulfide

1. Identify each ion and its charge.

From the periodic table, the aluminum ion is Al^{3+}.

Sulfur is a Group 16 non-metal, so its ion charge is 2−: S^{2-}

2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two aluminum ions are needed to balance the charges on three sulfide ions.

Charge from Al^{3+}	Charge from S^{2-}
An aluminum ion has a charge of 3+. The lowest common multiple of 3 and 2 is 6. To get 6+, multiply 3+ by 2. $2 \times (3+) = 6+$	A sulfide ion has a charge of 2−. To get 6−, multiply 2− by 3. $3 \times (2-) = 6-$

3. Use subscripts to write the formula. Remember to write the metal ion first.

The formula of aluminum sulfide is Al_2S_3.

Practice Problems

1. Write the formulas of the ionic compounds containing the following ions.
   - **a)** Na^+ and Br^-
   - **b)** K^+ and S^{2-}
   - **c)** Zn^{2+} and I^-
   - **d)** Mg^{2+} and N^{3-}
2. Write the formulas of the following ionic compounds.
   - **a)** sodium iodide
   - **b)** zinc oxide
   - **c)** magnesium chloride
   - **d)** potassium selenide
   - **e)** silver sulfide
   - **f)** aluminum iodide
   - **g)** aluminum phosphide
   - **h)** barium phosphide
   - **i)** calcium sulfide
   - **j)** rubidium bromide
3. Silver iodide has a crystal structure similar to ice and can cause water to freeze. It has been used in rainmaking experiments, in which it is released into clouds to try to induce precipitation. A silver iodide generator is shown in Figure 2.40. What is the chemical formula of silver iodide?

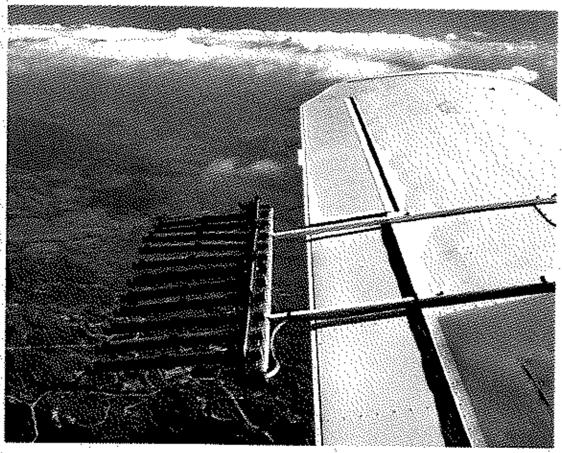


Figure 2.40 Silver iodide generators are designed for cloud seeding.

Extending the Connections

A Grain of Salt

Sodium chloride, ordinary table salt, is probably the most familiar of ionic compounds. Although salt is inexpensive and plentiful today, this was not always the case. Why was salt so expensive in the past? Where did people get salt in the past? How do we get salt today? What is the role of sodium chloride in the human body? What happens when you get too much? Choose one or more of these questions to investigate.

Connect to Investigation 2-G on page 174

Before you leave this page . . .

1. What is a formula unit and how does it relate to the formula for an ionic compound?
2. Even though ionic compounds are made up of charged particles, they are electrically neutral. Why is this?

CONCEPT 3

Multivalent metals form more than one ion.

multivalent metal a metal element that can form two or more types of ions with different charges

As you can see when you examine the periodic table, some metals form more than one type of ion. Such metals are called **multivalent metals**. For example, copper can form ions with a 1+ or 2+ charge, as shown in Figure 2.41. To distinguish between the ions, a Roman numeral is written after the name of the metal. For example, Cu^+ is written as copper(I), pronounced "copper one." Cu^{2+} is written as copper(II), pronounced "copper two." On the periodic table, the ion charges for a given element are listed with the most common charge at the top and the least common charge at the bottom.

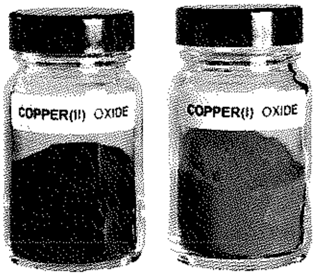


Figure 2.41 Although both of these compounds contain copper and oxygen, copper(II) oxide, CuO, is black and copper(I) oxide, Cu_2O, is red.

Naming and Writing Formulas for Ionic Compounds Containing Multivalent Metals

To write the chemical formula of a multivalent metal, follow the same process as for the binary ionic compounds you have been naming so far. The only difference is that you cannot tell the charge on the metal ion by looking at the periodic table because there is more than one choice. Instead, look at the Roman numeral in the name, which will tell you the charge.

The Roman numerals for charges 1+ through 7+ are given in Table 2.6. For example, the name chromium(III) chloride tells you that the chromium ion in the compound is Cr^{3+}. The chloride ion is Cl^-. For a neutral compound, there must be three chlorine ions for every one chromium ion, so the formula is $CrCl_3$. When naming a compound that contains a multivalent ion, you must include a Roman numeral to show which charge the ion has. Sample Problem on the next page shows how.

Table 2.6 **Roman Numerals**

Metal Ion Charge	Roman Numeral
1+	I
2+	II
3+	III
4+	IV
5+	V
6+	VI
7+	VII

Sample Problem

Naming an Ionic Compound with a Multivalent Metal

The compound Fe_2O_3 is the main source of iron in the making of steel, which in turn is used for a huge number of applications, from cutlery to freighters like the one shown in Figure 2.42. Pure Fe_2O_3 is reddish in colour and is used as a pigment in paints. What is the name of Fe_2O_3?

Solution

1. Identify the ions.
   - The ion of iron may be either Fe^{2+} or Fe^{3+}.
   - The ion of oxygen is O^{2-}.
2. Determine the ratio of ions in the compound.
   - According to the formula, the compound has 2 iron ions for every 3 oxide ions.
3. The negative charges and the positive charges must be equal in magnitude for the compound to be electrically neutral. Determine which of the two possible iron ions achieves this balance.
   - Since there are 3 oxide ions, there is an overall negative charge of 6−.
   - Since there are 2 iron ions, they must each have a charge of 3+ to give an overall positive charge of 6+.
4. Write the name of the compound using a Roman numeral to indicate the charge of the metal ion.
   - The name of Fe_2O_3 is iron(III) oxide.

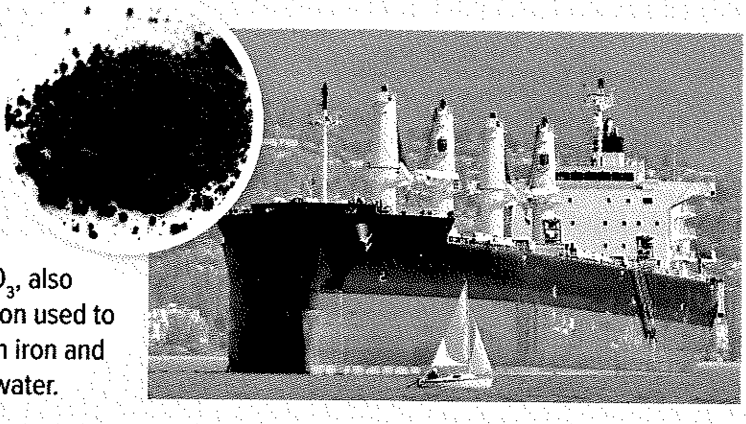


Figure 2.42 The iron compound Fe_2O_3, also called hematite, is the source of most iron used to make steel today. The rust that forms on iron and steel is a form of Fe_2O_3 combined with water.

Practice Problems

1. Write the names of the compounds with the following ions.
   - a) Co^{3+} and O^{2-}
   - b) Cu^{+} and Br^{-}
   - c) Cu^{2+} and Cl^{-}
   - d) Mn^{4+} and S^{2-}
2. Write the names of the following compounds. Each contains an ion of a multivalent metal.
   - a) FeO
   - b) Cu_3N
   - c) SnS_2
   - d) Sn_3N_2
   - e) Ni_2S_3
   - f) $MoCl_3$
   - g) PbF_4
   - h) TiS_2

Before you leave this page . . .

1. Explain why copper is able to form two different compounds with oxygen.
2. Why are Roman numerals included in the names of multivalent metal ions?

CONCEPT 4

Polyatomic ions are made up of more than one atom.

Activity

Research a Polyatomic Ion

Work in groups. Your teacher will assign you one of the polyatomic ions in Table 2.7. For your ion, conduct research to answer the following questions:

1. What is the shape of your ion? Use a kit or craft supplies to make a model.
2. What are two compounds in which your ion is found?
3. Choose one compound from question 2 and find out more about it. What are its properties? Is it found in nature? Does it have any applications?

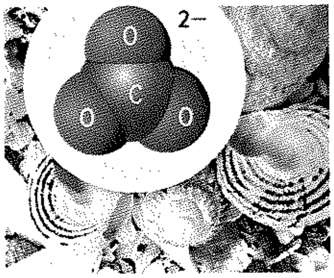


Figure 2.43 Shellfish use calcium carbonate to make their shells. The carbonate ion is shown here.

polyatomic ion an ion made up of two or more covalently bonded atoms

Limestone is an important industrial mineral that is obtained from quarries in several locations around British Columbia. Limestone is made of an ionic compound called calcium carbonate, $CaCO_3$, which is also the compound that shells such as those shown in Figure 2.43 are made of. The carbonate ion, CO_3^{2-}, is composed of carbon and oxygen atoms. An ion that, like carbonate, is composed of two or more atoms is a **polyatomic ion**—essentially, a charged molecule. Compounds containing polyatomic ions are not binary compounds because they always contain at least three elements. But like binary compounds, compounds containing polyatomic ions are named by writing the name of the positive ion followed by the name of the negative ion.

There are a limited number of polyatomic ions that regularly occur in compounds. You can look up their names, formulas, and charges in a table such as Table 2.7. Notice that the only positively charged polyatomic ion listed is the ammonium ion, NH_4^+.

Table 2.7 **Names, formulas, and charges of some common polyatomic ions**

1+ Charge	1− Charge	2− Charge	3− Charge
ammonium, NH_4^+	acetate, CH_3COO^- chlorate, ClO_3^- chlorite, ClO_2^- hydrogen carbonate, HCO_3^- hydroxide, OH^- nitrate, NO_3^- nitrite, NO_2^- permanganate, MnO_4^-	carbonate, CO_3^{2-} chromate, CrO_4^{2-} dichromate, $Cr_2O_7^{2-}$ peroxide, O_2^{2-} sulfate, SO_4^{2-} sulfite, SO_3^{2-}	phosphate, PO_4^{3-} phosphite, PO_3^{3-}

Sample Problem

Writing Chemical Formulas of a Compound with a Polyatomic Ion

Calcium nitrate is a key component of nitrogen-containing fertilizers. Nitrogen-containing fertilizers are important in increasing the yield of farms, but can also cause problems when an excess of nitrogen enters waterways. What is the formula of calcium nitrate?

Solution

1. Identify each ion and its charge. Use Table 2.7 (or another table of polyatomic ions) to find the formula of the polyatomic ion.
   calcium: Ca^{2+} nitrate: NO_3^-
2. Determine the number of ions needed to balance positive charges with negative charges. In this case, two nitrate ions are needed to balance the charge on calcium.

Charge from Ca^{2+}	Charge from NO_3^-
A calcium ion has a charge of 2+. 1 × (2+) = 2+	A nitrate ion has a charge of 1−. Therefore, 2 nitrate ions are needed to balance the charge of one calcium ion. 2 × (1−) = 2−

3. Use subscripts to write the formula. *If the polyatomic ion is going to take a subscript, use parentheses to enclose the polyatomic ion before adding the subscript, as shown.* This shows that the nitrate ion is a unit, and that there are two of them for each calcium ion. The formula of calcium nitrate is $Ca(NO_3)_2$.

Practice Problems

1. Write the formula of each of the following compounds.
   - **a)** barium nitrate
   - **b)** potassium carbonate
   - **c)** nickel(II) sulfate
   - **d)** magnesium phosphate
   - **e)** sodium dichromate
   - **f)** iron(II) chromate
   - **g)** lead(IV) acetate
   - **h)** ammonium sulfate
2. There is an error in each of the formulas of the following ionic compounds. Explain the error and correct each formula.
   - **a)** sodium phosphate, Na_3P
   - **b)** magnesium nitrate, $MgNO_3^{2-}$
   - **c)** potassium sulfite, KSO_3^-
   - **d)** sodium hydroxide, $Na(OH)$
   - **e)** ammonium chloride, NH_3Cl
   - **f)** sodium acetate, $Na(CH_3COO)_2$
   - **g)** potassium dichromate, $(K)_2Cr_2O_7$

Before you leave this page . . .

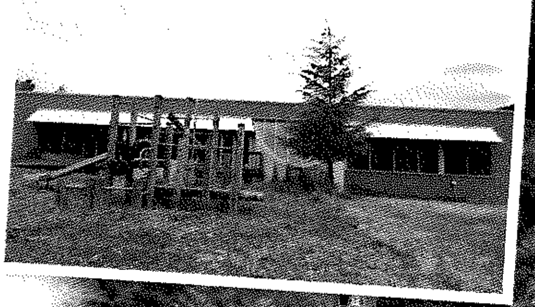
1. What is a polyatomic ion?
2. How are parentheses used in writing formulas containing polyatomic ions?
3. Give the names and chemical formulas of two different polyatomic ions that contain nitrogen and oxygen.

AT ISSUE

What happened at B.C.'s molybdenum ghost town?

What's the Issue?

About 180 km northwest of Terrace sits Kitsault, a modern-day ghost town that has been abandoned for over 30 years. In 1979, Kitsault was built as an instant town to provide a home for workers at the nearby molybdenum mine. The town was meant to be a community that workers and their families would call home year round. It offered apartments and family housing, shops, recreation centres, a theatre, a library, and even a hospital. Yet just three years later, the 1200 people living in Kitsault abandoned the town nearly overnight. Since then, caretakers have looked after the buildings and properties, many of which look eerily as if residents had just stepped out for a breath of fresh air.



Dig Deeper

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

1. Find out more about what happened to Kitsault in the past, and what is happening there now.
   a) Why was Kitsault abandoned? What did molybdenum have to do with it?
   b) What is the status of the mine and town today?
2. Molybdenum is a multivalent transition metal. In nature it is found in the form of various compounds (minerals) in rocks. All of Canada's molybdenum is mined in British Columbia. In what forms is molybdenum found in nature? What are some uses of molybdenum? Where is it currently mined in British Columbia and how? What effects does the mining have on local people and the environment?
3. The town of Kitsault lies within the traditional territory of the Nisga'a Nation. What sort of concerns do you think that First Peoples living near the molybdenum mine might have and why? Find out how any concerns have been addressed by the Nisga'a Nation.

SCIENCE AT WORK

Chemistry Connections

What kinds of jobs are there for people interested in elements and compounds?

hazardous waste technician

chemistry teacher

occupational safety officer

toxicologist

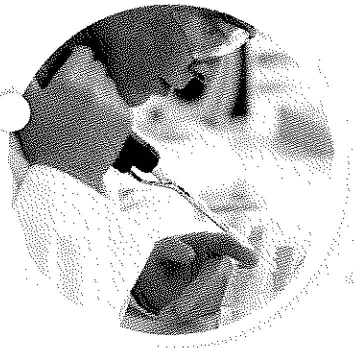
pharmacologist

Materials Engineer

Put your natural scientific curiosity and innovative mind to the test as a materials engineer. These experts spend their days researching and manipulating the properties of metals and other materials.

Chemistry Teacher

Organized, energetic, and passionate about chemistry: if this describes you, then you might have what it takes to be an inspiring chemistry teacher.



Forensic Scientist

It may not be the thrill-a-minute job you see on television, but if you are patient and detail-oriented, you may enjoy forensic science, a field that uses chemistry to help settle legal cases.

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?

CONCEPT 5

Names and formulas of covalent compounds reflect their molecular structure.

Activity

Chemical Formulas of Covalent Compounds

Your teacher will provide models of each of the following compounds:

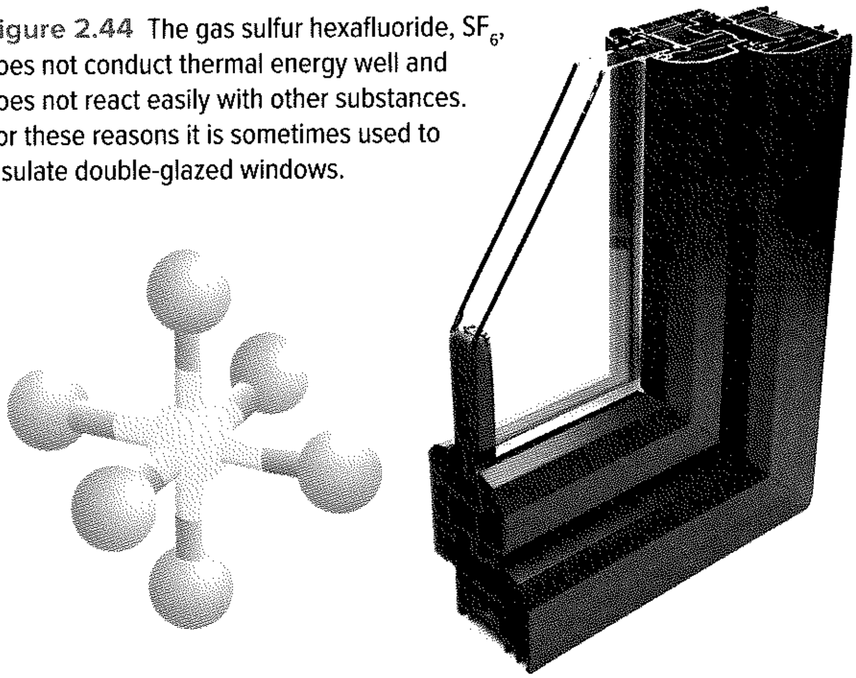
water, H_2O	carbon monoxide, CO
hydrogen peroxide, H_2O_2	propane, C_3H_8
carbon dioxide, CO_2	glucose, $C_6H_{12}O_6$

Sketch the models in your notebook. For each compound, compare the molecular model with the formula. What do chemical formulas of covalent compounds represent? How do they differ from ionic compounds? Why is the chemical formula of hydrogen peroxide not simplified to HO?

binary covalent compound a compound made up of the atoms of two elements joined by covalent bonds

Like binary ionic compounds, **binary covalent compounds** are made up of two elements only. Chemical formulas of binary covalent compounds indicate how many atoms of each element are present in a single molecule of the compound, as shown for sulfur hexafluoride, SF_6, in Figure 2.44. Like names for ionic compounds, names for binary covalent compounds have two parts—one part for each element in the compound. The following three rules will help you write names and formulas of binary covalent compounds.

Figure 2.44 The gas sulfur hexafluoride, SF_6, does not conduct thermal energy well and does not react easily with other substances. For these reasons it is sometimes used to insulate double-glazed windows.



Writing Names and Formulas of Binary Covalent Compounds

Follow these steps to write the name of a binary covalent compound.

1. The first element in the name and formula of a binary covalent compound is usually the one that is farther to the left on the periodic table.

   Example: In carbon monoxide, CO, carbon comes first because carbon is to the left of oxygen on the periodic table.

2. When naming, the suffix *-ide* is attached to the name of the second element.

   Example: Oxygen is changed to oxide in the name carbon monoxide.

3. When naming, prefixes are used to indicate how many atoms of each type are present in one molecule of the compound. Table 2.8 lists the first 10 prefixes. The prefix *mono-* is used only for the second element in the name. When there is no prefix, *mono-* is implied, as in carbon monoxide. Also, when *mono-* comes before *-oxide*, an "o" is dropped. Thus, you write *monoxide*, not *monooxide*.

   Example: Using prefixes correctly, the name of CO is carbon monoxide.

   Note that when the addition of a prefix results in two vowels appearing together, the vowel at the end of the prefix is usually dropped. The "i" at the end of the prefixes *di-* and *tri-* are never dropped, however.

   Example: the correct name for PI_3 is phosphorus triiodide.

To write the formula for a binary covalent compound, write the element symbols in the order they appear in the name. Add subscripts based on the prefixes used in the name. Examples are provided in the Sample Problem on the next page.

Table 2.8 **Prefixes Used to Name Binary Covalent compounds**

Prefix	Number	Prefix	Number
mono-	1	hexa-	6
di-	2	hepta-	7
tri-	3	octa-	8
tetra-	4	nona-	9
penta-	5	deca-	10

Sample Problem

Names and Formulas of Binary Covalent Compounds

Nitrogen and oxygen form a wide variety of different covalent compounds with different properties. Two examples are described below. A third is shown in Figure 2.45.

a) Dinitrogen tetroxide is used in rocket fuels. What is its formula?

b) The toxic brown gas NO_2 is found in smog in urban areas. What is its name?

Figure 2.45 The compound NO acts to widen blood vessels, which can lessen chest pain in heart patients. The patient takes nitroglycerin pills, which react in the body to form NO. **What is the name of the compound NO?**

Solution

a) Nitrogen comes first in the formula, as in the name, because it is to the left of oxygen in the periodic table. The prefix *di* tells you that there are 2 nitrogen atoms and the prefix *tetr-* tells you that there are 4 oxygen atoms. (The *a* in *tetra* was dropped.)

The formula of dinitrogen tetroxide is N_2O_4.

b) Follow these steps to name a binary covalent compound.

1. Name the leftmost element in the formula first.	The first element is N (nitrogen).
2. Name the second element, making sure the name ends with the suffix *-ide*.	The second element is O (oxygen), which becomes *oxide*.
3. Add a prefix to each element's name to indicate the number of atoms of each element in a molecule of the compound. If the first element would get the prefix *mono*, do not include that prefix.	The compound's name is nitrogen dioxide.

The name of NO_2 is nitrogen dioxide.

Practice Problems

1. Write formulas for each of the following covalent compounds.

- **a)** sulfur tetrafluoride
- **b)** disulfur difluoride
- **c)** dinitrogen trioxide
- **d)** oxygen difluoride
- **e)** nitrogen tribromide
- **f)** diiodine hexachloride

2. Write the names of the following covalent compounds.

- **a)** PI_3
- **b)** SO_2
- **c)** SO_3
- **d)** S_2F_{10}
- **e)** CCl_4
- **f)** N_2O_5
- **g)** N_2O
- **h)** NI_3
- **i)** P_2O_5
- **j)** PBr_5
- **k)** As_2S_3
- **l)** ICl_3

Exceptions to the Rules

One important group of compounds breaks the naming rules given in this section. These are the compounds that contain hydrogen. You might think that HCl, for example, would be ionic. It contains hydrogen, found in the same group as the alkali metals, and a halogen. In fact, hydrogen is a non-metal, and HCl is known to be molecular. In its pure form, it is a gas at room temperature.

Although it is a covalent compound, HCl is not named in the same way as other covalent compounds you have encountered so far. Like other binary hydrogen-containing compounds, it is named as though it is an ionic compound. The correct name for HCl is thus hydrogen chloride, not hydrogen monochloride. Similarly, the name of H_2S is hydrogen sulfide, not dihydrogen monosulfide. When these types of compounds are added to water they form acidic solutions. You are probably already familiar with the name "hydrochloric acid," which is what HCl is called when it is dissolved in water.

Compounds containing hydrogen and carbon, such as ethane, C_2H_6, or ethanol, C_2H_5OH, are called *organic compounds*, and these have yet another set of naming rules, which you will encounter if you continue your studies in chemistry.

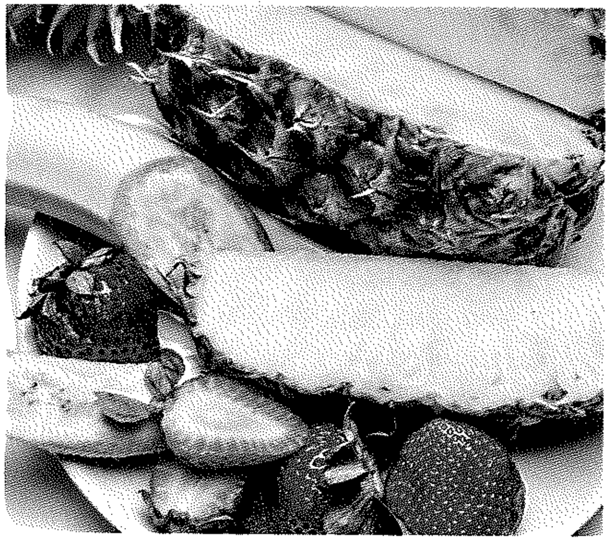


Figure 2.46 The characteristic smells of strawberries, pineapples, and bananas are due to organic compounds: methyl hexanoate, ethyl butanoate, and isoamyl acetate respectively. These compounds are named according to detailed rules based on their composition and structure.

Extending the Connections

Organic Compounds

Why are organic compounds so called? Are all organic compounds found in living things, like the ones in Figure 2.46? Find out the origin of the term *organic* in this context, and give some examples to demonstrate the diversity of organic compounds.

Before you leave this page . . .

1. What does the formula for a covalent compound tell you about the compound?
2. Identify two problems with the name mononitrogen monooxide for the compound NO and correct them.
3. Sketch a model of a molecule of carbon dioxide, CO_2, and carbon monoxide, CO. How do the names and formulas communicate the difference between these compounds?

TAKE a Stand

Make a Difference

What can we do about overconsumption of salt and sugar?

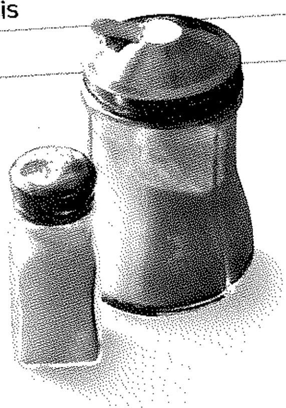
Salt and sugar: these two compounds, one ionic and one covalent, each have profound implications for human health. The media bombards us with different messages about consuming too much of these compounds, but how much is too much? On average, Canadians consume about 1.2 kg of salt and 40 kg of sugar annually. In other words, we consume the mass of a human brain in salt and the mass of four car tires in sugar each year. Are we consuming too much as a society? It would be hard to find an expert who did not think so. Many major health concerns in North America have been linked to overconsumption of these two compounds.

Too much sugar can lead to...

- obesity
- diabetes
- high blood pressure
- ageing of the body and brain
- heart disease
- tooth decay
- cancer

Too much salt can lead to...

- high blood pressure
- asthma
- osteoporosis
- obesity
- cancer



Changing how much of these compounds we eat and drink isn't always easy. Some foods that seem healthy are hidden sources of salt and sugar. For instance, ketchup actually contains more sugar than the same mass of ice cream. A piece of store-bought bread has a surprisingly large amount of salt in it. Reading nutrition labels can help, but are they clear enough and do they provide enough information?

Evaluate

1. Choose three packaged foods from your home and determine the sugar and salt content. Was this easy to do? How could the information have been clearer? What names were used for salt and sugar?

Analyze and Communicate

2. Choose one health problem related to consuming too much sugar that interests you, and one related to consuming too much salt. Find out more about each one. Do the results of your research leave you concerned about your own personal intake of salt or sugar, or that of family members? Explain your answer.
3. Decide which is more of a hazard, overconsumption of salt or overconsumption of sugar. Explain your position. Then design a plan to increase awareness about the hazards of overconsumption of salt or sugar at your school or at your home. Include strategies for reducing consumption.

Check Your Understanding of **Topic 2.5**

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 ending do all binary compounds share, whether they are ionic or covalent compounds? PA C

2. Examine the following list of compounds. Which of these are binary compounds?
$AlCl_3$, H_2O, CNO, $C_6H_{12}O_6$, MgS, PbF_2, $NaHCO_3$, NaOH PA E

3. Write the names of the ionic compounds that form when the following elements react. PA C
- **a)** silver and chlorine
- **b)** oxygen and zinc
- **c)** beryllium and iodine
- **d)** fluorine and magnesium

4. Write formulas for each of the following compounds. PA C
- **a)** iron(II) nitride
- **b)** lead(II) oxide
- **c)** copper(I) sulfide
- **d)** tin(IV) fluoride

5. Write formulas for each of the following compounds. PA C
- **a)** nitrogen dioxide
- **b)** sulfur trioxide
- **c)** dinitrogen tetroxide
- **d)** phosphorus pentachloride

6. Name each of the following compounds. PA C
- **a)** $AlPO_4$
- **b)** Na_2CO_3
- **c)** $KHCO_3$
- **d)** $Mg(OH)_2$
- **e)** NH_4Cl
- **f)** $Na_2Cr_2O_7$

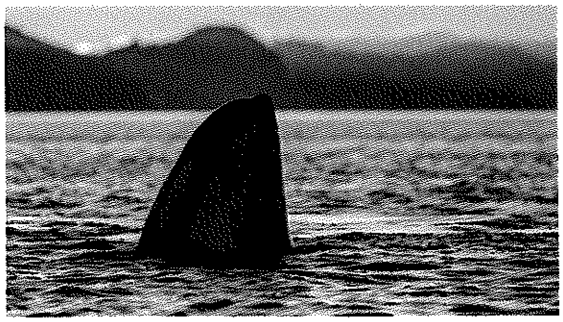
7. Identify the charge on the metallic ion in the following ionic compounds. Then name the compound. PA C
- **a)** PbO_2
- **b)** CuS
- **c)** CrF_3
- **d)** FeN

Connecting Ideas

8. Chromium is a transition metal used in chrome plating. PA E C
- **a)** What ions does chromium form?
- **b)** List the formulas and names of the possible binary ionic compounds chromium could form with oxygen and with fluorine.

Making New Connections

9. Seawater contains large quantities of dissolved ions, including sodium, calcium, magnesium, chloride, and bromide ions.



- **a)** List all of the binary ionic compounds that could form from these ions. Give the chemical name and formula for each.
- **b)** Which ions would you predict to be present in the greatest quantity in a sample of seawater? Explain your prediction and do research to check.
- **c)** Come up with an additional question about the ions in seawater and research to answer your question. QP PA C

INVESTIGATION

2-G

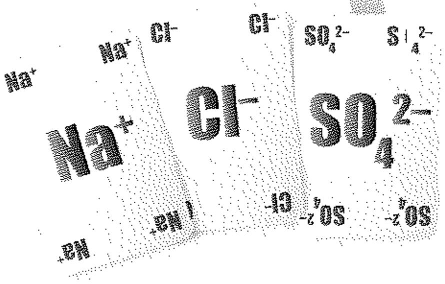
GUIDED INQUIRY

Skills and Strategies

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

What You Need (suggested)

- craft materials
- computer access



How can you make a game out of names and formulas of ionic compounds?

Apply your creativity and knowledge to design a game to let you and your classmates practise naming and writing formulas for ionic compounds.

Question

How can you design a game based on names and formulas of ionic compounds?

Procedure

1. Work in groups to come up with a game that involves the names and formulas for ionic compounds. Ask the following questions as you design your game:
   - What type of game will it be? a card game? a board game? a puzzle game? a computer game? a dice game?
   - What ions will you include in your game?
   - How will you include opportunities for naming and making formulas?
   - What will the rules for your game be?
   - What pieces will you need to make, if any?
2. Make a plan and produce your game.

Process and Analyze

3. Test your game several times within your group. Make adjustments to the game rules and pieces as necessary.
4. Set up a games café within the class. Teach other groups how to play your game and try out the games of other groups. Offer feedback on game play, accuracy of science content, and quality of game components.

Conclude and Communicate

5. Which was your favourite game, and why?
6. What worked well about the game you designed? If you were to try to market your game to science classrooms, what changes would you make, and why?

INVESTIGATION

2-H

STRUCTURED INQUIRY

Colours of Ionic Compounds

Skills and Strategies

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

Safety

- Some of these compounds are toxic. Do not remove them from their vials.

What You Need

- 8 vials of ionic compounds labelled with formulas
- 8 vials of ionic compounds labelled with names

Although the majority of common ionic compounds are white (as powders) or clear and colourless (as crystals), some compounds are coloured. The colour in these compounds is due to either the negative or positive ion (or very rarely, to both). By analyzing observations of a variety of compounds with different combinations of ions, we can infer which ion is coloured in a compound. For example, copper(II) nitrate is blue whereas sodium nitrate is white. We can conclude that the nitrate ion is not coloured and that therefore the copper(II) ion is coloured.

Question

How can we use our observations of different ionic compounds to identify coloured ions?

Procedure

1. Make a chart with columns for Formula, Name, and Appearance and eight blank rows. Examine the eight vials of ionic compounds that have the formulas marked on them. Record the formulas. Write the name for each compound after the formula. Also, describe the appearance of each compound, including its colour.
2. Make a chart with columns for Name, Formula, and Appearance and eight blank rows. Examine the eight vials of ionic compounds that have the names marked on them. Write the formula for each compound after the given name. Also, describe the appearance of each compound, including its colour.

Process and Analyze

1. Write the formulas of all the coloured compounds.
2. Inspect the formulas of the coloured compounds. What ions do the colourless or white compounds have in common?

Conclude and Communicate

3. Which positive and negative ions were coloured? Explain your conclusion. What further data could help you feel more confident about your conclusion?

UNIT 2

Summary

ESSENTIAL QUESTION

How do the electron arrangements of atoms determine the chemical and physical properties of elements and compounds?

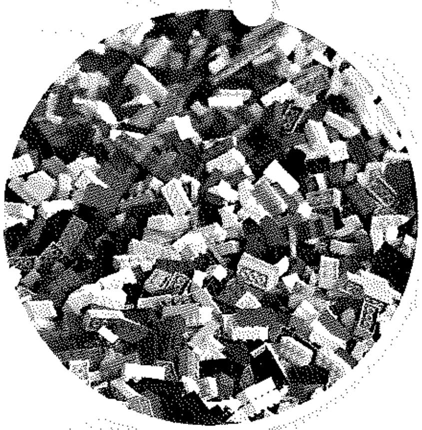
TOPIC 2.1:

How and why do we study matter?

- Matter and its interactions make up our world.
- Safety is key when working with matter.

Key Terms

matter	pure substance
mixture	element
compound	chemical reaction



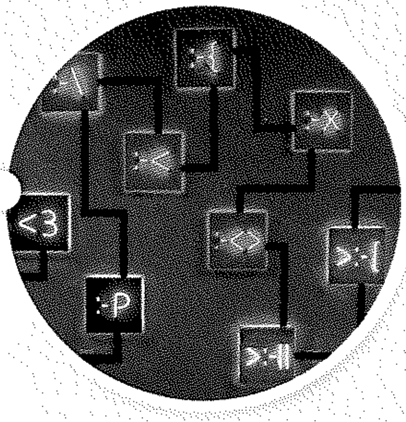
TOPIC 2.2:

How does the periodic table organize the elements?

- Elements are the building blocks of matter.
- Elements can be organized by their properties.
- The modern periodic table organizes elements in groups and periods.
- Elements are classified as metals, non-metals, or semi-metals.

Key Terms

group	period	metal
non-metal	semi-metal	



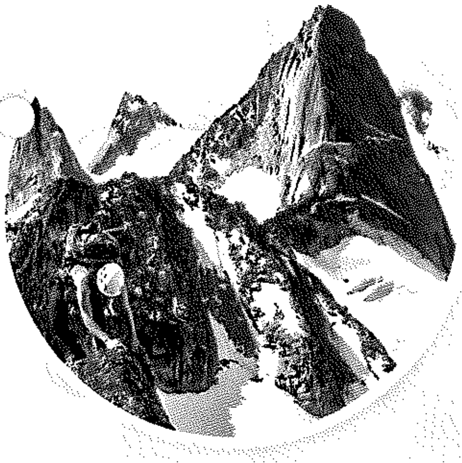
TOPIC 2.3:

How can atomic theory explain patterns in the periodic table?

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.

Key Terms

- valence shell
- valence electrons
- ion
- periodic trend



TOPIC 2.4:

How do elements combine to form compounds?

- Compounds account for the huge variety of matter on Earth.
- Ionic compounds are made of ions.
- Covalent compounds are made of molecules.
- Covalent bonding also occurs in elements and network solids.

Key Terms

- ionic compound
- molecule
- ionic bond
- covalent bond
- covalent compound

TOPIC 2.5:

How do we name and write formulas for compounds?

- The chemical name of an ionic compound communicates its composition.
- You can determine the formula of an ionic compound from its name.
- Multivalent metals form more than one ion.
- Polyatomic ions are made up of more than one atom.
- Names and formulas of covalent compounds reflect their molecular structure.

Key Terms

- binary ionic compound
- multivalent metal
- polyatomic ion
- binary covalent compound

UNIT 2

Review

What Do You Know?
Connecting to Concepts

Visualizing Ideas

1. As you prepare for an investigation, you read the procedure before starting and see the symbols below. In bulleted list, describe what precautions you would take based on each symbol.

a) 

b) 

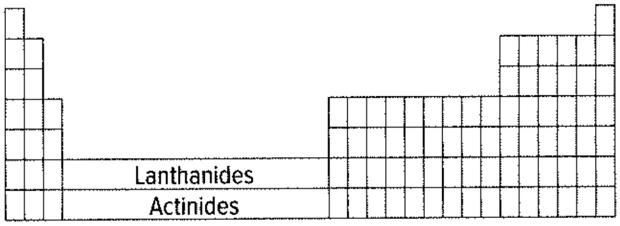
c) 

d) 

e) 

f) 

2. The silhouetted periodic table below shows how it would look with the inner transition metals, the lanthanides and actinides, in their place in the 6th and 7th period. What are the pros and cons of the periodic table being shown in this form, compared with the way you are used to seeing it?



Using Key Terms

3. Draw a concept map that shows the relationship between the following terms.
   - compound
   - element
   - matter
   - mixture
   - pure substance

4. Sketch an outline of the periodic table, and identify the following on your outline.
   - alkali metal
   - alkaline-earth metal
   - group
   - halogen
   - metal
   - noble gas
   - non-metal
   - period
   - semi-metal

Communicating Concepts

5. Draw a Bohr diagram that represents an atom of each of the following elements.
   a) oxygen
   b) neon
   c) lithium

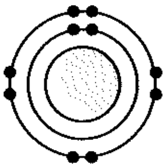
6. Describe the relationship between the reactivity of an element and the number of electrons in the valence shell of each atom of the element.

7. Use this incomplete box from the periodic table to answer the following questions.

12	2+
Mg	
24.3	

   a) What is the atomic number of the element?
   b) What is the full chemical name of the element?
   c) Draw the Bohr diagram of an atom of this element.
   d) Draw the Bohr diagram of an ion of this element. Explain why the element forms this ion.

8. Use this Bohr diagram to answer the questions below.



a) If this model represents an atom, what element is it? How do you know?

b) If this model represents an ion with a charge of 2+, what element is it? Explain your answer.

c) If this model represents an ion with a charge of 1−, what element is it? Explain your answer.

9. Copy and complete the table below in your notebook.

Properties of Neutral Atoms

Symbol	Atomic Number	Number of Electrons	Number of Protons
Ne			
	3		
Ca			
		18	

10. Use atomic theory to explain why noble gases are inert. Use a Bohr diagram as part of your explanation.

11. Describe two trends in the periodic table. Use examples of elements to support your answer.

12. Write the chemical formulas of each of the following ionic compounds.

a) lithium chloride

b) zinc sulfide

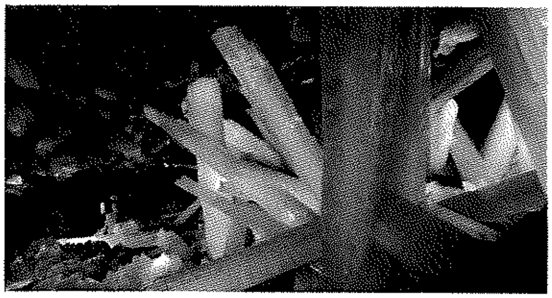
c) copper(II) chloride

d) ammonium acetate

e) manganese(III) nitrate

f) cobalt(II) phosphate

13. The giant crystals shown below are the largest so far discovered on Earth. They formed naturally in extreme conditions (50°C and 100% humidity) in a cave in Mexico called Cueva de los Cristales.



a) The crystals are made up of a compound consisting of calcium ions and sulfate ions. What is the name of the compound?

b) Write the chemical formula for the compound.

c) List at least three properties you would expect these crystals to exhibit.

14. Write the chemical formulas of each of the following covalent compounds.

a) sulfur dioxide

b) silicon tetrabromide

c) phosphorus pentachloride

d) dinitrogen trioxide

15. The vividly-coloured compound below is chromium(III) chloride. Chromium is a multivalent element.

a) What does multivalent mean?

b) What ions can chromium form?

c) Predict all of the different compounds that chromium could form with chlorine. Give their names and formulas.

Unit 2 Review *(continued)*

16. Write the chemical names for the following compounds. Identify each as an ionic or covalent compound.

a) SCl_2 **c)** $NiSO_4$

b) $AlBr_3$ **d)** P_2O_5

17. Compare how an ionic bond forms with how a covalent bond forms. How are they the same? How are they different?

What Do You Know?

Connecting to Competencies

Developing Skills

18. The properties of some common substances are listed below.

Properties of Common Substances

Material	Melting Point (°C)	Soluble in Water	Conducts Electric Current in Solution
Baking soda	decomposes	yes	yes
Cooking oil	–5	no	no
Table salt	801	yes	yes
Lip balm	40	no	no
Candle wax	50	no	no
sugar	170	yes	no
Dishwasher soap powder	851	yes	yes

a) Use the data to classify the substances as ionic or covalent.

b) Are there any substances that cannot be clearly classified as ionic or covalent? If so, explain why.

19. Design a flowchart that you could use to help you write a chemical formula when given the name of a compound. Make sure that your method includes how to write formulas for both ionic and covalent compounds.

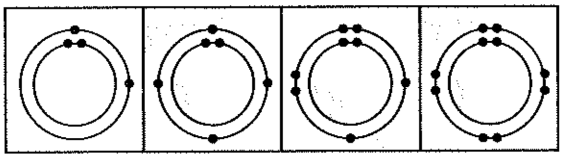
20. List the steps you would take to deal with each of the following situations safely.

a) While you are using a hot plate to heat a liquid, the fire alarm sounds.

b) You are heating a test tube that has liquid in it in using a laboratory burner. You notice that your test tube has a chip near the top.

Thinking Critically and Creatively

21. Diagrams showing the electron arrangements of atoms of five elements are shown below. Use these to answer the following questions.



a) Write the element symbol for each. Explain how you determined what element each diagram represents.

b) Do these elements belong to the same period or the same group? Which common period or group do they belong to? How do you know?

c) Describe a periodic trend of these elements.

22. Compare and contrast the bonding in a diamond crystal and a sodium chloride crystal.

23. The air we breathe is 78 percent nitrogen by mass. Write the chemical formula for nitrogen to show how it exists in air. Is a molecule of nitrogen considered a compound? Explain your answer.

24. Suppose you have been given two different white solids. One is a covalent compound and one is ionic.
   - **a)** Describe three safe tests you could perform to decide which is which.
   - **b)** If you could only perform one test, which one would it be? Explain your answer.

What Do You Know?
Making New Connections

Applying Your Understanding

25. Sucrose (white sugar) dissolves well in water. Would you expect a sugar-water solution to conduct electric current? Explain your answer.

26. Why would wearing gloves made from a covalent compound, such as rubber, help to prevent an electrician from being electrocuted?

Thinking Critically and Creatively

27. Sodium fluoride is added to many toothpastes to help reduce cavities.
   - **a)** What is the chemical formula for sodium fluoride?
   - **b)** Is sodium fluoride an ionic or a covalent compound? How do you know?
   - **c)** Predict at least three properties you would expect sodium fluoride to have.
   - **d)** Describe what happens when sodium and fluorine react to form sodium fluoride.

28. Covalent compounds are also called molecular compounds. Why is this name appropriate?

29. Use a graphic organizer to compare a crystal of diamond and a crystal of sodium chloride in terms of their properties, structure, and composition.

Connecting to Self and Society

30. Make a list of three ionic compounds and three covalent compounds that you use or rely on each day.
   - **a)** Describe the properties of these substances.
   - **b)** How are their properties associated with what they are used for?

31. Electrolytes are substances that exist as ions in solution. Common electrolytes are calcium, magnesium, and sodium. Electrolytes are required for your body to function properly. People lose electrolytes when they sweat.
   - **a)** People who run ultramarathons must take in water to rehydrate and foods with sugar for energy. What else would they need to take in? What kinds of foods could they eat?
   - **b)** In what other situations might a person need to replenish electrolytes quickly? Explain your answer.

32. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.
   - **a)** Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.
   - **b)** In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

What are the effects of mining for metals and industrial minerals in B.C.?

Metals or industrial minerals are part of the electrical wiring that lets you turn on a light or charge a device; the cement used to make a concrete sidewalk or a skyscraper; the glass in a window; paints, textiles, cosmetics, pharmaceuticals, electronics—the list goes on and on.

B.C.'s landscapes are rich in minerals. As a result, mining is an important industry in this province. Metals such as copper, gold, silver, lead, zinc, and molybdenum are all mined here, as well as industrial minerals such as limestone, clay, sand, and gypsum. The properties of these materials determine how we use them. Their properties also determine how they are extracted. Some types of mines and methods have greater effects on the environment and society than others.

Work as part of a group to do the following.

STEP 1 ► Reflect on the three options, their photos, and the question asked for each option.

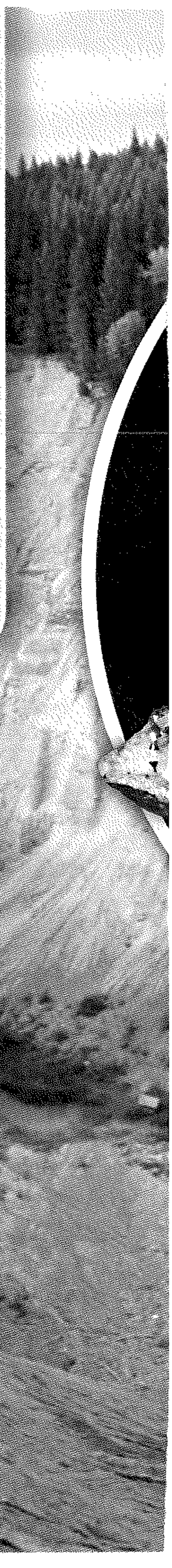
STEP 2 ► Brainstorm at least three more options and questions of your own about metals or industrial minerals in British Columbia.

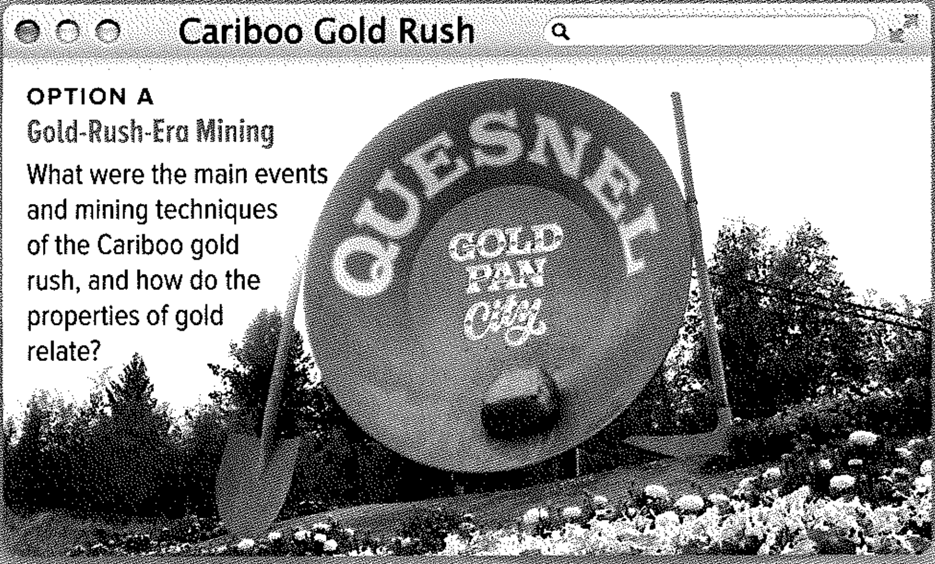
STEP 3 ► Decide on one of the six option questions to investigate.

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

Gold-Rush-Era Mining

What were the main events and mining techniques of the Cariboo gold rush, and how do the properties of gold relate?