Unit 2

Unit 2 Atoms, Elements, and Compounds

In this unit, students will learn to describe the world around them in terms of the chemical behaviours of matter. In Chapter 4, students are introduced to the physical and chemical properties of elements and compounds. In Chapter 5, students will learn that the periodic table of matter displays the chemical properties of the elements in a systematic way. They will study the Bohr-Rutherford model of the atom, and use the model to describe the structure of a large number of elements. They will also use the Bohr-Rutherford model to explain why the chemical elements in the periodic table display those properties. Finally, students will examine chemical trends within groups of the periodic table. In Chapter 6, students will first examine ionic bonding and the properties of ionic compounds. Students will then study covalent bonding and molecular compounds. Finally, students will learn to represent both kinds of bonding using several different kinds of models. The aim of this unit is to enable students to understand the chemical properties of materials that they use every day, and how those materials relate to their local and global environments. As students realize the importance of chemistry in their daily life, they become informed consumers of chemical products.

BIG IDEAS

- The use of elements and compounds has both positive and negative effects on society and the environment.
- Elements and compounds have specific physical and chemical properties that determine their practical uses.

Overall Expectations
Atoms, Elements, and Compounds

- **C1** assess social, environmental, and economic impacts of the use of common elements and compounds, with reference to their physical and chemical properties
- **C2** investigate, through inquiry, the physical and chemical properties of common elements and compounds
- **C3** demonstrate an understanding of the properties of common elements and compounds, and of the organization of elements in the periodic table

Materials

Please see page TR-35 for a list of the materials required for this unit and other units.

Using the Unit Opener (Student textbook pages 132 and 133)

- The opening photograph features a bale of crushed water bottles, with an inset of a reusable metal bottle. Students are familiar with “recyclable” plastic bottles, but do they know why these bottles became popular in the first place? (for convenience or due to safety concerns) Use the photograph to start a discussion on recycling plastic water bottles, and probe students’ understanding of recycling. Some ideas to consider are the following:
  - Where does the plastic come from? How much chemical matter and energy are used to make and dispose of each bottle?
  - What chemical properties make the plastic safe for drinking bottles? How do those chemical properties affect the disposal of the bottles?
  - What materials are used to make reusable, stainless-steel drinking bottles? Where do we get those materials?
  - Pair up spatial learners with linguistic learners to create posters to encourage responsible use of our resources, including water, plastics, and metals.
  - Have students draw spider maps to show what they already know about the topics in each of the three chapters in this unit, shown at the bottom of page 133. Refer students to Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook. They can revisit and revise these maps when they complete the Make Your Own Summary sections in the Chapter Reviews.
- Check what students know and believe already about the characteristics of electricity using **BLM 4-1 Unit 2 Anticipation Guide.** When you have completed the unit, check again, and have students reflect on how and why their understandings and attitudes may have changed.

Assessment OF Learning for Unit 2		
Activity	**Evidence of Learning**	**Supporting Learners**
Unit Inquiry Project	Students initiate and plan an investigation into methods used to reduce rusting.	Using cars as a model, lead students through a discussion of strategies that one might use to prevent rusting of a car. Begin by having students brainstorm in small groups, and follow up with a full class discussion.
	Students must design an experimental method, including appropriate controls.	Review Science Skills Toolkit 2, Scientific Inquiry (on page 532), and Science Skills Toolkit 3, Technological Problem Solving (on page 536).
	Students analyze, apply, and communicate their results effectively.	As a class, brainstorm a list of situations in which rust reduction would improve our lives and environment. Suggest an Internet search to expand the list.
Unit Issue Analysis Project	Students define the issue, describe multiple perspectives, and take a position with supporting evidence.	Refer students to Science Skills Toolkit 1, Analyzing Issues–Science, Technology, Society, and the Environment (on pages 529 to 531), and Science Skills Toolkit 11, How to Do a Research-Based Project (on pages 552 and 553). Use cellphones as an example of an issue to analyze. Have students brainstorm the advantages and disadvantages of using them, and then categorize their list into health, technological, environmental, political, and financial issues.
	Students conduct research and make a decision or concluding statement based on a risk-benefit-cost analysis.	See **BLM A-5 Investigating an Issue Checklist.**
	Students communicate their position and findings using appropriate language.	Appoint peer editors to ask questions about language and conclusions that are unclear.

Get Ready (Student textbook pages 134 and 135)

Prerequisite Learning

Students would benefit from understanding

- the states of matter. (questions 2 and 5)
- the composition of matter, including mixtures and solutions. (question 3)
- the properties of matter. (questions 1 and 4)

Prerequisite Skills

Students need to be able to

- analyze and interpret graphs. (questions 6 and 7)
- interpret data from a table, converting units as necessary. (question 8)
- communicate in writing. (question 9)

Students can review some of these skills using **BLM 4-2 Skills for Unit 2.**

Answers

Concept Check

1. Answers may include the following:

   colour, shininess (lustre), crunchiness, toughness, clear, cloudy, liquid, solid, thick (viscous) or thin liquids, magnetism, density, ability to conduct electricity, ability to conduct heat

2. **a.** sand, blanket, truck, ice cream, ice, balloon
   b. lake, drinking water, melted ice cream
   c. air, helium in balloon
   d. melting ice, melting ice cream
   e. drying towel, lake, drink
   f. melting, evaporation
   g. cooking, sun burning, combustion

3. **a.** Fruit punch is a solution
   b. Rocky road ice cream is a mechanical mixture
   c. Helium is a pure substance.

4. **a.** physical and chemical property; perfume, flower, food
   b. chemical property; water bottle, air, sand
   c. physical property; sand, stone, towel
   d. physical property; toy, stop sign, blood.

5. **a.** Water is nearly incompressible, so the particles must be close together.
   b. Each particle in air is surrounded by a vacuum that is about 2000 times its own volume.
   c. Both air and water particles move freely, so both materials flow.

Inquiry Check

6. About 240 g of sugar, but only 37 g of salt, will dissolve in 100 mL of water at 50°C.

7. The solubility of sugar increased by about 250 g/100 mL. The solubility of salt increased only by about 10 g/100 mL.

Numeracy and Literacy Check

8. **a.** 100 mg/L is the same as 0.100 g/L.
   b. 12 mg/L is the same as 0.012 mg/mL.

9. Answers will vary, but students might include dissolved materials in the water, including such pollutants as lead, chlorine, fluorine, or sulfur; or such desirable minerals as calcium and magnesium. Others may include taste, clarity, and hygiene.

Assessment FOR Learning		
Tool	**Evidence of Learning**	**Supporting Learners**
Get Ready Concept Check	Students use the particle theory of matter to describe the composition of matter.	Provide samples of matter, including melting ice, dissolving salts or sugars, and evaporating water. Have students explain the observed behaviour in terms of the constituent particles.
Get Ready Inquiry Check	Students correctly read the graph.	Choose a number of points on the graph to check students' understanding, and to correct students' misunderstanding.
	Students interpret the data displayed on the graph.	Use simple graphs to model graphical analysis. For example, use graphs of mass vs. volume as a review of density from Grades 7 and 8, and guide students through analyzing and interpreting the graphs. See also **BLM G-4 Making Observations and Inferences.**
Get Ready Numeracy and Literacy Check	Students analyze a data table to extract information.	Have students create a bar graph of the data to produce a visual display of the information to analyze. Use **BLM 4-2 Skills for Unit 2.**
	Students write articles that advocate consuming, or not consuming, bottled water, and provide reasons for that position.	Students read their articles to small groups of their peers. The peers can suggest ways to strengthen each argument (even if they disagree!).

Introducing the Unit 2 Projects

Invite students to look at the unit projects on pages 258 and 259 of the textbook. For the Inquiry Investigation, students will need a solid understanding of physical and chemical properties and their applications. Have them scan the unit and identify which sections might help them learn about these properties.

Have students read Skills You Will Need at the beginning of Chapters 4, 5, and 6, and predict how these skills may be useful to them in completing each project. As students work through the chapter, encourage them to point out information or activities that may prepare them for the projects. For example, the Case Study on pages 146 and 147 provides a model of analyzing a many-sided issue, similar in nature to An Issue to Analyze, The Impact of Metal Mining. Making a Difference on page 147 describes a person who undertook a project similar to Inquiry Investigation, Rust Prevention (on page 258), with similarly significant applications.

Using Making a Difference (Student textbook pages 147, 204, and 240)

Making a Difference on page 147 describes how Meghana Saincher designed and conducted an investigation showing that toxic wood preservatives can be replaced with oregano oil, a natural product derived from the herb oregano. This finding became the foundation of a biotechnology club at her high school. Students are challenged to research other situations in which naturally derived chemicals can be used to replace environmentally hazardous substances that are currently used. Students might investigate refrigerants, packaging, propellants, fibres, lubricants, building materials, and many others. (For more information, see **www.scienceontario.ca**.) Students can present their findings in a method of their choice (for example, an oral presentation, a Bristol board presentation, a poster, a pamphlet, a computer slide show presentation, and so on). You can use **BLM A-30 Presentation Rubric,** or **BLM A-31 Communication Rubric,** to guide them. Distribute the rubric before students begin to plan their presentation.

Making a Difference on page 204 describes how Patrick Bowman designed and conducted an investigation into the toxic effects of mercury from fluorescent tubes. He demonstrated that some biological damage was due to mercury, and communicated his findings to a large audience. At the end of the feature, students are challenged to use effective communication strategies to raise their communities' awareness of the toxicity of fluorescent tubes. The results of their work could be displayed for a wider audience, such as the school or community.

Making a Difference on page 240 describes how Dayna Corelli applied her knowledge of rainfall, solutions, plant needs, and other related topics to contribute to a proposal that reduced Sudbury's water consumption and improved its efficiency. At the end of the feature, students are asked to investigate changes that could be made in their own municipalities to improve water quality and energy conservation. Students could begin by writing or talking to local environmental groups to learn about their own community's priorities. This research could be used as a springboard to propose how students could contribute to solving some of these problems.

Using Science at Work (Student textbook pages 256 and 257)

Carol Ann Budd used her high school chemistry experiences to become a chemical engineer. Today, she combines her interest in chemical engineering, automobile safety, and societal and environmental issues. Science, the environment, and social issues interact all around us. Ask students to suggest ways that science, the environment, and social issues interact in your science classroom.

Question 3 on page 257 asks students to investigate the essential skill set needed for a career in a chemistry-related field. As an alternative to researching a career relating to electricity that interests them, students may opt to research the career opportunities specifically related to "green technology."

Using the Case Studies

The suggestions below provide opportunities for students of multiple learning styles to engage in and explore issues. The strategies chosen support bodily-kinesthetic, spatial, and interpersonal learning styles. The strategies also serve as pre-reading strategies and scaffolds for English language learners.

Chapter 4 (Student textbook pages 146 and 147)
Almost every community in Ontario has some connection to the chemical industry. After reading the What Is the Cost of Our Products? case study, have students look through a business directory to identify chemical industries in your locality. Ask, "What products do they make?" "What raw materials do they use?" "What waste by-products are formed?" Ask students to investigate the health and environmental effects of the relevant chemicals. Create a list of 10 common chemicals whose use in their community should be monitored. Have them begin their search at **www.scienceontario.ca**.

Chapter 5 (Student textbook pages 202 and 203)
Before reading the Diamond Mining: Beyond the Sparkle case study, place students in small groups to generate discussion. (If you have several English language learners with the same first language, they could form one group and discuss in their first language as well as in English.) Give each group chart paper to record their ideas.

- Have students jot down the advantages and disadvantages of mining.
- Many Ontario communities are now, or were in the past, the site of active mines. Ask students to list factors (such as value of the material being mined, financial cost of mining and refining, and environmental impact) which they should consider as they evaluate the impact of a particular mining operation. Ask students to assign a weighting for each factor, with −5 being a strong disadvantage, and +5 being a strong advantage. Ask students to compare their weightings with those of other students in their small groups.
- Use this case study to build scientific decision-making skills. With students, discuss the process for making a decision. (See Science Skills Toolkit 1, Analyzing Issues—Science, Technology, Society, and the Environment, on page 529 of the student textbook.) See also **BLM G-18 Decision-Making Organizer.**

Chapter 6 (Student textbook pages 238 and 239)
Shopping bags, lunch bags, garbage bags, and other bags from a variety of sources, are used in many households. Before reading the Taking a Stand on Plastic Bags case study, ask students to list the different kinds of plastic bags that they use, and estimate the number of each kind that are used in their home in a month. Ask them to consider if, in their current circumstances, they could move closer to eliminating their use of plastic bags. Ask them to represent their estimate with a number from 1 (unlikely to eliminate any plastic bags) to 10 (likely to eliminate all plastic bags). After reading the case study, ask students to revise their estimate, and make a plan to reduce their use of plastic bags.

Chapter 4 Properties of Elements and Compounds

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- For section 4.1, prepare at least three samples of each class of matter in sealed 500 mL water bottles. See section 4.1 Instructional Strategies for detailed suggestions.
- Students can review the Key Terms in Chapter 4 using **BLM 4-3 Chapter 4 Key Terms.**

In this chapter, students will learn about the molecular structure and physical and chemical properties of different forms of matter: elements, compounds, mixtures, and solutions. They will learn about the hazards that some of those properties can present, review lab safety procedures, and become familiar with common safety symbols.

Using the Chapter Opener (Student textbook pages 136 and 137)

- Have students examine the photograph and read about the properties of aerogel on page 136. Together, list other things that we use to insulate, and the properties they have that make them good insulators. Some examples are fibreglass or foam insulation in homes, fabric fibres in clothing, and a vacuum in a vacuum bottle.
- Talk about the properties of aerogel that make it useful for space exploration. (It insulates well and has very little mass.) Have students suggest other applications where similar properties might be important.
- As an alternative, pass around a common classroom object, such as a piece of chalk. Invite students list the properties of the chalk. Then have students work in groups to list properties of other common substances they have come into contact with recently, for example, toothpaste, sugar, and ink. Have them suggest how these properties make the substance useful to us.
- ELL A concept map focussing on matter is a good way to introduce this unit to English language learners. This graphic representation of key concepts will help students keep the big ideas in focus as they participate, and to see relationships between ideas. Add to it, or have students add to it, as they progress through the chapter. This concept map will become a good tool to use as students review and revisit concepts during the chapter and in the chapter review.

Activity 4-1 Raisin' Underwater Artifacts (Student textbook page 137)

Pedagogical Purpose

Students observe properties of common solids, liquids, and gases, and consider the applications of those properties in the world around us.

Planning		
Materials	50 mL water 400 mL beaker 100 mL graduated cylinder 150 mL vinegar	5 raisins 25 g baking soda Electronic balance
Time	25 min	
Safety	Ensure that students wear safety goggles and a lab apron.	

Background

Students should observe that the vinegar, water, and raisins do not change significantly when they are added to the beaker. The raisins will sink to the bottom. The baking soda, when it is added, reacts with the vinegar to produce carbon dioxide bubbles. These bubbles will be violent at first, then subside. Some will attach themselves to the raisins, causing them to rise to the surface of the liquid. As the bubbles come to the surface, they will burst, causing the raisins to sink and accumulate more bubbles. Eventually, this cycle will slow and stop.

Activity Notes and Troubleshooting

- Set up a central station for students to obtain materials. The activity could progress more quickly if all materials were premeasured, but measuring volumes and masses of materials to use in this activity builds skills that students will apply throughout the unit.

Additional Support

- Interested students could research some other examples of gases being used to raise and lower solids in air or in water.
- ELL Before beginning, create three lists on the chalkboard with the headings "Solid," "Liquid," and "Gas." Have students categorize each of the materials and print the name in the appropriate list. Leave these on display for students to refer to as they work.
- ELL English language learners and spatial learners may want to answer questions 1 and 2 by drawing and labelling diagrams.

Study Toolkit		
Strategy	**Page Reference**	**Additional Support**
Previewing Text Features	Page 142 (Key Term definitions, diagrams and a caption, headings, and a summary list) Page 157 (sample problems)	Review Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook, with students.
Multiple Meanings	Page 143 (multiple meanings of *compound*)	Refer students to Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook. Students can use **BLM G-34 Concept Map,** to draw word maps.
Summarizing	Students can also summarize the content on page 164 as shown on page 138.	**BLM G-31–BLM G-39** contain various forms of graphic organizers. Students can choose a format that they feel comfortable with to create summaries.

Section 4.1 Studying Matter (Student textbook pages 139 to 148)

Specific Expectations

- **C1.1** assess the usefulness of and/or the hazards associated with common elements or compounds in terms of their physical and chemical properties
- **C3.3** distinguish between elements and compounds

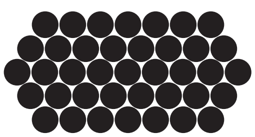
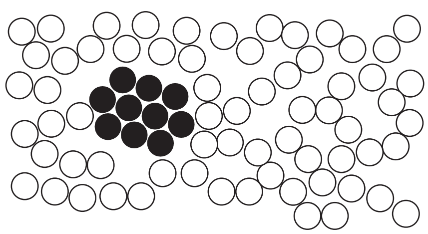
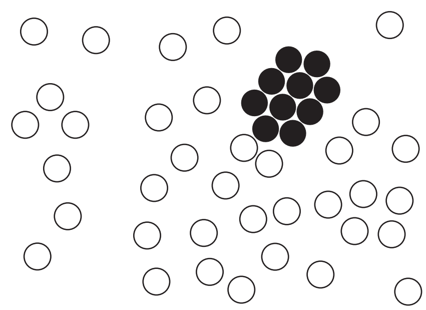
In this section, students will learn how to distinguish between pure substances and mixtures, between mechanical mixtures and solutions, and between elements and compounds.

Common Misconceptions

- **Students tend to believe that matter is continuous.** They tend not to hold and use the particle theory of matter as scientists do. When students first learn the particle theory, they tend to mix the idea of particles with the idea of continuous matter; they might believe that the particles of matter are embedded in the matter, rather like tapioca particles in a continuous pudding. Students find it very difficult to believe that between the particles is empty space, a complete vacuum. Explain that matter appears to be continuous, but is actually made of separate particles with a vacuum between them.

Background Knowledge

Particle diagrams can help students remember the molecular structure of elements, compounds, pure substances, mixtures, and solutions. Draw particle diagrams carefully for students, pointing out that each particle moves about in a vacuum. In your instruction, refer to particle diagrams to illustrate each of the categories of matter: elements, compounds, mixtures, solutions, and pure substances. Insist that students use particle diagrams as often as possible. Some examples appear below.

		
Pure substance, solid state, small spaces, little freedom to move, strong forces	Homogeneous solution, black solute particles in white liquid solvent particles	Heterogeneous mixture, solid (black) smoke particle suspended in a gas (white)

Repeated use of diagrams such as these can both clarify the classification of matter and make students more proficient at drawing and visualizing particle diagrams. These types of diagrams are invaluable to English language learners and should be referred to often. Provide the table as a graphic organizer for English language learners, leaving a blank section for them to add comments or key words.

Point out to students that Canada's Aboriginal peoples live in a way that has a relatively low chemical impact on the environment. They use materials that are readily available from the environment, such as minerals for arrowheads and tools; hides for clothing, shelter, and tools; and available plant materials for medicines and food. English language learners may not have any knowledge of Aboriginal communities. Provide a brief explanation using visuals if possible.

Literacy Support

Using the Images

- To prepare for reading, have students interpret Figures 4.1 to 4.6, on pages 139 to 145 of the student textbook, by examining only the diagrams, their labels, and their captions. Have students write a short sentence to summarize what they learned in each figure. If you wish, students can record their notes on **BLM 4-4 Elements Compounds,** Pure Substances, and Mixtures. Discuss each figure as a class, and invite students to share what they wrote about it. Ask students what they think they will learn by reading this section of text. Pair English language learners with strong English speaking students to discuss and write sentences. Encourage them to explain vocabulary and to provide any background information that will help English language learners better understand unfamiliar contexts, for example, propane depot, WHMIS, helium, apparatus, magnet.

Using the Text

- ELL Continue as a partner activity so peers can clarify the language of instruction (*scan, predict*) and the language of the text (*Raisin', artefacts, versus*). Discussing text as students work with a partner ensures that English language learners understand key concepts and peers can model the process of note taking.

Before Reading

- Instruct students to preview the organization of the text by scanning the headings in the textbook from pages 139 to 147. Ask students to write each heading on the left side of a sheet of paper. Then, instruct students to predict the contents of each subsection of text, below the heading they wrote, using the headings and diagrams as clues.

During Reading

- Allow students to read the text silently, writing a summary of each of the subsections on the right side of their note-taking page. Have them identify the main idea and the details in each subsection by highlighting or underlining the appropriate parts of their notes.
- ELL Provide **BLM 4-4 Elements, Compounds, Pure Substances, Mixtures,** for students to refer to and note Key Terms and information on as they read.

After Reading

- Instruct students to compare their summaries in groups of two or three, and to make additions and corrections as needed, in order to create study notes that identify the most important information in students' own words. Encourage English language learners to make notes in their first language and to review these notes with other students who speak the same first language.
- ELL Review classification of matter by writing the heading "Matter" on the chalkboard, the headings "Mixture" and "Pure Substance" below it, and the headings "Element" and "Compound" below "Pure Substance." Invite English language learners, and other students, to suggest definitions and examples for each category.
- Students can record what they have learned about elements, compounds, pure substances, and mixtures using **BLM 4-5 Matter,** and **BLM 4-6 Classification Tree.**

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
BLM 4-5 Matter	Students' summaries are complete and accurately reflect the content of the text.	Have two or three students share one book. Have one student turn the pages slowly as students look for diagrams and headings. Allow students to discuss what they see before they write their predictions and notes.
BLM 4-6 Classification Tree	Students provide usable definitions, choose appropriate examples, and draw acceptable representations of each class of matter.	Provide a partially completed blackline master with just enough scaffolding to guide students as they complete the exercise.
Activity 4-3 Element, Compound, or Mixture? page 145	Model displays students' correct understanding of elements, compounds, and mixtures.	If models are incorrect, bring two or three students together to compare their models. Use students' errors as an opportunity for them to learn.

Instructional Strategies

- Prepare at least three samples of each class of matter in sealed 500 mL water bottles: two elements (for example, aluminum, sulfur, copper), two compounds (for example, sodium chloride, copper(II) sulfate, water), two solutions (for example, soda water, brass key, corn syrup), and two heterogeneous mixtures (for example, sand, milk + water, water + oil).
- Label the bottles to support the needs of students. For students who need language support, you might provide complete labelling. For students who need support with drawing diagrams, you might provide an example diagram on one or more of the samples, similar to the diagrams shown in the teaching notes for Activity 4-3 (on page 145 of the student textbook).
- Refer to the samples throughout the section, and keep the samples for future classes.
- Instruct students to pass around the samples as they complete **BLM 4-6 Classification Tree,** so that students can become familiar with them.
- Point out the appearance of the samples. Only the heterogeneous mixtures have two or more visible kinds of matter. Solutions, compounds, and elements are all homogeneous in appearance.
- Point out the complexity of each sample. The elements are the simplest, followed by the compounds and then the solutions. The heterogeneous mixtures are the most complex.
- Draw particle diagrams of each kind of matter. Elements contain one kind of atom. Compounds contain two or more different kinds of atoms, attached in a fixed ratio. Solutions distribute individual molecules of solute throughout the solvent. Heterogeneous mixtures contain clumps of pure substance mingled irregularly with each other. Display these for students to refer to throughout the chapter.
- The Case Study on pages 146 and 147 of the student textbook introduces students to some of the positive and negative effects that new products can have on society.
    - **ELL** References to nicknames (Chemical Valley, Bucket Brigade) may not be understood. Provide a map for English language learners as a quick overview of the key concepts (economic advantage, industrialization, pollutants, toxins), and to show the significance of the geography (Sarnia, port, Lake Huron).

- Making a Difference on page 147 of the student textbook emphasizes the importance of research, and of individual initiative, in finding the best product for a job.
- ELL In the Section 4.1 Review, English language learners may have difficulty with the structure (*using the diagram, apply*) or the language of questions (*explain your reasoning*). Break questions that have multiple directions, such as question 3, into smaller steps. Provide examples of answers that show solid reasoning for question 5.

Activity 4-2 Safety First! (Student textbook page 141)

Pedagogical Purpose

Chemistry is perceived by many students and teachers as the most hazardous of the sciences. Familiarity with safety labelling and safety procedures, and awareness of safety hazards in science labs, will help increase student vigilance, increase student awareness, and reduce the possibility of an accident occurring.

Planning	
Materials	Remind students to bring their textbooks, pens, pencils, paper, and so on.
Time	Class time: about 10 min

Background

The use of safety symbols has become widespread in laboratories and industry. For their future education, students need to be familiar with the lab safety symbols. For their future employment, students need to be familiar with the WHMIS labelling system.

Activity Notes and Troubleshooting

- Consider setting up one small demonstration for each instruction (see Differentiating Instruction). Demonstrate each activity and give students a couple of minutes to note the symbols that apply.
- Students can use **BLM G-2 WHMIS Symbols and Hazardous Household Product Symbols**, at any time as a reminder of the significance of the WHMIS symbols.
- Students can read and sign **BLM G-1 Safety Contract.**

Additional Support

- ELL English language learners will be able to participate more fully if you set up demonstrations that correspond to the instructions in Activity 4-2, on page 141. Use the demonstrations to actively show the potential safety hazard.
- ELL To increase your confidence in students' ability to read and recognize each symbol, ask students to identify large images of each of the safety symbols.
- DI To involve bodily-kinesthetic learners, invite two students at a time to demonstrate the potential safety hazard using the equipment that you have set up.

Answers

1. eye safety, clothing safety
2. Students' answers will vary.

   Examples: **A.** "Caution! Water can conduct electricity. Wipe up spills before plugging in the hot plate." **B.** "Caution! Water may boil and spatter the hot sugar." **C.** "Caution! Overheating can cause the contents to suddenly boil."

Activity 4-3 Element, Compound, or Mixture? (Student textbook page 145)

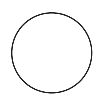
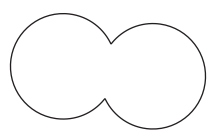
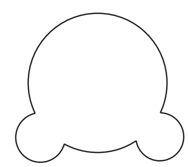
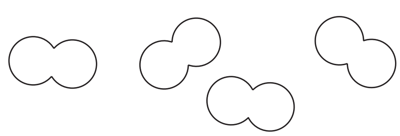
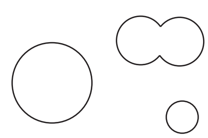
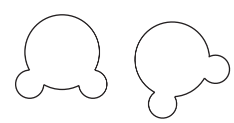
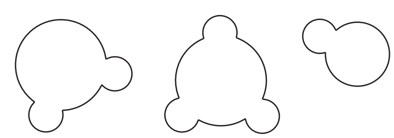
Pedagogical Purpose

This activity supports student growth in understanding three categories of matter by composition, using paper clips to model single atoms.

Planning	
Materials	3 sets of at least 10 paper clips, each set a different colour
Time	Preparation time: 10 min Class time: 20 min

Background

Making the distinction among the element, compound, and mixture categories is very challenging. Students assume that the categories can be distinguished by visual appearance or granularity, which leads to confusion. The real distinction among the three categories is in their composition, at the level of particles that cannot be seen with the naked eye.

	Element: simplest form of matter, cannot be chemically decomposed into simpler kinds of matter	**Compound:** two or more elements combined in a fixed ratio
Atom: a single particle of an element		It is impossible to have an atom of a compound.
Molecule: a particle made of two or more atoms bonded together		
	Elements can be **pure samples**  or **mixtures.** 	**Compounds** can be **pure samples**  or **mixtures.** 

In this activity, students use paper clips to model atoms and then use those models to construct models of elements, compounds, and mixtures. A model of a pure element would consist of only one kind of paper clip, either on its own or in pairs (see top diagram above). A model of a pure compound would consist of several identical groups of paper clips. A mixture could be modelled by two or more different groups of paper clips mixed together.

Activity Notes and Troubleshooting

- Prepare 15 sets of paper clips. As an absolute minimum, each set should include 10 paper clips in one colour, 10 paper clips in a second colour, and 10 paper clips in a third colour. (If enough paper clips are available, the number of paper clips in each set can be doubled to 20 of each colour.)

- Have student groups inspect one another's collections of elements, compounds, and mixtures to detect errors and suggest improvements.
- Refer to the samples that you prepared for this section as you discuss students' models.

Additional Support

- ELL The activity is very friendly to English language learners. Objects are used to represent the following concepts: atom, molecule, element, compound, mixture. Make sure students understand these terms by identifying the particle diagram that corresponds to each. Provide synonyms for vocabulary that may interfere with learning (*bonded → joined, sphere → circle*).
- DI The activity is appealing to bodily-kinesthetic learners. Be sure to emphasize the concept words that this activity is intended to support.

Answers

1. Each colour represents a different element, so there were three elements all together.
2. Students' answers will vary. Most students will take the paper clips that they sorted in step 1 and linked together in step 2, and simply arrange them together without hooking them together to complete step 4.
3. Students' answers will vary. Single atoms could not be decomposed any further. A sample of an element contains only one kind of paper clip (atom). Compounds are made of different atoms in fixed ratios. Mixtures can contain many different combinations of paper clips (atoms).

Learning Check Answers (Student textbook page 144)

1. eye protection and clothing protection
2. A pure substance contains only one kind of particle.
3. A compound is made of atoms joined together. A filter cannot take them apart, and they can be broken down only by chemical methods.
4. Students' answers will vary. Example: "Oxygen is all around me. I breathe it."

Section 4.1 Review Answers (Student textbook page 148)

Please see also **BLM 4-7 Section 4.1 Review (Alternative Format).**

1. The liquid might vapourize, increasing the pressure. The cork might blow out at high speed, or the test tube itself might burst, scattering broken glass at high speed.
2. Students' answers will vary (for example, firefighter, custodian, restaurant workers, hospital workers).
3. The water particles are free to move around. Strong forces of attraction pull the particles together. The strong forces pull the particles inward, and the particles flow to make a round shape.
4. pure elements and pure compounds
5. **a.** Salt water is a solution, not a pure substance.
   b. Gold might be a pure substance, if it is a coin.
   c. A pencil is not a pure substance; it has many different substances in it.
6. No. There is only one kind of particle in a pure substance, so it cannot separate.
7. Compounds are made of elements combined in fixed ratios.
8. Students' diagrams will vary. A compound should include several identical molecules, each one including at least one atom of each element. A mixture should include several different molecules or atoms. In a mixture, some particles may be elements and some may be compounds. Yes, it is possible to draw many different compounds because you can combine the atoms in different arrangements.

Section 4.2 Physical Properties (Student textbook pages 149 to 159)

Specific Expectations

- **C1.1** assess the usefulness of and/or the hazards associated with common elements or compounds in terms of their physical and chemical properties
- **C2.3** plan and conduct an inquiry into the properties of common substances found in the laboratory or used in everyday life, and distinguish the substances by their physical and chemical properties
- **C3.4** describe the characteristic physical and chemical properties of common elements and compounds

In this section, students will identify and describe a number of physical properties of matter. They will also explain some of the implications of these properties.

Common Misconceptions

- **Students might not relate the physical properties of a given substance to the particle theory.** Relating physical properties of a substance to features of the particles of that substance can help students understand why substances have the properties that we observe. Coach students to represent each substance as a collection of particles, and have them relate each representation to the statements in the particle theory of matter on student textbook page 142. Then relate the particle diagrams to each physical property discussed.

Background Knowledge

The terms *physical change* and *physical property* are closely connected. A physical change is any change in a sample of matter that does not change the composition of the particles of that sample. Denting a piece of copper does not change the composition of the particles. Crushing a candy does not change the composition of the sugar particles.

A physical property of a sample of matter is any property that can be observed during a physical change. Denting the copper and crushing a candy provide evidence of the malleability of the copper and the hardness of the candy.

Physical properties can be related to the particle theory. For example, water in the solid and liquid states is incompressible, because the particles are touching and cannot be squeezed closer together. Water in the gas state is compressible because the particles are moving about in a large vacuum. The forces between the particles determine melting and boiling temperatures. If the forces are weak, as in alcohol, the particles can fly apart easily, even if they have little kinetic energy. If the forces are strong, as in iron, the particles must be given a large amount of kinetic energy in order to make them fly apart.

Literacy Support

Using the Text

- ELL Preview vocabulary with English language learners. Throughout this section, they will need to understand and use the terms in Table 4.1, Separating Mixtures, on student textbook page 144; Table 4.2, Qualitative Physical Properties on page 150; and Figure 4.8, on student textbook page 152. Remind them to refer to these features as necessary.
- ELL Explain the difference between the terms *qualitative* and *quantitative* and then discuss Table 4.2 on page 150. Encourage students to add other examples to ensure understanding. Antecedents are difficult for English language learners. Preview pages 149 and 150 with students. Explain that the first paragraph describes an approach or a way to describe things. Look at the second paragraph and explain that a *similar approach* to describing elements and compounds refers to the first paragraph. Explain the use of the term *for example,* and point out that it refers to the previous sentence.

Before Reading

- Have students create a K-W-L chart, or use **BLM G-30 K-W-L Chart.** In the first column, have students write a brief summary about what they already know about physical properties in general, and about states of matter, viscosity, solubility, hardness, conductivity, and density. In the second column, have them ask one or two short questions that summarize what they want to know.
- ELL To support English language learners and other students who would benefit from support in reading, suggest that students work in small groups to compare their comments after they complete each column.

During Reading

- The words for some physical properties may be unfamiliar to students. Have them identify the base word in each property and think about other words they know in the same word family. For example, *quantitative* is related to quantity, and *soluble* is related to dissolve. You might refer students to Study Toolkit 3, Word Study: Common Base Words, Prefixes, and Suffixes in Science, on page 565 of the student textbook.

After Reading

- Instruct students to write a brief account of what they have learned, in the third column of their K-W-L chart, and compare it to what they already know (written in column 1). Alternatively, students could demonstrate what they learned using **BLM 4-8 Physical Properties.**

Using the Images

- Many of the images illustrate common examples of physical properties. Use these images as springboards for discussion. Invite students to describe events from their own lives that relate to each image.
  - ELL Use these images prior to reading to provide language that English language learners will come across as they read the text, and to provide a walk-through of the key concepts that will be presented. Examples: *Figure 4.10, on page 153, shows a type of fog or smoke that is used by bands. This process of sublimation will be described on page 152. What is happening in Figure 4.12, on page 154? In the text, you will read about a substance called DDT and how it bioaccumulates and biomagnifies in mammals.*
- Figure 4.8, on page 152, includes a lot of information about changes of state, including the nature of each state as well as the processes involved in changing states. As a review, invite students to state aloud what different parts of the diagram show.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Strategies and Tools for Intervention**
Student summary, "What I Learned" (or **BLM 4-8 Physical Properties**)	Students provide written evidence of growth in their learning as they move from Know, to Want to know, to Learned.	Work with a group of students to contribute to one K-W-L chart. Have one student read aloud, and have the other students in the group listen and contribute orally.
Student table (**BLM 4-9 Using the Particle Theory to Explain Physical Properties**)	Students' diagrams are complete; notes describe most important behaviours of particles in each case.	Use simple demonstrations to reinforce such features as speed, spacing, and force (magnets vs. marbles). Have one student complete one box, and have a second student complete the contrasting box.
Learning Check questions, page 156	Students correctly identify quantitative and qualitative physical properties and their applications.	Have students attempt to answer the questions with concrete samples of substances that display the physical properties in question. Examples: Sulfur and aluminum; paraffin wax and mineral oil; oil and water in a salad dressing bottle
Practice Problems, page 157	Solutions for density are well organized and correct.	Provide a problem-solving scaffold that follows the GRASP method (See **BLM G-24 Problem Solving Using GRASP**).

Instructional Strategies

- Prepare a demonstration of substances that model each of the properties. You will need sidewalk salt, vegetable shortening, clean copper pennies, water, and vegetable oil.
- Use **BLM 4-9 Using the Particle Theory to Explain Physical Properties,** to guide students' understanding of each property.

- After reading, demonstrate each property as follows:
  - Compare solid (salt, sulfur, copper); liquid (water, oil); gas (air).
  - Compare salt + water (soluble), salt + oil (insoluble), and other combinations.
  - Compare hard (copper) with soft (vegetable shortening).
  - Compare low density (sulfur, vegetable shortening) with high density (copper).
  - Compare low viscosity (water) with higher viscosity (oil).
- Ask students to identify what property is being demonstrated, what difference they observe between the two materials, and what change is taking place. Have them identify whether the molecules in any of the substances are changing their structure. (They are not.)
- You might have students work through the density calculations on page 157 in groups of two or three. Identify a student with strong mathematical abilities in each group to model one solution for the group, following the GRASP method (see **BLM G-24 Problem Solving Using GRASP**), and then to facilitate a discussion of the other solutions. Students should provide a complete solution, as in this answer to Practice Problem 1.

  1. $D = \frac{m}{V}$

  $$= \frac{(21.6\ \text{g})}{(8.00\ \text{cm}^3)}$$

  $$= 2.7\ \text{g/cm}^3$$

  The density of the metal is 2.7 g/cm^3. It is aluminum.
- Refer students to Math Skills Toolkit 2, Significant Digits and Rounding, on page 556 of the student textbook.
- Inquiry Investigation 4-A, Testing Physical Properties of Substances, on pages 166 and 167 of the student textbook, provides practice identifying substances by observing physical properties, and is a good reinforcement of this section.
- Enrichment—Have students complete the activity on **BLM 4-10 Using Physical Properties to Separate a Mixture.**
- ELL Ensure that the syntax of the questions in the section review is not getting in the way of English language learners' understanding. For example, break longer problems into parts, and discuss each part, to ensure each part of a question is understood. Make sure students understand what you expect when you ask them to *explain* or *describe.*

Activity 4-4 What's So Special about Paper Clips?

(Student textbook page 150)

Pedagogical Purpose

This activity provides a brief opportunity for students to observe physical properties.

Planning	
Materials	2 paper clips Wire strippers (optional) Uncoated paper clips (optional) **BLM G-23 Data Table** (optional)
Time	Preparation time: 5 min Class time: 10 min
Safety	If using coated paper clips, show students how to use the wire strippers, and remind students to use the wire strippers with caution.

Background

Paper clips are a well engineered technology based on the malleability, springiness, and durability of metal, as well as the smoothness and toughness of the plastic coating.

Activity Notes and Troubleshooting

- Coated paper clips have two different materials with very different properties. Have students make two lists: one for the clip itself and one for the coating.
- Option: Have students use the wire strippers to remove the plastic coating from the paper clips, and then have students examine the metal under the coating.
- You can use uncoated paper clips as well. The advantage is that students would not need to strip off the coating; however, the disadvantage is that students would not have the opportunity to examine the properties of the coating.

Additional Support

- ELL Some of the words may be unfamiliar to English language learners. Have students demonstrate their understanding of each word by using physical motions (for example, bending a paper clip to demonstrate malleability).
- Provide a model table on the chalkboard for students who have difficulty with organization. The table might include the following columns: Property, Description, and How the Property Relates to the Function. Students can record on **BLM G-23 Data Table.**

Answers

1. Students' answers will vary. Sample answer: silver colour, smooth texture, odourless, solid state, malleable, shiny
2. The odour, state, malleability, and lustre properties are typical of metals. Coatings provide colour and smooth texture.
3. Sample answer: A paper clip bends easily and is flexible; you can easily clip it onto a stack of paper without it breaking. Its smoothness helps to slide it onto the paper.

Activity 4-5 Slow as Molasses (Student textbook page 151)

Pedagogical Purpose

This activity reviews a property of matter that is often neglected in demonstrations.

Planning		
Materials	2 beakers of the same size 2 mL water 2 medicine droppers	2 scoopulas 2 mL molasses Stopwatch
Time	Preparation time: 15 min Class time: 15 min	
Safety	Remind students not to taste anything in the lab.	

Background

Viscosity depends on the size of the fluid's particles, and the strength of attractive forces between those particles. Small particles can move about freely, but long, stringy particles can become tangled, like spaghetti. Increasing the forces of attraction between particles of a fluid can increase friction between particles, and can make a fluid more resistant to flow—that is, more viscous.

Activity Notes and Troubleshooting

- Pure molasses may be too viscous to flow in a scoopula. You may need to dilute it with a little water. Make sure the molasses is no colder than room temperature or it may not flow at all!

- Load 15 droppers with molasses before class to save a few minutes of time.
- After the activity, you can use the same materials to demonstrate two additional physical properties: density and solubility. Molasses sinks in a beaker of water. It is denser than water. Molasses will dissolve in water. (Some cloudy material may remain not dissolved.)

Additional Support

- ELL The use of idioms is difficult for English language learners. After completing the activities, go back and talk about the reason the headings *Slow as Molasses* and *Hard as Nails* were used.
- ELL A quick demonstration of what students are to do will ensure that students who have trouble understanding written English instructions are able to participate.
- Prepare two unbreakable bottles: one that contains water, and one that contains vegetable oil. Put the largest marble that you can fit into each bottle, and seal the bottle with the cap. A student with motor difficulties can invert the bottle, and observe each fluid's resistance to the motion of the marble.

Answers

1. Students' answers should note that molasses takes more time to run down the scoopula than water does.
2. viscosity
3. Accept all reasonable answers. The answers should reflect differences in resistance to flow.

Activity 4-6 Hard as Nails (Student textbook page 155)

Pedagogical Purpose

This activity reviews hardness: a physical property that is related to the strength of the forces of attraction between the particles of matter. A scratch test is a common way to rank the hardness of materials.

Planning		
Materials	Piece of talc Copper penny	Steel nail **BLM G-23 Data Table** (optional)
Time	Preparation time: 15 min Class time: 15 min	
Safety	Caution students that nails are sharp and should be handled with care.	

Background

The physical property of hardness is dependent on (1) the strength of the attractive forces between the particles of that substance, (2) the closeness of the particles, and (3) the readiness of the solid crystal lattice structure to "slip." The iron atoms in steel (very hard) are tightly packed, experience strong attractive forces, and are unable to slip. Talc (quite soft) has larger particles, weaker forces, and its crystals are able to "slip" past each other.

Activity Notes and Troubleshooting

- Constructing and understanding the table may be the most difficult part of this simple activity. Demonstrate it on the board. Ensure that students understand that the materials on the left side of the table are attempting to scratch the materials listed across the top.
- Suggest that students try some other solids as well (for example, fingernails, pencil "lead" [actually graphite + clay], plastic or wood items) and add them to their tables.

Additional Support

- ELL In English, *hardness* is not the same as *toughness* or *strength* as it is in some other languages. Use examples to clarify: A piece of glass is harder than the wood in a tree trunk, but wood is stronger. It will support the tree. Glass is not strong enough to do that.

Answers

1. talc; copper penny; steel nail; A pure substance can cause scratches on softer materials, as well as on itself.
2. Answers may vary; students should be able to tell that talc is the least hard material.
3. Chalk is softer than the chalkboard; otherwise, chalk would scratch the chalkboard.

Learning Check Answers (Student textbook page 156)

1. Qualitative properties are different kinds of properties, and are not measured. Quantitative properties are measurable differences within one property.
2. DDT is soluble in fat.
3. Even if two substances look alike (qualitative properties), they are likely to have different melting points (a quantitative property).
4. Diamond is harder than glass, so diamond should scratch glass.

Practice Problems (Student textbook page 157)

1. 2.7 g/cm^3
2. 1.06 g/cm^3
3. 0.0014 g/cm^3
4. 6.13 g/cm^3
5. Its density is less than the density of water. It will float on water.

Section 4.2 Review Answers (Student textbook page 159)

Please see also **BLM 4-11 Section 4.2 Review (Alternative Format).**

1. Qualitative physical properties are not measured numerically (such as colour, odour, state, texture, lustre, and malleability). Quantitative physical properties can be measured numerically (such as viscosity, melting point, boiling point, solubility, hardness, conductivity, and density).
2. A substance at its melting point changes state, but does not form a new substance.
3. DDT does not break down and, due to its fat solubility, bioaccumulates in fat tissue and biomagnifies so that animals higher in the food chain have higher levels than those lower in the food chain. Seals are higher in the food chain than cod.
4. conductivity
5. If the density of the material is small, then a large volume can have little mass.
6. density = $\frac{25.04 \text{ g}}{4.99 \text{ cm}^3}$ = 5.02 g/cm^3; The sample is iron pyrite.
7. The least dense material (olive oil) is the top layer and the more dense material (vinegar) is the bottom layer.
8. Accept all reasonable responses. Sample answer: If ice were denser than liquid water, a lake or pond would freeze from the bottom up. Many animals in ponds would die because the lake would become completely frozen.

Section 4.3 Chemical Properties (Student textbook pages 160 to 165)

Specific Expectations

- **C1.2** assess social, environmental, and economic impacts of the use of common elements or compounds
- **C2.4** conduct appropriate chemical tests to identify some common gases (e.g., oxygen, hydrogen, carbon dioxide) on the basis of their chemical properties, and record their observations
- **C3.4** describe the characteristic physical and chemical properties of common elements and compounds

In this section, students will identify and describe a number of chemical properties. In addition, they will investigate some of the chemical properties of everyday substances.

Common Misconceptions

- **Students often believe that when two chemicals (for example, vinegar and baking soda) are combined, only one chemical (for example, baking soda) reacts.** Students are likely to believe that the vinegar causes the baking soda to change, but that the vinegar does not change. It just gets "used up." Avoid terms like *used up* or *consumed.* Write complete equations to show reactions, demonstrating to students that there are reactants on the input side and there are products on the output side of the reaction.
- **Students may believe that a substance like vinegar can change its properties, such as odour or strength, but that it does not change in any fundamental way.** Use particle diagrams of chemical changes to show that all of the chemicals are changed.

Background Knowledge

The terms *chemical change* and *chemical property* are closely connected. A chemical change is any change that causes a change in the composition of the particles. Burning a sample of wood changes the composition of the particles. Reacting vinegar with baking soda changes the composition of both the vinegar and the baking soda.

A chemical property is any property that can be observed only during a chemical change. Burning wood is evidence of the flammability of wood. Fizzing of vinegar and baking soda is evidence of the chemical activity of those two substances.

Literacy Support

Using the Text

- ELL Draw students' attention to the Key Terms *combustibility, stability,* and *toxicity.* Have them identify the root word for each term, the common suffix, and other words they know with the suffix *-ity.* A definition of the suffix appears in Study Toolkit 3, Word Study: Common Base Words, Prefixes, and Suffixes in Science, on page 565.
- ELL Use the section summary found on page 165 as an overview of the text for English language learners.
- ELL English language learners need specific instruction on how to interpret text. For example, use page 163. Compare the margin definition of *combustibility* to the first sentence in the text. Ask which words are added (*is a chemical property/referred to*). Explain that the writer is trying to make the definition clearer. *For example* signals further information is being added, and *Figure 4.17* also supports understanding.

Before Reading

- Instruct students to preview the headings in the textbook. Ask students to write each heading and subheading on the left edge of a sheet of lined paper.
- Have students predict the content of each subsection of text, using the images and headings as clues.

During Reading

- Encourage students to read the text silently, writing a summary of each subsection to the right of the heading they wrote before reading.

After Reading

- After summarizing, instruct students to discuss their summaries, making additions and corrections as needed.
- Students can summarize the main ideas of sections 4.2 and 4.3 by creating a T-chart to compare and contrast physical and chemical properties. See **BLM G-38 T-chart.**

- Students can consolidate their learning using **BLM 4-12 Chemical Properties,** or **BLM 4-13 Chemical Properties (Alternative Version).**
- ELL Have English language learners work with more experienced English speakers. Use the Additional Support instructions below.

Using the Images

- Before or after reading, instruct students to summarize each image and its caption in one to five words that describe a chemical property that is being illustrated.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Strategies and Tools for Supporting Learners**
Student summary on **BLM 4-12 Chemical Properties**, or **BLM 4-13 Chemical Properties (Alternative Version)**	Students' summaries are complete and accurately reflect the content of the text.	Organize two or three students around one book. Repeat the activity, having one student turn pages slowly as the other students look for diagrams and headings. Instruct students to discuss what should be written on the blackline master.
Learning Check questions, page 163	Students identify chemical properties and their applications.	Alternate questions between students who have learned the ideas, and those who have not. Ask the more knowledgeable students to explain how they arrived at their answers. Ask other students to use these explanations to formulate their own.
Inquiry Investigation 4-B, Chemical Properties of Common Gases, pages 168 and 169	Students connect the chemical changes that a gas undergoes to the chemical properties of the gas and to the chemical test for that gas.	Model the connections using one gas as an example. Hydrogen plus oxygen chemically changes into water. The reactivity of hydrogen is a chemical property. This reactivity is a good test for hydrogen. Ask students to extend this test to other gases.
Plan Your Own Investigation 4-C, Properties of Common Substances, pages 170 and 171	Students distinguish between chemical and physical properties, and explain the differences.	Provide samples of several substances that display a range of properties (for example, charcoal, sulfur, quartz, water, and hydrogen peroxide). Have students discuss observations as they answer the questions.

Instructional Strategies

- Prepare several demonstrations of substances that model each of the properties. You can use them before reading, interspersed with reading, or as a review.
- ELL This approach is very important for English language learners. It enables them to see concepts that are being studied, hear and use academic and instructional language, and gain more meaning from print material. Consider using Activity 4-7, on page 162 of the student textbook, prior to reading the text as well.
- Demonstration 1: Drop one lump of calcium carbide into a beaker containing water. Ignite the gas that is produced with a spark lighter.
- Demonstration 2: Fluff up a small wad of steel wool. Use a spark lighter to strike some sparks on the steel wool. The iron will combust in oxygen.
- Demonstration 3: Drop one lump of zinc metal into a 250 mL flask containing 1.0 M HCl. Bring a flame to the mouth of the flask to ignite the hydrogen produced.
- Demonstration 4: Place several pennies on a hot plate. Place one tiny lump of sulfur on each penny. Slowly heat the pennies, and the sulfur will melt and react with the copper.
- Inquiry Investigation 4-B, Chemical Properties of Common Gases (on pages 168 and 169), allows students to apply what they have learned about chemical properties to test for common gases.

- In Plan Your Own Investigation 4-C, Properties of Common Substances (on pages 170 and 171), students apply their understandings of both physical and chemical properties to design tests to distinguish among six common substances.

Activity 4-7 What's New? (Student textbook page 162)

Pedagogical Purpose

Three distinct objectives are addressed in this activity. First, this activity can be used to introduce the idea that chemical change results in the production of new materials. Second, these two reactions are examples of the concept that chemical properties are observed only during a chemical change. Third, this activity provides opportunities to observe change of colour and appearance of a gas as two visible chemical changes.

Planning		
Materials	4 g sodium bicarbonate 50 mL 5% acetic acid Test-tube rack Balloon	Test tube 5 mL water Universal indicator Calcium
Time	Preparation time: 30 min Class time: 20 min	
Safety	Use sufficiently large balloons because small balloons may burst. Ensure that students wear safety goggles. Remind students not to handle magnesium with their fingers. Have ready a large vessel to hold waste.	

Background

The familiar vinegar–baking soda reaction is given a new twist by capturing the carbon dioxide. Although the solution does not heat up during the reaction, energy is still produced. The carbon dioxide produces mechanical pressure inside the balloon, which could propel the balloon around the room. Calcium reacts readily with water, displacing hydrogen gas, and producing calcium hydroxide. This reaction does produce enough heat to warm the test tube. The universal indicator will change from green to blue to purple as the solution is changed from neutral to basic.

Activity Notes and Troubleshooting

- Four grams of baking soda will produce about 1 L of carbon dioxide gas. Choose balloons that can hold 1 L of gas without bursting, with 15 cm diameter or larger.
- Use a large diameter funnel to put 4 g of baking soda into each balloon.
- Measure 50 mL of vinegar into each bottle.
- Tell students to snap the balloon over the neck of the bottle, without spilling the powder into the vinegar.
- Perform the reaction of calcium with water as a demonstration.
- Add 10 mL of water to the test tube, and several drops of indicator.
- Put the calcium into the solution. The reaction will generate hydrogen gas.

Consider trying these variations, or having interested students try them as an additional challenge:

- Use 5 g of sodium carbonate in the balloon and 90 mL of white vinegar in the bottle. Add several drops of universal indicator to the bottle. The reaction is similar, and the colour will change from red, through orange, yellow, green, and blue, to purple. Blue indicates that the vinegar, an acid, has all been changed to sodium acetate.
- Dilute the vinegar by adding water to slow the reaction down. (Have students predict the result before they carry out the experiment.)

- Use cold vinegar to show how temperature can slow this reaction. (Have students predict the result before they carry out the experiment.)
- To introduce or reinforce the difference between an observation and an inference, use **BLM G-4 Making Observations and Inferences.**

Additional Support

- DI The experience for bodily-kinesthetic learners can be more meaningful if they assemble the apparatus themselves.

Answers

1. The balloon expanded because of the production of a gas from the reaction.
2. Students should see the solution turn pink (phenolphthalein) or blue (universal indicator). Bubbles of hydrogen gas are produced. A precipitate of magnesium hydroxide forms.
3. Sodium reacts too violently with water; even the moisture in the air would cause a reaction.

Learning Check Answers (Student textbook page 163)

1. **a.** the smell of natural gas
   b. the combustibility of propane
2. Reflection is a physical property. No new substances are formed.
3. Highly combustible substances like gasoline may be dangerous and require special care.
4. It is a physical property because no new substances are formed. The dissolved carbon dioxide is simply coming out of the solution.

Section 4.3 Review Answers (Student textbook page 165)

Please see also **BLM 4-14 Section 4.3 Review (Alternative Format).**

1. **c.** Hydrogen can burn and explode. The other choices do not involve chemical changes.
2. Yes. The gas is a new substance, so new molecules must have been formed.
3. Yes. Chemical properties are observed during chemical changes. Rust is a new substance. Rusting is a chemical property of iron.
4. Sample answer: Be sure to wear gloves. Peroxide in hair dyes can cause irritation to the eyes and skin.
5. Propane is combustible.
6. When a compound does break down, at least one new substance is formed.
7. Toxicity can be measured, so it is a quantitative property.
8. Sample answer: A substance that is both highly toxic and highly stable will have a greater detrimental effect than a substance that is either easily broken down or only slightly toxic.

Inquiry Investigation 4-A Testing Physical Properties of Substances (Student textbook pages 166 and 167)

Pedagogical Purpose

Section 4.2 emphasizes physical properties of matter. This inquiry provides an opportunity for students to clarify their understanding of these properties, to learn how to test for these properties, and to compare the properties of several substances.

Planning	
Materials	A small amount of each of the following: • aluminum • carbon (graphite) • copper(II) sulfate • magnesium sulfate Water Conductivity tester Scoopula Five 25 mL test tubes Test-tube rack 50 mL water 10 mL graduated cylinder **BLM 4-15 Inquiry Investigation 4-A Testing Physical Properties of Substances** (optional) **BLM G-23 Data Table** (optional) **BLM G-5 Science Inquiry Organizer** (optional) **BLM A-26 Inquiry Investigation Rubric** (optional)
Time	Preparation time: 60 min Class time: 45 min
Safety	Hot plates present a burn hazard. Caution students to keep all flammable materials away from the hot plates, including hair and clothing. Tell students to clean up all spills to prevent electric shock. Ensure students wear safety clothing, including lab aprons, protective gloves, and protective eyewear.

Background

The physical behaviour of substances covers an enormous range. The materials tested in this activity represent several classes of matter: metals (aluminum), non-metals (graphite), ionic compounds (copper sulfate and magnesium sulfate), and covalent compounds (water). The behaviour for each will differ substantially. Provide a simple table based on this classification for English language learners to make sketches or simple statements of what they have observed.

Activity Notes and Troubleshooting

- You may substitute, or add, any of these materials for each class of matter: metals (copper, tin), non-metals (sulfur), ionic compounds (salt, baking soda), and covalent compounds (sugar, camphor, vegetable oil).
- If you wish, provide some additional examples of substances with odour: camphor, peppermint oil, limonene (lemon oil). These substances tend to have small covalent molecules.

- Demonstrate melting behaviour for students. Choose a hot plate that has cooled to room temperature. Cover the top with aluminum foil and place several substances on top of it: elements (aluminum, silicon, sulfur, graphite) and compounds (sugar, wax, camphor, salt, copper(II) sulfate). You can label each with a marking pen. Turn on the hot plate, and note the time at which each substance melts or changes. A longer time can be interpreted as the requirement for a higher temperature to melt the sample.

Additional Support

- ELL Terms like *solubility* and *conductivity* present a special challenge to English language learners. Not only are these students learning a new word, but they are learning a concept for which they may not have learned the words in their own language. Emphasize these concept-words in your conversations with these students. Use other words in the same word family as well, for example, *dissolve* and *conduct*.
- DI For students who enjoy a challenge, have additional materials available to test.
- If students choose to extend their inquiry and research skills, they can use **BLM G-5 Science Inquiry Organizer,** to help them. Use **BLM A-26 Inquiry Investigation Rubric,** to guide and assess their work.

Answers

Analyze and Interpret

1. Usually, the substances can be broadly grouped as metals (aluminum) or non-metals (carbon); ionic (copper sulfate, magnesium sulfate) or covalent (water).
2. Students' answers are likely to vary. Watch for categories that group metal/non-metal and ionic/covalent. Encourage students to use these words, in anticipation of having the terms explained in later chapters. Print the words as they come up in discussion, for English language learners.
3. Students' answers will vary. Two broad groups are metals (shiny, no odour, good conductor, does not melt, insoluble) and ionic compounds (clear, crystalline, odourless, poor conductors, soluble in water).

Conclude and Communicate

4. Students' answers will depend on their initial predictions. Look for coherent comparisons of predictions and observations.

Extend Your Inquiry and Research Skills

5. Tests could be designed to use one of these physical features: malleability, reactivity, conductivity of solution, or density.
6. Students should list usefulness and hazards of aluminum, carbon, copper, or magnesium.

Inquiry Investigation 4-B Chemical Properties of Common Gases (Student textbook pages 168 and 169)

Pedagogical Purpose

Section 4.3 emphasizes chemical properties of matter. This inquiry provides an opportunity for students to clarify their understanding of three common gases, to learn how to test for these gases, and to compare the properties of these gases.

Planning		
Materials	10 mL of 1.0 mol/L hydrochloric acid Test-tube rack Rubber stopper 2 wooden splints Yeast 5 mL limewater Cobalt chloride paper **BLM 4-16 Inquiry Investigation 4-B Chemical Properties of Common Gases** (optional)	4 test tubes Mossy zinc Test-tube holder 5 mL 3% hydrogen peroxide Marble or limestone Balloon
Time	Preparation time: 60 min	Class time: 60 min
Safety	Goggles, a lab apron, and skin protection are necessary near hydrochloric acid. Practise fire safety when near the burning splints. Remind students to tuck in loose clothing and long hair.	

Background

Oxygen in the air supports combustion at a concentration of 20 percent. In this activity, the concentration can approach 100 percent, and the ability to support combustion is increased. The high concentration accounts for oxygen's ability to rapidly combust a glowing splint. Hydrogen is very combustible, combining rapidly with oxygen when ignited. Carbon dioxide dissolves in water to make carbonic acid, H_2CO_3. This acid reacts with limewater and calcium hydroxide, $Ca(OH)_2$. The product is insoluble calcium carbonate, which is what makes the mixture appear milky. Cobalt chloride is blue when dry. The cobalt ion strongly attracts water molecules, turning pink as it does so.

Activity Notes and Troubleshooting

- Prepare the limewater at least 24 h before the activity. Mix calcium oxide (quicklime) or calcium hydroxide (slaked lime) with distilled water. Let the mixture sit overnight. It will settle into a clear liquid (saturated calcium hydroxide solution, or limewater) and a white sediment. Without disturbing the sediment, decant the clear liquid through a filter. The clear filtrate is limewater. Seal it in a plastic bottle.
- Hydrogen peroxide should be stored in the refrigerator between uses.
- Dry the cobalt chloride paper before use. Spread the strips over a hot plate set to its lowest setting.
- Each experiment produces only 50 to 60 mL of gas. If more gas is needed, increase the volume of the liquid in each case.
- The candles serve as a ready flame. You can light them as you circulate through the lab.

Additional Support

- ELL The instructions are intricate, and may be difficult for English language learners. Demonstrate each of the procedures for students. Have English language learners work with other students who have strong English-reading skills.
- DI While the activity itself is highly engaging for bodily-kinesthetic learners, the calculations and analysis require a more analytical temperament. Encourage students to form pairs in which both kinds of learners make a contribution.

Answers

Analyze and Interpret

1. No. For example, all the physical properties listed in Table 4.2, Qualitative Physical Properties, on page 150 of the student textbook, would be similar for all the gases produced in this investigation.
2. Part 1: combustibility to detect hydrogen gas, Part 2: combustibility to detect oxygen gas, Part 3: reactivity to detect carbon dioxide, Part 4: reactivity to detect water vapour

Conclude and Communicate

3. Do not allow any source of flame or spark into the workplace. These sources include Bunsen burners, smoking materials, and items that produce static electricity. Explain to English language learners what is meant by *giving advice.*

Extend Your Inquiry and Research Skills

4. Questions will vary. Students may include questions about whether hydrogen gas, oxygen gas, carbon dioxide gas, or water vapour are present. Summarize students' questions. Use them with English language learners to talk about which questions are scientific and which questions are not, and why.
5. Make sure that English language learners understand the syntax (both *useful* and *hazardous*). For example, oxygen gas is combustible, stable, not toxic, and not reactive with water. It is also colourless, odourless, and a gas. These properties make it important in workplaces in which things are burned or heated, for example metal refining and glass manufacturing. Its combustibility make it hazardous, as well. The fact that it is colourless and odourless means that workers have to be very careful to ensure concentrations of oxygen are carefully controlled before any sources of flame are introduced.

Plan Your Own Investigation 4-C Properties of Common Substances (Student textbook pages 170 and 171)

Pedagogical Purpose

Planning an investigation such as this one demands higher-order thinking skills. First, students must anticipate possible properties of each material, which requires students to apply their understanding of matter to a set of new substances. Second, students must choose tests that distinguish between two anticipated properties. Third, students must prioritize tests, so that tests that are absolutely necessary are performed before those that provide only supplementary data.

Planning	
Materials	Table sugar (sucrose) Baking soda (sodium bicarbonate) Aluminum strips Tin strips Cooking oil Vinegar (5% acetic acid in water) Test tubes Test-tube rack Scoopula Other equipment, as needed, to perform tests: Conductivity tester Hot plate Small hammer or substitute Electronic balance Other glassware **BLM 4-17 Plan Your Own Investigation 4-C Properties of Common Substances** (optional) **BLM G-23 Data Table** (optional) **BLM A-27 Plan Your Own Investigation Rubric**
Time	Preparation time: 45 min Class time: 70 min
Safety	The materials themselves are generally regarded as safe; however, students should follow standard lab safety procedures. Ensure students do not taste the chemicals or inhale them directly. Hot plates present a burn hazard. Caution students to keep all flammable materials, including clothing and hair, away from the hot plates. Ensure that students wear safety goggles and a lab apron. Remind students to clean up all spills immediately and inform you.

Background

Students have learned a number of observational and chemical testing skills. This inquiry challenges students to apply their skills to a new set of substances. To effectively complete this investigation, students must plan carefully the tests that they believe would be helpful. The planning process itself is perhaps the most important part of this activity.

Activity Notes and Troubleshooting

- Provide necessary equipment for a large variety of tests. Some students may wish to investigate density, melting behaviour, viscosity, solubility, reactivity, and conductivity. Show students what equipment is available to them before they develop a plan for their inquiry.
- Flammability tests are best conducted on a hot plate. Students should put a small sample (about the size of a match head) of the material on a piece of aluminum foil on a hot plate and then turn it on. Attempt to ignite any fumes produced.

- Consider substituting alternative substances for students to test.
  - Calcium metal, calcium carbide, and anhydrous copper(II) sulfate are all reactive with water. All three materials produce considerable heat. Calcium metal produces hydrogen gas. Calcium carbide produces flammable acetylene gas. Use amounts that are about the size of a pea or smaller.
  - Plant derivatives (for example, turpentine, camphor, peppermint oil, lemon oil) are often combustible in oxygen, and have odour.
- You can guide and assess students' work using **BLM A-27 Plan Your Own Investigation Rubric.**

Additional Support

- ELL Have English language learners who need support during the planning stage work with fluent English speakers to plan their tests. Talk to these peer supporters about the difference between supporting and doing the activity for their partners. Brainstorm ways in which they could involve English language learners in the planning and how they could support their language needs for example, explaining instructions (safety precautions), ensuring understanding of directions (*examine, analyze*), and explaining syntactical issues in questions. (*If so, which properties?*)
- Ask questions of all students to probe for understanding. Use the results of your questioning to assess and correct both scientific and linguistic misconceptions and misunderstandings.
- DI Bodily-kinesthetic learners are sometimes challenged by organizational tasks. Use chalk to draw a large table on a desktop, and physically place the materials and the testing equipment in the columns of that table to help students organize their data.

Answers

Analyze and Interpret

1. Students might notice that smelly, insoluble, oily materials have low melting points; and that odourless, crystalline, solid materials have high melting points. Three distinctively different groups can be observed (metals, covalent compounds, and ionic solids), although students will not have names for them.
2. Students might find that three substances are all colourless, but differ in hardness.

Conclude and Communicate

3. Some tests, such as reactivity with water, produce very few positive results. Students may suggest that these tests be replaced with other tests.

Extend Your Inquiry and Research Skills

4. elements: aluminum, tin; compounds: baking soda, sugar, cooking oil; mixture: vinegar
5. Students' answers may vary. Sugar's sweetness depends on its solubility: we could not taste it if it did not dissolve. Metals are used because they are harder and more resilient than plant materials. Perfumes and deodorants are made from oily or waxy materials that dissolve in water.

Real World Investigation 4-D CFC Production and Canada's Ozone Layer (Student textbook page 172)

Pedagogical Purpose

In this investigation, students research an environmental effect of the reactivity of a common chemical.

Planning	
Materials	Graph paper Ruler Coloured pens or pencils (optional) Calculators (optional) **BLM 4-18 Real World Investigation 4-D CFC Production and Canada's Ozone Layer** (optional) **BLM G-25 Constructing a Line Graph** (optional) **BLM G-26 Interpreting Line Graphs** (optional) **BLM A-28 Real World Investigation Rubric**
Time	Class time: 40 min

Background

Before 1930, refrigerators used either sulfur dioxide (SO_2) or ammonia (NH_3) as refrigerants. Trichlorofluoromethane (CCl_3F) was invented in 1928 to replace these toxic compounds. Given the trade name *Freon,* this covalent compound was produced in ever-increasing amounts until scientists became aware that it was causing ozone in the stratosphere to decompose. High-altitude ozone absorbs most of the ultraviolet radiation from the Sun. As the ozone layer is depleted by Freon and related compounds, the surface of Earth is exposed to UV radiation. These graphs follow the production, the atmospheric concentration, and the ozone layer thickness over a 60-year interval. Students can extrapolate further.

Trichlorofluoromethane was marketed as Freon-11. It was the first, but by no means the only, chlorofluorocarbon (CFC) brought to market. In fact, the total mass of Freon-11 is only a small fraction of the total CFC production from 1930 to the present. When CFCs are exposed to ultraviolet (UV) light, the UV light breaks off the chlorine atoms. Single chlorine atoms have one unpaired electron. Atoms or molecules with one unpaired electron are called free radicals. One chlorine free radical can destroy tens of thousands of ozone molecules, so even very small amounts of CFC are very harmful to the ozone layer.

The Montréal Protocol is an international agreement to reduce production of CFCs. It was achieved in 1997 at a meeting of international scientists in Montréal.

Activity Notes and Troubleshooting

- Students' greatest challenge will be choosing appropriate scales for their graphs. Remind them to look at the greatest values in all three data sets, and then choose a scale that allows them to show that value on their graph. The independent variable is date, so it should go on the horizontal axis of the graph. All of the data can be made to correspond to one vertical scale: 0 to 400.
- You can guide and assess students' work using **BLM A-28 Real World Investigation Rubric.**

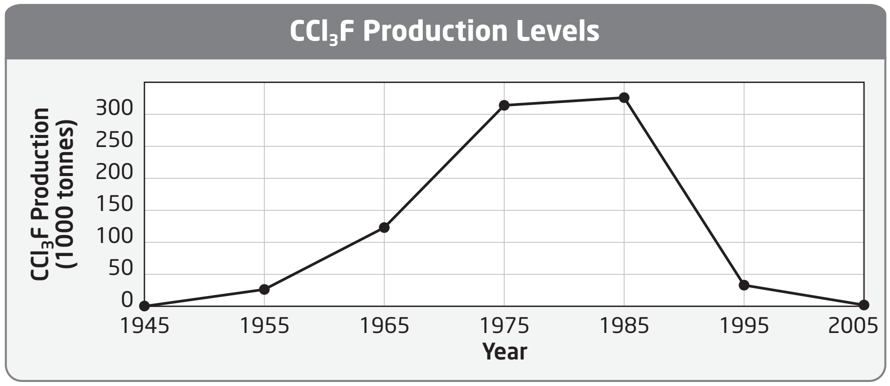
Additional Support

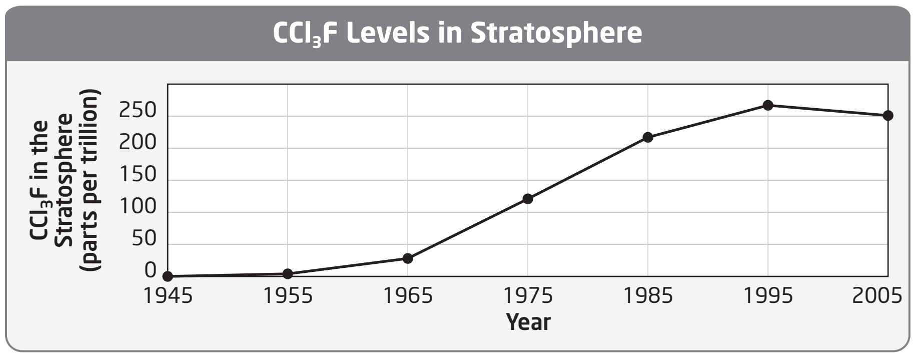
- ELL This page contains many technical terms that may be unfamiliar to English language learners (for example, *ozone layer, CFC, propellant, hole* in ozone layer, *stratosphere, coolant,* and *refrigerator*). Provide additional modes of communication to ensure that English language learners understand the context of this investigation. For example, demonstrate propellants from a spray can, or make use of a refrigerator or an air conditioner to illustrate where coolants are used.
- ELL Tables and graphs are usually presented in a "universal language," but they are especially challenging when they contain technical data and units. Be sure to explain what the data in each column are measuring.
- If students are not confident drawing and interpreting graphs, refer them to Math Skills Toolkit 3: Organizing and Communicating Scientific Results with Graphs; **BLM G-25 Constructing a Line Graph;** and **BLM G-26 Interpreting Line Graphs.**
- ELL Ensure that English language learners know what is meant by a blog. Let them find examples with a partner and talk about how they are designed. Consider a shared writing activity in which you model the process of making a blog, using the information gathered by English language learners, or have English language learners work with a strong English speaking partner to write. If equipment is available, let students take photographs as the process unfolds, for use on their blog.
- Some students may enjoy the challenge of extrapolating the trends into the future.

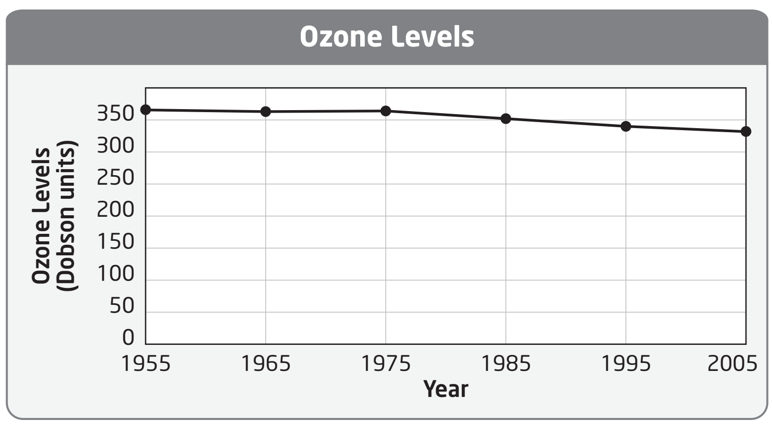
Answers

Organize the Data

1.







Analyze and Interpret

1. 25 years
2. 1985
3. 10 years

Conclude and Communicate

4. Students' answers will vary. Encourage clear expression of cause-and-effect thinking.

Extend Your Inquiry and Research Skills

5. Students' responses should refer to the many kinds of damage that UV radiation does to humans, animals, and plants.

Chapter Review Answers (Student textbook pages 174 and 175)

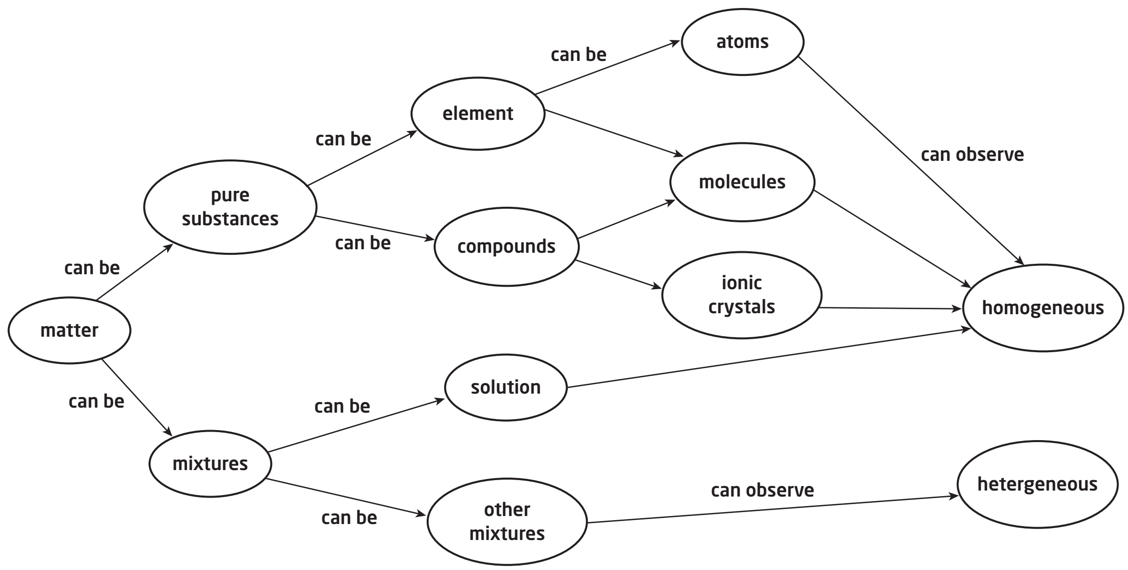
Please see also **BLM 4-19 Chapter 4 Review (Alternative Format).**

- ELL Consider asking English language learners to group the review questions. Have the students pick the questions that they feel they can answer independently. Have them select questions for which they are not sure of what they are being asked. Clarify these questions by restating them. Let students select the questions for which they may need some language support and, finally, those questions for which they need peer support or reteaching.

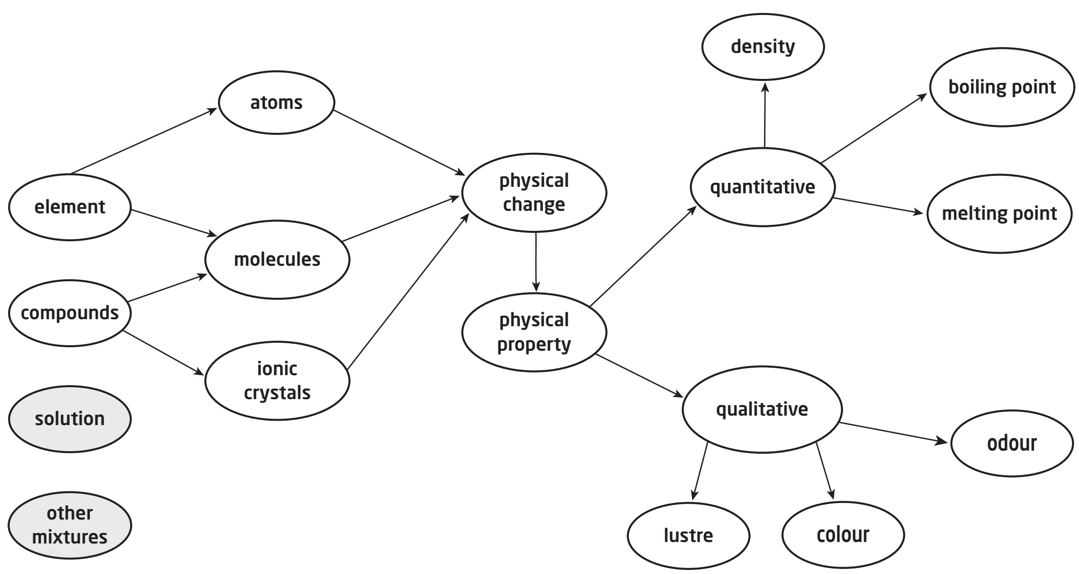
Make Your Own Summary

A concept map is appropriate to show the many interrelated concepts in this chapter. The arrows should be labelled with the nature of the relationship.

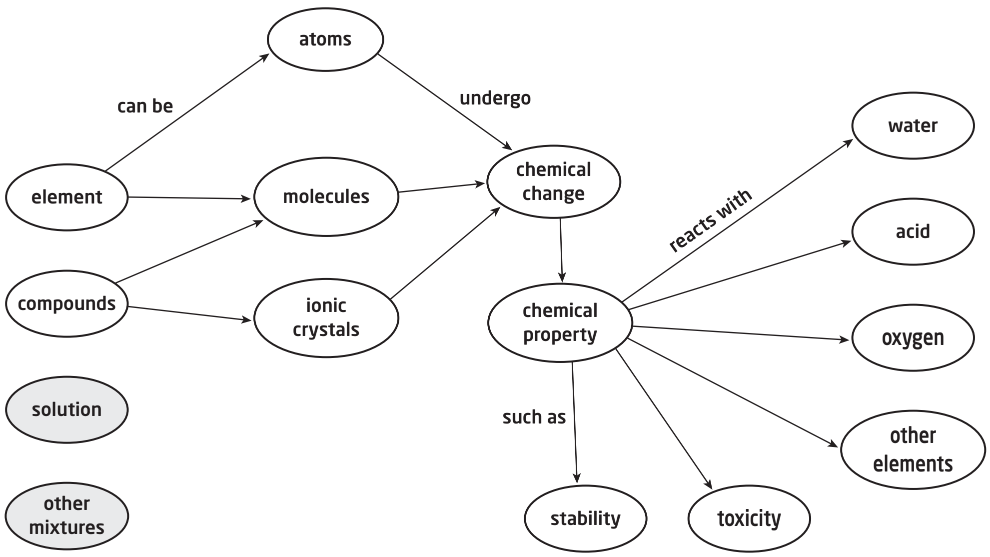
1. An example of an appropriate concept map is shown below.



2. The physical properties of a substance are those that can be observed without a chemical change. Very often, they can be observed during a physical change.



3. The chemical properties of a substance can be observed only when that substance is undergoing a chemical change. During that process, new substances are being formed.



Reviewing Key Terms

1. physical property
2. density
3. atom
4. element
5. chemical
6. compound

Knowledge and Understanding

7. a. physical
   b. physical
   c. chemical
   d. chemical
   e. physical
   f. physical
   g. chemical
8. The two elements must be chemically combined to form the compound, so the elements do not have their original properties. The elements are physically mixed to form a mixture, so each element keeps its identity and properties. An example of a mixture is when oxygen, O_2, and nitrogen, N_2, are mixed in air. An example of a compound is when nitrogen dioxide, NO_2, is formed in lightning bolts.
9. The particles in a pure substance are identical; therefore, the pure substance has the same composition throughout.
10. 105 g
11. Sample A has the greater density. It contains more mass in the same volume. In the equation $D = \frac{m}{V}$, the larger the mass is, the larger the density becomes.
12. The substance must be soluble in water.
13. a. aluminum: element
    b. air: mixture
    c. sugar: compound
    d. orange juice: mixture
    e. DDT: compound
    f. tin: element
14. combustibility: reactivity with oxygen
15. chemical property
16. high lustre, transparency, and reflection of light for gemstones; hardness, low reactivity with chemicals, low electrical conductivity, high thermal conductivity, and high density for industry
17. a. 7.13 g/cm^3
    b. 1.43 g/L, or 0.00143 g/mL
    c. 2.70 g/mL, or 2.70 g/cm^3
18. An element is a pure substance that cannot be broken down further by chemical or physical methods. A compound is a pure substance that is made of two or more different elements that are chemically combined.
19. Hydrogen peroxide reacts with melanin in hair to produce a colourless compound. Hydrogen peroxide can irritate the eyes or broken skin. At high concentrations, it can cause bleaching, redness, and even skin blisters.

Thinking and Investigating

20. The statement is not correct. An object can have a large volume and still have a small mass if it has a low density. The helium in a party balloon has a greater volume than a hockey puck, but it also has a lesser mass than a hockey puck.

21. While cleaning up, he or someone else nearby might break a piece of glassware or splash a chemical. The goggles and apron are important to protect him.

22. mass of water = 105.75 g – 55.75 g = 50.0 g
volume of water = 50.0 cm^3
capacity of container = 50.0 cm^3
mass of unknown liquid = 123.75 g – 55.75 g = 68.00 g

$$D = \frac{m}{V} = \frac{68.00 \text{ g}}{50.0 \text{ cm}^3} = 1.36 \text{ g/cm}^3$$

Therefore, the unknown substance is corn syrup.

Communication

23.

Effects of DDT on Society and the Environment	
Positive Effects	**Negative Effects**
• eliminates insect-carrying diseases • increases crop yields	• does not break down easily, so stays in environment • is stored in the fatty tissue of animals, which has a negative impact on the animals, and causes the DDT to biomagnify through the food chain

24. Students' advertisements will vary, but they should include some of the following ideas: Diamonds are useful as gemstones because of their high lustre, transparency, and ability to reflect light. Diamonds are also very useful for industry because of their hardness, low reactivity with chemicals, low electrical conductivity, high thermal conductivity, and high density. Diamonds are very durable and are used for drilling, cutting, and grinding.

25. The density of a substance is the same no matter how large or small the sample is. Both mass and volume change depending on the size of the sample.

Application

26. Sample B is more viscous than sample A. Sample B required more time to travel the 100 cm length of the tube.

27. Sample answer: When I exhale, my breath contains gases, including carbon dioxide and water vapour. These gases quickly cool, and the particles slow down. The attractions between the particles of water overcome the motion of the particles, and the water vapour condenses to a liquid. The tiny drops of liquid water are what I see.

28. Sample answer: The facial tissue is soft, flexible, and absorbent, which makes it able to be shaped to a person's nose and absorb bodily fluids without scratching the person's skin. The paper is smooth and flat, which makes it a good surface for writing or printing on. The cardboard box is stiff, so it is able to hold its shape and protect items inside. All three materials share the chemical property of combustibility.

29. Water can absorb a lot of heat before it begins to get hot, and it is resistant to sudden temperature changes. It is stable and not combustible, so there is no danger placing it near a car engine.

Chapter 5 Understanding the Properties of Elements

In this chapter, students will trace the development of the atomic model as scientific knowledge was accumulated. They will examine the Bohr-Rutherford model in detail, draw diagrams, build a model, and apply what they learn to analyze patterns that appear in the properties of elements on the periodic table.

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- Order 7 to 8 kg of modelling clay.
- Prepare 2.0 L of 1.0 M HCl.
- Check the batteries of the conductivity testers. Replace the batteries if necessary.
- Students can review the Key Terms in Chapter 5 using **BLM 5-1 Chapter 5 Key Terms.**

Using the Chapter Opener

- Show students many different forms of aluminum: aluminum foil; aluminum wire; automobile, airplane, or bicycle parts; cooking tools; doors, windows, or furniture; and so on. Also, show products that include chemicals containing aluminum: many deodorants; some antacid preparations; alum; and many cosmetics.
- Ask students, “Why does aluminum have so many uses?”
- Tell students that aluminum is the third most abundant element in Earth’s crust, although not as abundant in Earth’s core. Ask, “Why would that be?”

Activity 5-1 The Atomic “Black Box” (Student textbook page 177)

Pedagogical Purpose

This activity uses a model to provide students with experiences analogous to exploring the atom. Students will probe an object (whose contents are unknown) to obtain information of one kind (touch, in this case). Then students will draw conclusions based on their observations, to construct a model of the inner workings of the atom.

Planning		
Materials	Modelling clay (7–8 kg) Simple objects (such as coins, marbles, nuts, bolts, washers, and thimbles)	2 thin stir sticks
Time	30 min in class	

Background

The first occurrence of the term *black box* in English literature, in about 1670, referred to a coffin! Today, any device whose inner workings are mysterious is referred to as a black box. The cell phone is a black box to most of us. We know what goes in (finger taps and voices) and we know what comes out (pictures, words, and music), but most users have no idea what goes on inside.

Activity Notes and Troubleshooting

- Choose objects with shapes that are simple enough to distinguish by probing (for example, a flat coin, washer, large hex nut, bolt, die, marble, dry cell, thimble).
- Avoid objects that differ in small features, but not in shape (for example, chess pieces, figurines, very small objects).
- Warm the modelling clay before use to make it pliable. Keep its temperature just above body temperature, about 35°C, for several hours.
- Some brands of modelling clay leave greasy stains. Choose carefully.
- Thin, bamboo shish-kebab sticks can be substituted for stir sticks.
- An equator and two meridians scratched onto the surface of the ball can provide students with some reference points for probing.

Additional Support

- ELL The procedure is relatively straightforward. Demonstrate the steps before students begin, to ensure that English language learners understand what to do. Explain academic vocabulary, like indirect observation, infer, and strategy.
- DI Bodily-kinesthetic learners might not be very systematic about their probing. Encourage them to probe systematically, and to pause frequently to record and discuss their thinking. Pair them with more methodical students.

Study Toolkit

Strategy	Page Reference	Additional Support
Visualizing	Models by Dalton, Thomson, Rutherford, and Bohr: pages 180–184 Bohr Rutherford models: page 190	Activity 5-2, How Small Is Too Small? on page 180 Inquiry Investigation 5-A, The Bohr-Rutherford Model of the Atom, on page 212 Activity 5-7, The Bohr-Rutherford Periodic Table, on page 208
Suffixes	After finding words with the suffixes -ic, -al, and -ity in section 5.1, point out that these suffixes and others can help students predict meaning in other sections, as well. In section 5.3, students can use the suffix -oid, to predict the meaning of *metalloid.*	Refer students to Study Toolkit 3, Word Study: Common Base Words, Prefixes, and Suffixes in Science, on student textbook page 565. Encourage English language learners to think about similarities and differences in English and their first language.
Asking Questions	After students read the first paragraph on page 179, ask some to share their questions with the class, in order to model the process of posing questions for the others.	**BLM A-2 Asking Questions Checklist** English language learners would benefit from teacher modelling. Start with a heading, and suggest a question a reader might ask. Read the first paragraph, continuing to ask and answer questions. Include questions about connections between the text and the visuals.

Section 5.1 Evolution of the Atomic Model

(Student textbook pages 179 to 186)

Specific Expectations

- **C2.1** use appropriate terminology related to atoms, elements, and compounds
- **C3.1** explain how different atomic models evolved as a result of experimental evidence
- **C3.2** describe the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass

In this section, students will trace the development of the atomic model, up to about 1915. Students will encounter brief biographical and historical sketches to provide contextual support for the concepts themselves. The cumulative nature of scientific knowledge is highlighted, as the contributions to the model by one scientist after another are outlined.

Common Misconceptions

- **Students may think of a model as a physical thing, like a model car.** Encourage them to think of mental models instead. A mental model is a mental representation, like a mental map, which provides students with the means to navigate or think through a problem.
- **Students may think of the Bohr-Rutherford model as a fixed, planetary model.** Provide some tantalizing ideas from quantum mechanics: the electron is a wave; photons carry force; and so on. From time to time, draw the Bohr-Rutherford model with wavy lines for orbits.
- **Never provide students with information that will have to be unlearned later.** Do not speak of any of this material as the final word. Instead, speak of each model as an idea in need of further refinement.

Background Knowledge

A helpful image of the development of atomic models is to describe each one as "bringing the last model into better focus." Dalton, Curie, Thomson, Rutherford, Chadwick, and so on, each provide a clearer look, but the model remains blurry. There is more to learn!

This image also includes a place for the role of technology in the development of each model. Technologies such as good balances, reliable batteries, electric charge detectors, chemical processes, and vacuum pumps all contributed to improving the focus on the atom. Future technological advances will no doubt contribute to continued refinements of the atomic model.

Literacy Support

Using the Text

- ELL Provide English language learners with a time line or concept map that introduces the development of atomic models. Include key scientists, dates, and theories, as described in the summary review. Draw simple sketches. Preview the section in the textbook to identify the key models, and encourage students to refer to the time line or concept map as they work their way through the activities and discussions in the section. Because of the abstract nature of the concepts, arrange first language support groups, where possible.

Before Reading

- Instruct students to preview the text features. Identify and read the main heads (blue) and the subheads (purple). Have students copy each heading onto a sheet of paper. Under each heading, have students generate two or three questions beginning with "Who…", "What…", "When…", "Where…", "Why…", or "How…", leaving space to answer the questions. You can refer students to Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook, and guide their question posing using **BLM A-2 Asking Questions Checklist.**

During Reading

- Instruct students to read the text, and use the descriptions and figures to visualize each model, answering their questions as they go.

After Reading

- Have students make up one or two more questions that they could have asked for each section, or one or two questions that they would like to investigate further.

Using the Images

- The entire focus of this section is about using images and models to understand scientific concepts. Instruct students to study Figures 5.2, 5.4, 5.6, and 5.7, on pages 180 to 184. Ask, "What is the same among these diagrams? What is different?"
- Have students draw all four diagrams in their notes, making each one the same size. By doing this, students can become competent at drawing and visualizing these models, and also see how each new model added some detail to the previous model.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, pages 183 and 184	In questions 3, 4, 6, and 7, students sketch and/or describe Dalton's, Thomson's, Rutherford's, and Bohr's models of the atom.	Rather than write sentences, have students draw diagrams and explain them verbally. Give English language learners time to practise their oral explanations using key vocabulary from a list of words or from their concept maps.
Activity 5-3, Atomic Model Time Line, on page 185	Students produce correct and complete time lines.	Have students work in pairs to compare time lines and add to their own. They could then compare as a small group.
Section 5.1 Review questions, page 186	In questions 5 and 7, students describe the main understandings that Bohr's and Rutherford's models helped to illustrate.	Allow students to answer using a diagram and/or an oral explanation.

Instructional Strategies

- Use a hydrogen discharge tube to demonstrate Bohr's observations. The visible red band is due to the 3 → 2 transition; green is due to the 4 → 2 transition; and the violet band is due to the 5 → 2 transition in the Bohr-Rutherford model of the atom. Thomson used a similar apparatus to demonstrate that electrons were emitted from atoms of every known element.
- To illustrate Rutherford's observations, provide two disk magnets, flipped to repel each other. Hold one disk firmly on the desk (nucleus), and flick the second disk at it, crokinole-style, as a model for the Rutherford experiment. At this scale, two adjacent nuclei would be many metres apart. Most alpha particles go straight through, some change direction slightly, but a few that directly hit the nuclei bounce nearly straight back. These types of demonstrations are important and provide English language learners with a better understanding of concepts. Print key vocabulary and encourage drawings and labelling to support language growth as well.

Activity 5-2 How Small Is Too Small? (Student textbook page 180)

Pedagogical Purpose

It is very difficult for students to imagine how small an atom is. This experience provides three things that students can grasp: the initial size of the paper, the operation of cutting in half, and the number of times the operation is repeated.

Planning		
Materials	Round-tipped scissors	Strip of paper (28 cm × 2.5 cm)
Time	Preparation: 10 min	Class time: 10 min
Safety	Caution students about the safe use of scissors.	

Background

To get down to the width of one atom, students would have to cut the paper in half 31 or 32 times!

Activity Notes and Troubleshooting

- Emphasize cutting the paper in half. Uneven cutting will skew the number of cuts.
- The textbook instructs students to cut lengthwise. Many students will interpret this as making a cut that is 28 cm long. Encourage them to cut across the paper (a 2.5 cm cut) instead. This will make the activity more manageable.

Additional Support

- **ELL** Show examples of items around the classroom divided in half, and divided into other fractions less than or greater than one half: half a pencil, half the chalkboard, less than/greater than half the book, and so on. English language learners may understand the concept but not have the mathematical language (lengthwise) or academic language (discard) to follow directions.
- **DI** Encourage bodily-kinesthetic learners to take on the role of paper cutter.
- Ask a student to use a calculator to calculate the size of the paper after 8 cuts, 9 cuts, 10 cuts, and so on, up to 31 cuts.

Answers

1. A student who cuts very carefully, using very sharp scissors, might manage eight or nine cuts.
2. For example, use a calculator to divide 28 cm (or 2.5 cm, depending on which way the paper was cut), and repeat as many times as I cut the paper.
3. 31 times

Activity 5-3 Atomic Model Time Line (Student textbook page 185)

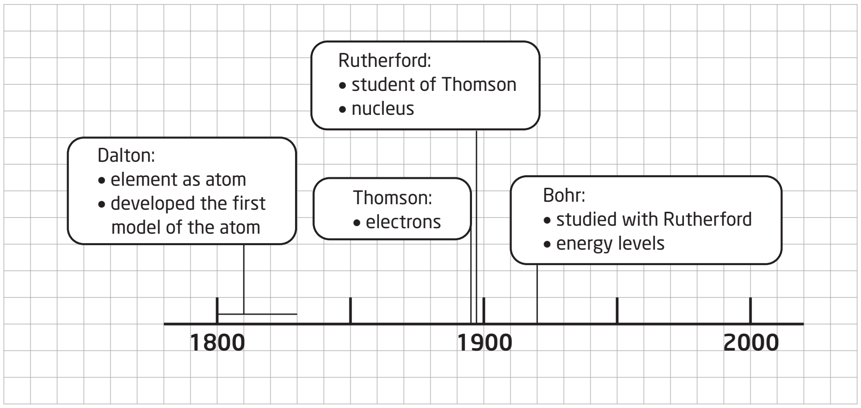
Pedagogical Purpose

One of the goals of history is to organize events into a coherent story, into which the student-historian can enter. This exercise provides a vehicle for students to do just that. Placing the models and their characteristics on a time line can help students appreciate the cumulative nature of scientific understanding.

Planning		
Materials	1 sheet of graph paper	Coloured pencils
Time	Preparation: 5 min	Class time: 40 min

Background

Students' finished time lines should include the information shown below.



Activity Notes and Troubleshooting

- Suggest that students display connections between people (for example, Rutherford was Thomson's student) by drawing and annotating a line.

Additional Support

- Provide a much larger sheet of flipchart paper, and have students cut and paste coloured paper with the required information.
- Enrichment—Provide books with information about additional scientists who explored beyond the information provided in the textbook. Challenge students to add these scientists and their accomplishments and relationships to their time lines. Other scientists might include Marie and Pierre Curie, James Chadwick, Antoine Lavoisier, Robert Boyle, and Amedeo Avogadro.

Answers

1. Rutherford was Thomson's student; Bohr studied with Rutherford. Rutherford tested Thomson's model; Bohr challenged Rutherford's model. Students may have other examples.
2. High voltage gas discharge tubes provided beams of electrons; purified radioactive isotopes provided beams of alpha particles.

Learning Check Answers (Student textbook page 183)

1. Dalton envisioned atoms as small spheres. Atoms of different elements differed in their mass, size, and their combining power.
2. The cathode rays behaved exactly the same, no matter what element they came from. Thomson showed that the cathode rays were, in fact, made up of electrons.
3. Dalton's model was a simple sphere. Thomson's model contained two different kinds of matter: electrons, and some kind of positive matter.
4. Acceptable diagrams should show a small central nucleus, containing all of the positive charge and most of the mass, surrounded by electrons.

Learning Check Answers (Student textbook page 184)

5. Bohr proposed that electrons could only orbit the atom in fixed energy levels.
6. Acceptable diagrams should show a small central nucleus, containing all of the positive charge and most of the mass, surrounded by electrons orbiting in fixed energy levels.
7. If an electron absorbs a specific amount of energy, it can move from a lower energy level to a higher energy level.

8. In neon lights, the electrons in neon gas are excited to higher energy levels, and then fall, releasing light of a specific colour. In light-emitting diodes (LEDs), electrons in silicon and arsenic fall from one energy level to another, releasing very clear colours. Computer screens, lasers involve electrons occupying specific energy levels.

Section 5.1 Review Answers (Student textbook page 186)

Please see also **BLM 5-2 Section 5.1 Review (Alternative Format).**

1. Dalton proposed that atoms of different elements are different in mass and size from each other; atoms of the same element are identical in mass and size, no matter what their source is.
2. All atoms contain electrons, embedded in some kind of positive matter.
3. The electrons revolve around the nucleus like planets around the Sun.
4. Rutherford expected only a small number of the particles to be slightly deflected as they passed through the Thomson atoms in the foil, and that most particles would pass through in a straight line. He observed that most particles did pass straight through, and that some particles were deflected to the side. However, he also observed that a few particles bounced backward.
5. Bohr wanted his new theory to explain the coloured bands in the spectrum of hydrogen gas.
6. A: electron; B: proton; C: neutron
7. Thomson's model has electrons distributed throughout some kind of positive matter. Rutherford's model has electrons orbiting a very tiny, positive nucleus.
8. Accept all reasonable responses. Sample answer: The negative particles would likely have been unaffected by the electrons, so most would have passed through. Encourage students to explain their answers.

Section 5.2 The Structure of the Atom

(Student textbook pages 187 to 193)

In this section, students will more fully explore the details of the Bohr-Rutherford model of the atom, including characteristics and placement of protons, electrons, and neutrons.

Common Misconceptions

- **It is less a matter of students having a misconception in this material, and more a matter of students having no conception at all.** By using simplified diagrams and models, we run a risk of *creating* new misconceptions. In particular, teachers may unintentionally encourage students to believe that the nucleus is quite large, that the electron energy levels are like fixed orbits, and that the electrons hold fixed positions. Occasionally, draw the Bohr-Rutherford model with an exceedingly tiny nucleus, a wobbly energy level, and wildly circulating electrons to dispel these misconceptions.

Background Knowledge

Three main ideas dominate this section:

1. The nucleus is extremely tiny. One hundred thousand nuclei placed side-by-side would approximate the diameter of a typical atom. If the nucleus was the size of one loonie, it would cost $100 000 to create a loonie diameter for an atom.
2. The electrons occupy the volume around the nucleus. Draw a nucleus on the chalkboard. Use a piece of chalk to trace the "path" of an electron as it swoops toward the nucleus, then out to the limits, then back in, and so on. Your chalk curve is a record of the volume occupied by the electron.
3. An energy level relates to the amount of energy that an electron has. An electron in a given energy level has a constant amount of energy, even as it swoops around the atom.

Literacy Support

Using the Text

- ELL English language learners will benefit from concise explanations of the key points in Background Knowledge before they begin to read. Use diagrams and key vocabulary to explain the concepts. A short cloze passage can provide English language learners with an opportunity to internalize the concepts and use the vocabulary before reading.

Before Reading

- Connect to prior knowledge by asking students to list everything they already know about the structure of atoms, both from section 5.1 and from other sources. This discussion will construct a knowledge base to build on as well as reinforce key vocabulary for English language learners.

During Reading

- Arrange students into pairs. Instruct one student to draw a half-page table like Table 5.1, Subatomic Particles, on page 188, and the second student to draw a half-page diagram like Figure 5.9. The table or drawing will be the graphic organizer on which students will write their notes. Have students read each section, and add notes to the table or diagram to record the main points of the reading.
- ELL Remind English language learners to use sticky notes to indicate material in the text that they do not understand. Encourage English language learners to try different strategies to make sense of the print but encourage them to ask their partner to explain things when they feel they are getting confused. (Waiting until they finish may be frustrating and will interfere with understanding.)

Specific Expectations

- **C3.2** describe the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass
- **C3.5** describe patterns in the arrangements of electrons in the first 20 elements of the periodic table, using the Bohr-Rutherford model

After Reading

- Have each pair of students compare their notes that they made as they read, adding missing information or insights.

Using the Images

- The figures in this section are linked to one another. Have students fold a sheet of paper into quarters. In each quarter, have students make representations of Figures 5.9, 5.10, 5.11, on pages 188 to 190, or Table 5.1, Subatomic Particles, on page 188. Instruct students to use a coloured pen or marker to draw a line connecting two related features from one diagram to the others. Label each connection line. The finished page might have 10 to 20 connections or more. Ensure that English language learners understand the language of instructions. Use strategies like sketching instructions, modelling the task, or using simple explanations for difficult words.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 192	In question 3, diagrams are correct in every way, and distinguish between isotopes.	Provide **BLM 5-3 Bohr-Rutherford Diagrams,** with two blank Bohr-Rutherford diagrams on it. Ask students to fill in the protons, neutrons, and electrons of one atom. Then have students create another atom, identical to the first except with one or two more neutrons. Have students explain the difference between the two diagrams, in writing. Have English language learners practise this explanation with a partner.
Inquiry Investigation 5-A, the Bohr-Rutherford Model of the Atom, on page 212	Twenty index cards are complete, neat, and correct.	Provide a set of 20 cards with blank Bohr-Rutherford diagrams photocopied on them. Students complete the cards in order. Demonstrate by completing one card while students watch, or have students work in pairs, with one student completing the card while the other student watches. Then students can switch roles.
Section 5.2 Review questions, page 193	Question 5 is a good probe. Students indicate that three energy levels are occupied: 2–8–2.	Provide **BLM 5-3 Bohr-Rutherford Diagrams,** with two blank Bohr-Rutherford diagrams on it. Have students use the diagrams as a reasoning tool.

Instructional Strategies

- On a large sheet of paper (for example, a flipchart), draw a neat diagram of a blank Bohr-Rutherford diagram. Fasten the paper to the chalkboard with magnets or tape. Use brightly coloured magnets for protons, electrons, and neutrons. This method can be used to build and modify Bohr-Rutherford diagrams at a very low cost. The small learning curve makes this approach effective at starting class discussions. You could build a carbon atom to use as you introduce the section.
  - This diagram will be useful again in section 5.4.
- As a class, practise finding the mass number; atomic number; and number of protons, neutrons, and electrons of selected elements; or have students challenge one another to do this.

Inquiry Investigation 5-A, on page 212, provides practice drawing and interpreting Bohr-Rutherford diagrams. The cards students create can also be used as study aids later. Review key instructional vocabulary (represents, nearest, depicted) with English language learners before doing this activity and before drawing Bohr-Rutherford models on page 190 of the student textbook.

Activity 5-4 What's Your Number? (Student textbook page 189)

Pedagogical Purpose

Students apply the knowledge of atomic structure to determine the characteristics of a set of elements and acquire the skill of interpreting the structure of atoms.

Planning	
Materials	Appendix A: Properties of Common Substances, on page 568 **BLM G-23 Data Table** (optional)
Time	Class time: 30 min

Background

The symbol for each element is usually the first letter of the element's name. If two elements have the same first letter, then an additional letter—often the second letter—from the name is used. If three or more elements start with the same letter, then the second letter is different for each element. For elements known in ancient times, such as copper or iron, symbols are derived from their Latin names.

Activity Notes and Troubleshooting

- Students can conduct this activity individually or in pairs.
- Provide a larger list of elements if you think students can manage the challenge, or have students add elements of their choice to their list.
- Consider providing several isotopes of an element to the list, to begin a discussion of isotopes.

Additional Support

- DI Support bodily-kinesthetic learners by providing a physical model of a Bohr-Rutherford atom, perhaps using coloured paper circles to represent protons, neutrons, and electrons. Students can move the circles around until they correctly represent the atom, and then count the pieces.
- Provide additional isotopes and elements for students who like a challenge. Suggestions: carbon isotopes 11, 12, 13, 14; oxygen isotopes 15, 16, 17, 18; anomalous mass pairs argon and potassium.

Answers

1. O, C, H, and N; the first letters of each name
2. Ca, first and second letter. Using C alone would confuse this element with carbon.
3. Ag, Au, Cu, Fe, Hg, Pb, and Sn; first letter plus following letter or another letter in the metal's Latin name
4.

Standard Atomic Notation	Name of Element	Atomic Number	Mass Number	Number of Electrons	Number of Protons	Number of Neutrons
$^{12}_{6}C$	carbon	6	12	6	6	6
$^{65}_{30}Zn$	zinc	30	65	30	30	35
$^{32}_{16}S$	sulfur	16	32	16	16	16
$^{40}_{20}Ca$	calcium	20	40	20	20	20
$^{17}_{4}N$	nitrogen	7	14	7	7	7

Activity 5-5 Make Your Own Atom (Student textbook page 191)

Pedagogical Purpose

Students can, with the help of a three-dimensional model, visualize the complex structure of the Bohr-Rutherford atom, including the regions in which electrons can move.

Planning		
Materials	Metal rings (3 different sizes) or wire Clay (3 different colours) **BLM A-6 Developing Models** Checklist (optional)	Styrofoam® ball String
Time	Preparation: 30 min	Class time: 50 min
Safety	If students will be cutting wire, they should wear safety goggles.	

Background

The models that Bohr and Rutherford proposed are immensely more complex than those built in this activity. This exercise supports students as they attempt to visualize the model.

Activity Notes and Troubleshooting

- Prepare the string and wire beforehand OR have students cut them at a designated location.
- The wire must be soft enough to bend. Soft iron wire works well.
- Consider adding labels to the string to indicate the element represented in each model.
- The resulting mobiles can be displayed in the classroom and referred to throughout the unit.
- You can guide and assess students' model building using **BLM A-6 Developing Models Checklist.**

Additional Support

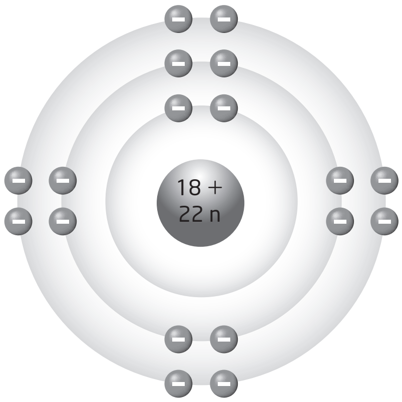
- ELL Prepare large Bohr-Rutherford diagrams to serve as examples. With these examples, students will not need to rely on understanding the written instructions. Ask group members to explain key instructional language so that English language learners will be able to transfer what they are learning about instructional language to other science activities.
- Have students build and label the first 20 elements, and organize them into a large periodic table for display.

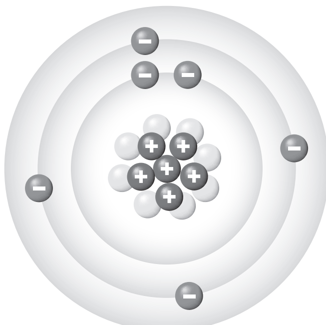
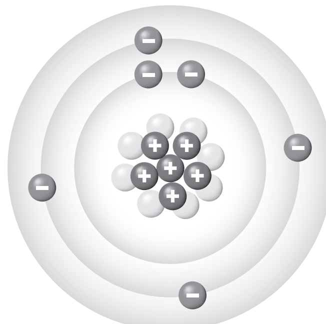
Answers

Students' answers will vary in all cases. Sample answers are provided.

1. size of particles, number of particles, location of particles
2. A three-dimensional model shows the large volume occupied by the electrons, size and shape of the atom, and so on.
3. Electrons are not stationary; they move. Protons, neutrons, and electrons are much smaller than in students' models.

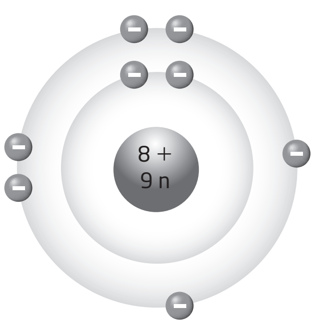
Learning Check Answers (Student textbook page 192)

1. eight protons, eight neutrons
2. 

3.  
4. A *neutral* position on an issue means neither for nor against. In the case of the neutron, *neutral* means no charge at all.

Section 5.2 Review Answers (Student textbook page 193)

Please see also **BLM 5-4 Section 5.2 Review (Alternative Format).**

1. Students' answers should resemble the information included in Table 5.1, Subatomic Particles, on page 188. Ensure that English language learners have had experience with comparing and contrasting before being asked to do this in the review.
2. An electron has a very small mass.
3. atomic number (protons) + neutron number = mass number
4. ${}^{16}_{8}O$
5. three
6. No. The element is determined by the proton number. Seven p^+ is nitrogen; six p^+ is carbon.
7. The element is oxygen-17, an isotope of oxygen.


8. Hydrogen-1 and hydrogen-2 both have only one proton. The hydrogen-2 atom has one additional neutron.

Section 5.3 The Periodic Table (Student textbook pages 194 to 206)

Specific Expectations

- **C1.1** assess the usefulness of and/or the hazards associated with common elements or compounds in terms of their physical and chemical properties
- **C3.7** compare and contrast the physical properties of elements within a group (e.g., alkali metals) and between groups (e.g., the carbon group and noble gases) in the periodic table

In this section, students will learn about the history and the structure of the modern periodic table. Students will be able to explain why the elements were arranged in this particular way. Finally, students will be able to describe the chemical properties of four distinctive families on the periodic table.

Common Misconceptions

- **Teachers often speak of the table determining the chemical characteristics.** However, the chemical behaviour is caused by atomic structure, and reflected in the organization of the table, not vice versa.

Background Knowledge

Mendeleev would have had encyclopedic knowledge of the properties of the elements of his day, but no knowledge at all of the noble gases! The spectrum of helium was noticed in the solar corona in 1868. Argon was characterized in 1895; krypton, radon, and neon followed. Mendeleev quickly included helium and argon in the table in 1902, creating a new group of elements. The noble gases are one of the most characteristic groups of elements, and probably the most important point of reference on the table.

Literacy Support

Using the Text

- There are two distinct bodies of text in this section. The periodic table itself is covered on pages 194 to 200, and 205. Metals are covered on pages 201 to 204. For students, these sections might be better treated separately.

Before Reading

- Have students preview the figures as outlined in "Using the Images". The reference to the sport of baseball may be unfamiliar to many English language learners. Start with a familiar topic to introduce the concept of collections and organizing, such as foods.

During Reading

- Have students begin reading page 194. Using a blank periodic table (or **BLM 5-5 Build a Periodic Table**) as a graphic organizer, they should record notes on the table, including titles, groups, names, trends, properties, and any other textual information. This is best done as a partner activity so that English language learners can discuss material as they proceed.
- Have each student compare notes with a partner.
- Instruct students to lightly skim pages 201 to 204 about metals, as if they were pages in a magazine. Have them summarize the gist of each "magazine article" in one paragraph.
  - ELL Model the writing of a paragraph for English language learners, explaining the function of each sentence in it. Then write a paragraph, leaving out key vocabulary, and have students finish it. Write a partial paragraph and have students complete it. Then have them write a paragraph on their own.

After Reading

- Have students compare and contrast the properties of metals, non-metals, and metalloids. They can refer to their notes to find details to use in their comparisons. Ensure that English language learners understand what is meant by compare and contrast.
  - Some students may be able to compare two groups, but may run into problems organizing a comparison of three. Allow them to compare and contrast metals and non-metals, and then ask them orally about metalloids.

Using the Images

- After reading the introduction to the section, distribute a large, blank periodic table, such as **BLM 5-5 Build a Periodic Table,** for students. Instruct students to examine Figures 5.15, 5.16, and 5.17, on pages 197 to 200; Table 5.2, Physical Properties of Metals and Non-Metals, on page 200; and marginal notes, for a couple of minutes.
  - ELL English language learners may need more time and would benefit from talking about what they are reading with a partner.
- Instruct students to add colours, words, and phrases to their tables, using the illustrations (10 min). The purpose of this task is not to label each element, but to label and code groups, columns, and common properties. Students then use this table as a graphic organizer to help them read and understand the text.
  - ELL Encourage the use of first languages, if it will help English language learners understand and recall what they have read.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 196	In question 2, students describe the key features of the organization of the periodic table.	Provide a copy of a blank periodic table, such as BLM 5-5, Build a Periodic Table. Have students add the main features: atomic number, mass number, and four families.
Section 5.3 Review questions, page 206	Students provide neat, complete answers to questions 7 and 8, identifying key features of the periodic table and navigating the table to locate an element.	Gather students to work on these questions together. Use their cards (from Inquiry Investigation 5-A, on page 212), and answer the questions as a bodily-kinesthetic activity.

Instructional Strategies

- Begin by having students complete Activity 5-6, What's In Blackbock's Lake? on page 195, as an exercise in classification, in preparation for reading about Mendeleev's classification of elements.
- Use a ruler or a graphics program to prepare a blank periodic table containing only Groups 1, 2, and 13 to 18 (see Figure 5.17, on page 200). Photocopy several copies for each student. Alternatively, use **BLM 5-6 Periodic Table**—Groups 1, 2, and 13 to 18.
- Have students use markers to colour and label the elements. They can then cut the table into separate elements. Without aids, they must attempt to organize the elements back into the order of the periodic table, based on their chemical properties.
- Prepare 20 cards for each student, with the name and descriptive chemical properties on one side, and a blank Bohr-Rutherford diagram on the other side. Students must then put the cards back into the order of the periodic table.

- **ELL** English language learners and spatial learners will find that most of the factual information in the section is available through a careful examination of the figures, tables, and captions. Have students work in groups, asking one another questions, to make sure they understand the visual elements. Any questions they cannot resolve can be asked of a larger group, or of you. Important STSE concepts can be discussed as a class to be sure all students learn from them. These concepts include Mining for Metals (page 202), Metals and Health (page 203), and Mercury Pollution of Aboriginal Lands (page 204).
- Inquiry Investigation 5-B, Physical Properties of Metals and Non-metals, on page 213, allows students to apply what they have learned about metals and non-metals to classify four elements based on their properties.

Activity 5-6 What's In Blackbock's Lake? (Student textbook page 195)

Pedagogical Purpose

The fish are analogous to the elements that Mendeleev had to work with. If students classify the variations in the fish, and organize them into a table, they can find the identity of the missing fish. Mendeleev would have used a similar form of reasoning, but one that was many times more complex. Completing this activity before reading section 5.3 will allow English language learners and others to gain an understanding of the concept of classification, and will help them to make sense of Mendeleev's work.

Planning		
Materials	**BLM 5-7 Activity 5-6 What's in Blackbock's Lake** (optional) **BLM G-23 Data Table** (optional)	
Time	Preparation: 30 min	Activity time: 30 min
Safety	Remind students of the safe use of scissors.	

Background

The term *Blackbock's* is a play on "black box." Mendeleev had to work with an astounding amount of data about properties of elements, without being able to see inside of an atom and with much of the data arriving as he worked.

He had to classify "major variations" and then subclassify "variations of the variations." In this activity, students can arrange the fish in rows and columns either by three fin shapes, or by three kinds of stripes.

Activity Notes and Troubleshooting

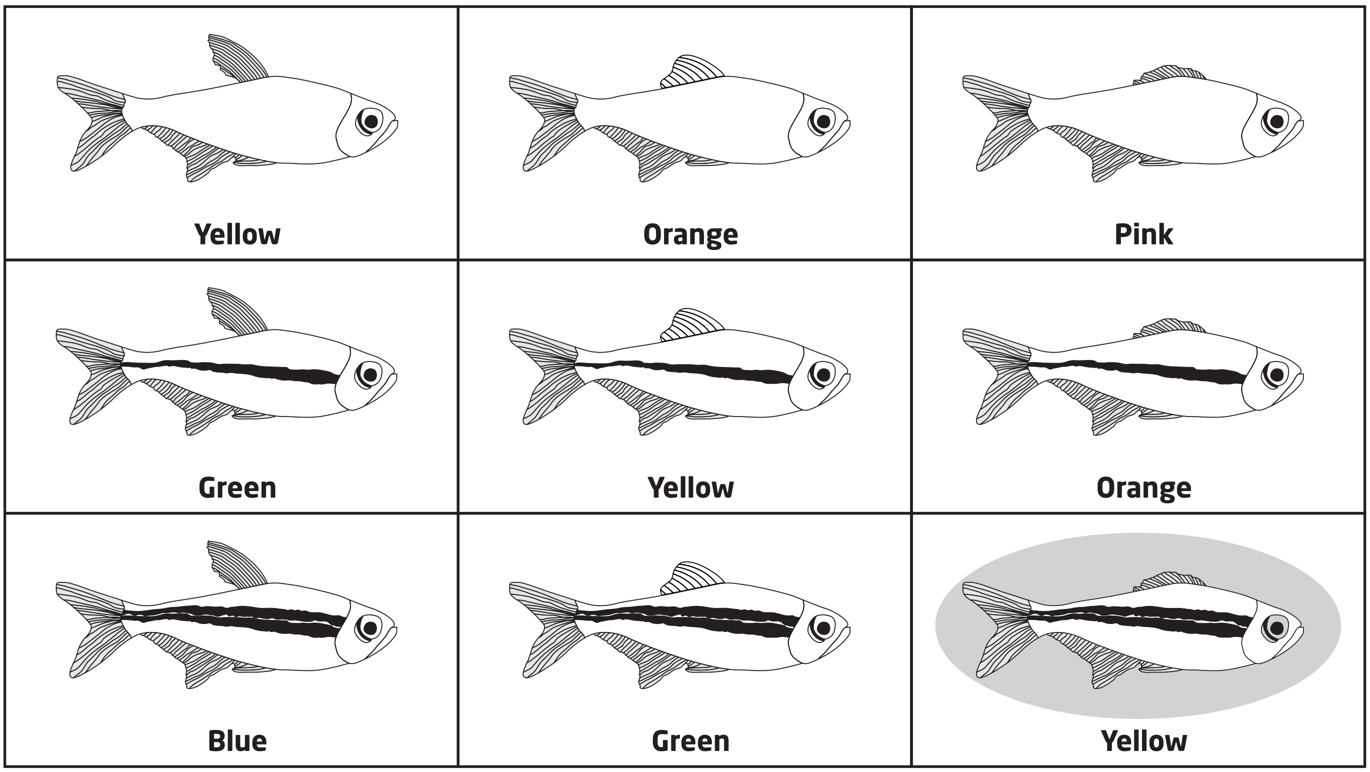
- Students may need hints. Help them as necessary as they work.
  - Hint: How many different fin types are there?
  - Hint: How many different stripe patterns are there?
  - Hint: Colour is not a reliable way to classify the fish, or the elements.
  - Hint: Colour is still important! What do you notice about fish that are the same colour?
- Keep a copy of the periodic table nearby, so students understand how this exercise is similar to organizing the periodic table.

Additional Support

- DI Some students may prefer to work on their own, but interpersonal learners may have more success working in pairs.
- DI Bodily-kinesthetic learners might prefer to colour the fish, cut them out, and then move them around on a grid to obtain a pattern. Use **BLM 5-7, Activity 5-6 What's in Blackbock's Lake?**
- Invite students who like a challenge to add either one more row or one more column to the existing table, design more fish to continue the patterns, and make a new puzzle.

Answers

1. Classifying features and creating groups probably took the most time. Students may mention that they had to make up the rules.
2. square fin, two stripes, yellow



3. Scientists grouped the elements by their different characteristics, and then looked for patterns.

Learning Check Answers (Student textbook page 196)

1. Mendeleev did not know about subatomic particles. They were discovered later.
2. sequentially by atomic number, grouped according to electron shells (levels)
3. Palladium is Pd, atomic number 46, atomic mass number 106.4.
4. If nuclei could combine, there would be a new element with a new number of protons, neutrons, and electrons.

Section 5.3 Review Answers (Student textbook page 206)

Please see also **BLM 5-8 Section 5.3 Review (Alternative Format).**

1. After Mendeleev found the pattern of the periodic table, he left gaps wherever there was a break in the pattern. It was then discovered that the properties of unknown elements could be predicted based on the properties of known elements.

2. **a.** potassium
atomic number: 19
atomic mass number: 39.1

b. phosphorus
atomic number: 15
atomic mass number: 31.0

c. nitrogen
atomic number: 7
atomic mass number: 14.0

3. Metals are typically hard, shiny, malleable, and good conductors of electricity and heat.

4. Mercury has contaminated the drinking water and accumulated in living fish. When the Aboriginal peoples eat the fish, they accumulate the toxic mercury. The mercury poisoning has caused severe illness and has forced some communities to stop fishing, which is an important traditional activity that is both a source of food and income for Aboriginal peoples.

5. the noble gases

6. Sodium is an alkali metal and will react violently with water, so it could not come from a river.

7. **A:** column or group (alkaline-earth metals)

B: row or period (Row 4 elements)

C: the metals

D: the metalloids

E: the non-metals

8. **a.** Group 2, Period 3: magnesium (Mg)

b. Group 14, Period 2: silicon (Si)

c. Group 18, Period 4: krypton (Kr)

Section 5.4 Trends in the Periodic Table

(Student textbook pages 207 to 211)

In this section, students will connect the atomic theories, the periodic table, and the Bohr-Rutherford model to help them explain the relationship between the periodic table and chemical properties.

Specific Expectations

- **C2.2** conduct an inquiry to identify the physical and chemical properties of common elements and compounds
- **C3.6** explain the relationship between the atomic structure of an element and the position of that element in the periodic table
- **C3.7** compare and contrast the physical properties of elements within a group and between groups

Common Misconceptions

- **Some students will attempt to explain atom behaviour as if the electrons or atoms had perceptions and intentionality.** For example, students might say, "The atom sees that it is short two electrons, and tries to get two electrons to make itself happy." Suppress such personification vigorously!

Background Knowledge

As one reads left to right along a row of the periodic table, each succeeding atom has both one more proton in the nucleus, and one more valence electron. Each succeeding atom displays a notable difference in gross chemical properties. In general, the trend is from very active metal, to less active metal, to metalloid, to modestly active non-metal to very active non-metal, and finally to the noble gas.

As one reads top to bottom along a group in the table, the atoms are similar in their gross chemical properties, but differ in degree. This appears to be due to the increasing size of successive atoms.

Literacy Support

Using the Text

- Review the energy levels of electrons using the large blank Bohr-Rutherford diagram you created in section 5.2 and magnets for the electrons. To prepare students for the reading, define *valence electrons* for them.

Before Reading

- Instruct students to skim the headings (blue) and the subheadings (purple), and list them on a sheet of lined paper, with about 10 to 15 lines between each one. Have students construct one or two questions under each heading and subheading to which they would like to know the answer. Suggest they use the following questioning words: Who? When? Where? What? Why? How? Instruct students to compare their questions with a partner and add any to which they would like to find answers. You can guide and assess their questioning using **BLM A-2 Asking Questions Checklist.**

During Reading

- Have students write answers to their questions as they read, as well as any other important information.
- Students could work in pairs, with one student reading the Reactivity and the Outermost Electrons section, and the other student reading the Reactivity and Atom Size section. Students can then summarize the section they read, for their partner. Students should both be responsible for ensuring that each student in the pair has learned the content.

After Reading

- Have students summarize what they have learned about reactivity and outermost electrons, and reactivity and atom size, by writing one or two sentences telling the main idea about each topic.
- Have students consider what other questions they might have asked before they read. Have students make up one or two more questions for each section, based on the information they have learned.

Using the Images

- Direct students' attention to Figures 5.21 to 5.26, on pages 207 to 210. Have students try to synthesize all of the information in these figures. For example, they could try to draw Bohr-Rutherford diagrams for the elements shown in Figure 5.21, on page 207, with the overall sizes represented in Figure 5.25, on page 210.
- Students could add the descriptive information contained in the remaining figures and/or draw Bohr-Rutherford diagrams to illustrate the elements referenced in Figure 5.26, on page 210.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Activity 5-7, The Bohr-Rutherford Periodic Table, on page 208	Students correctly organize cards to match the periodic table.	Select only one part of the deck at a time (for example, only Row 2) and ask students to organize just that row. Other examples are only Group 1 or only Group 2.
Section 5.4 Review questions, page 211	In questions 5, 6, and 8, students predict the properties of elements accurately, based on trends in the periodic table.	Students can sometimes answer questions more accurately if they have an example in front of them. Encourage them to use one or more of their cards to help them answer the questions. (If their cards are not available, they can use another student's cards.)

Instructional Strategies

- This section could potentially deal with an overwhelming amount of information. Limit students' attention to Groups 1, 2, 13 to 18, and to Rows 1 to 4.
- Be prepared to demonstrate key properties of each of the element families, or show video clips.
  - Noble gases: Helium from a balloon can be trapped by releasing the balloon underneath a large inverted flask. The helium rises, and is trapped under the inverted flask. Light a wooden splint, and thrust it upward into the helium. The splint's flame will be extinguished.
  - Halogens are easily generated by adding a small amount of the halogen salt to a test tube full of hydrogen peroxide. Iodine is generated instantly, bromine quickly, and chlorine very slowly.
  - The reactivity trends for Group 2 elements magnesium and calcium can be demonstrated as a repeat of Inquiry Investigation 5-C, Reactivity Trends in the Periodic Table, on page 214.
  - Group 1 elements can be shown from short video clips that are available on-line. See **www.scienceontario.ca.**
  - To consolidate concepts from this section and Section 5.3, students can complete **BLM 5-9 The Row Three Elements** or **BLM 5-10 The Row Three Elements (Alternative Version).**
  - As an extension, students can complete **BLM 5-11 The Noble Gases.**

Activity 5-7 The Bohr-Rutherford Periodic Table

(Student textbook page 208)

Pedagogical Purpose

After having completed Inquiry Investigation 5-A, on page 212, students will have a set of 20 cards representing the 20 elements. This activity is organized like a card game in which the cards are not turned over until students have decided on a pattern. The strategy will be analogous to Activity 5-6, on page 195, where students sorted the fish in Blackbock's Lake. Students must read the Bohr-Rutherford diagram, and not the name, to organize the elements by electronic structure.

Planning	
Materials	20 Bohr-Rutherford index cards, which students made in Inquiry Investigation 5-A, on page 212
Time	Class time: 30 min

Background

Although the elements were originally grouped according to observed chemical properties, this activity challenges students to sort the elements by their electron structure.

Activity Notes and Troubleshooting

- Arrange students into pairs for this activity. Students working in pairs can share grouping ideas, but also sufficiently participate.
- Students will need a large space in which to work, at least 1 m wide by 0.5 m deep.
- Students without cards can work with another group, or photocopy a set of cards.
- Students will devise a number of strategies. Check their progress early to catch errors.
- Students should begin working with the Bohr-Rutherford diagrams facing up. Once students have decided on a pattern, have them flip over the cards. If the symbols do not match the periodic table, students can make corrections.
- Some students may come up with a valid, but different, organization from that in the periodic table. Validate students' organization, but tell them that they need to organize their cards in the same way that the periodic table is organized.

Additional Support

- ELL English language learners should not have trouble arranging the cards. Pair these students with fluent speakers of English to help them answer the questions.
- ELL Some students, including English language learners, are overwhelmed by large amounts of information. Use chalk to outline a blank periodic table on top of the lab bench, to provide some structure.
- DI This activity requires both bodily-kinesthetic and logical-mathematical skills. Set up pairs of students so that both skills are represented in most pairs.

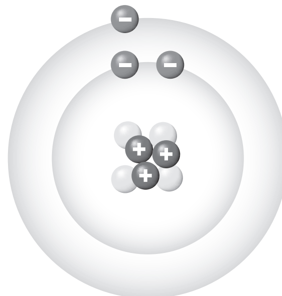
Answers

1. The valence electrons in Row 2 are all in the same energy level. There is a different number of valence electrons in each element as you read across the row.
2. One more energy level is added to each atom as you read down the column. Every atom has two valence electrons.
3. The number of neutrons varies in an unpredictable way.

Section 5.4 Review Answers (Student textbook page 211)

Please see also **BLM 5-12 Section 5.4 Review (Alternative Format).**

1. Answers may vary. For example, lithium has one valence electron.



2. The diagram shown has four valence electrons, so the one immediately to its right on the periodic table will have five valence electrons.
3. An atom of phosphorus has five valence electrons. An atom of aluminum has three valence electrons. So, an atom of phosphorus has more valence electrons than an atom of aluminum.
4. Silicon also has four valence electrons and can react with a variety of other elements. It is directly below carbon in the periodic table.
5. Noble gases have a full outer energy level of electrons, which provides chemical stability. Halogens, however, are capable of holding one more electron in their valence shell. Elements that only need to lose or gain one electron to have the same electron arrangement as a noble gas are very reactive.
6. Atoms get larger as you read from left to right across a row. Atoms get larger as you read down a column.
7. An atom of sulfur is larger because it has one more energy level of electrons.
8. Calcium is more reactive than magnesium because a calcium atom has one more energy level, and is therefore larger, than a magnesium atom. The farther the valence electrons are from the nucleus of an atom, the easier it is for the electrons to be lost, and therefore the atom is more reactive.
9. Students' answers should refer to a model similar to Figure 5.25, on page 210.
10. A potassium atom has one more energy level, and is therefore larger, than a sodium atom. The farther the valence electrons are from the nucleus of an atom, the easier it is for the electrons to be lost, and therefore the atom is more reactive.

Inquiry Investigation 5-A The Bohr-Rutherford Model of the Atom (Student textbook page 212)

Pedagogical Purpose
Students apply what they have learned about standard atomic notation to analyze the periodic table, including the names and symbols of the first 20 elements. Students will draw Bohr-Rutherford diagrams and complete cards to use throughout the unit.

Planning		
Materials	20 blank index cards **BLM 5-13 Inquiry Investigation 5-A The Bohr-Rutherford Model of the Atom** (optional)	
Time	Preparation: 5 min	Class time: 60 min

Background
Students will write information about each element using standard atomic notation and illustrate each element using a Bohr-Rutherford diagram. Standard atomic notion and Bohr-Rutherford diagrams are explained in section 5.2, on pages 189 and 190.

Activity Notes and Troubleshooting
- If index cards are too costly, sheets of ordinary paper cut into six rectangles will do.
- Two students, working together, should be able to represent all 20 elements and answer the questions in one class.
- The completed cards will be used in Activity 5-7 in section 5.4, on page 208. Students may also find them helpful to refer to at other times.
- Students will find the names of, and symbols for, the elements in Appendix C, on page 572.

Additional Support
- ELL Emphasize using symbols and diagrams, as they are simpler than the full instructions. Review the instructions on page 190, create one card for students as an example, and then have students create the rest of the cards, following your model. To support language growth, have students work with a partner.
- Enrichment—Students who enjoy a challenge may wish to create cards for the rest of the elements in Row 4 of the periodic table.
- Have students keep the cards as study aids.

Answers
Analyze and Interpret
1. The mass number is approximately double the atomic number.
2. Most elements with even atomic numbers follow the general rule: H, He, Be, C, N, O, F, Na, Al, and P. All elements with odd atomic numbers follow the rule approximately: Li, B, Ne, Mg, Si, S, Cl, Ar, K, and Ca.

Conclude and Communicate
3. only H
4. He, Ne, and Ar
5. F and Cl

Extend Your Inquiry and Research Skills
6. Sample answers may include B-10, B-11; C-12, C-13, C-14; N-14, N-15.

Inquiry Investigation 5-B Physical Properties of Metals and Non-metals (Student textbook page 213)

Pedagogical Purpose

To classify a metal or a non-metal, students must link the behaviour, position on the periodic table, and structure of elements. This activity helps link the first two items.

Planning	
Materials	Carbon (charcoal) Aluminum 1 mallet Sulfur Magnesium 1 conductivity tester **BLM 5-14 Inquiry Investigation 5-B Physical Properties of Metals and Non-metals** (optional) **BLM G-23 Data Table** (optional) **BLM A-26 Inquiry Investigation Rubric** (optional)
Time	Preparation: 30 min Class time: 30 min
Safety	Goggles and a lab apron must be worn. If any students are allergic to sulfur they should not touch it. Ensure students handle all materials carefully.

Background

Metals are shiny, malleable, and good conductors of electricity and of heat. Non-metals are poor conductors, and they appear in many states and colours.

Activity Notes and Troubleshooting

- Students may need coaching on how to use a conductivity tester.
- Any small metal object could serve as a mallet: for example, a stainless steel spoon.
- Consider adding the metalloid silicon. It shares properties with both groups.
- Consider adding a thermal conductivity test. Hold the substance against an ice cube, and ask, "Can you feel the cold?"
- You can assess students' work using **BLM A-26 Inquiry Investigation Rubric.** Distribute the rubric before students begin their investigation.

Additional Support

- ELL Provide additional elements (for example, tin, copper) to serve as examples.

Answers

Some English language learners may benefit from completing statements, for example, _____ and _____ have similar properties.

Analyze and Interpret

1. Aluminum and magnesium have a similar set of properties.

Conclude and Communicate

2. aluminum and magnesium. The metals are shiny, malleable, and good conductors of heat and electricity.
3. carbon and sulfur. Non-metals are poor conductors of heat and electricity, and have a wide variety of other properties.

Extend Your Inquiry and Research Skills

4. There are many possible answers. Iron is tough, strong, and used for steel; platinum is non-reactive, and used to make catalysts.

Inquiry Investigation 5-C Reactivity Trends in the Periodic Table (Student textbook page 214)

Pedagogical Purpose
Students practise setting up and observing chemical reactions to draw conclusions about patterns in the periodic table.

Planning		
Materials	30 mL of water 1 test-tube rack Calcium 20 mL of 1 mol/L acid solution (HCl) **BLM 5-15 Inquiry Investigation 5-C Reactivity Trends in the Periodic Table** (optional) **BLM G-23 Data Table** (optional) **BLM A-21 Safety Checklist** (optional)	3 test tubes Aluminum Magnesium
Time	Preparation: 30 min	Class time: 45 min
Safety	Students should not touch calcium with their bare hands. These reactions generate heat. Do not allow students to use less than 10 mL of water for each one. All of these reactions generate hydrogen gas. Ensure that there are no flames or sparks in the area. 1 mol/L HCl must be distributed with caution. Place the solution away from the edge of the desks, and clean up any spills immediately. Safety goggles and protective clothing must be worn at all times. Review these safety cautions with English language learners to ensure they understand.	

Background
The chemical activity of the Group 1 and Group 2 metals provides one of the clearest trends that can be explained by the Bohr-Rutherford model of the atom in the periodic table.

Group 1 and Group 2 metals react by losing one and two electrons, respectively. Each element that is farther down the group has one more electron shell, as students found out in Activity 5-7, on page 208. Because the valence electrons are farther from the nucleus, they are easier to remove. Therefore, metals farther down the column are more reactive than those closer to the top.

Activity Notes and Troubleshooting
- You can remind students of safe laboratory procedures using BLM A-21, Safety Checklist.
- Use only small pieces of each metal (the size of a pea).
- The calcium reacts with water quite quickly. Magnesium might produce some small bubbles.
- Acid will cause the magnesium to react quickly. The aluminum foil will just begin to react.
- You can guide and assess students' work in this investigation using BLM A-32, Using Tools, Equipment, and Materials Rubric.

Additional Support

- If you are not confident that a student can safely do the experiment, demonstrate each reaction and have students observe and record. Draw appropriate Bohr-Rutherford diagrams in chalk on the desktop or chalkboard, and show the student what is happening as the reactions occur.
- ELL Review concepts like most/least and increase/decrease. Explain the reference to neighbours in the research activity.
- ELL To support language development, record some of the student explanations for Conclude and Communicate question 4.

Answers

Analyze and Interpret

1. The most reactive metal was calcium. The metal that had a medium reactivity was magnesium. The least reactive metal was aluminum.
2. Reactivity increases as you read down a column in the table.
3. Metal reactivity decreases as you read left to right across a row in the table.

Conclude and Communicate

4. The more valence electrons that an atom has, the more difficult the electrons are to remove. The larger the atom is, the father away the valence electrons are from the nucleus, and the easier the electrons are to remove.

Extend Your Inquiry and Research Skills

5. Reading across: Potassium is more reactive than calcium; sodium is more reactive than magnesium.

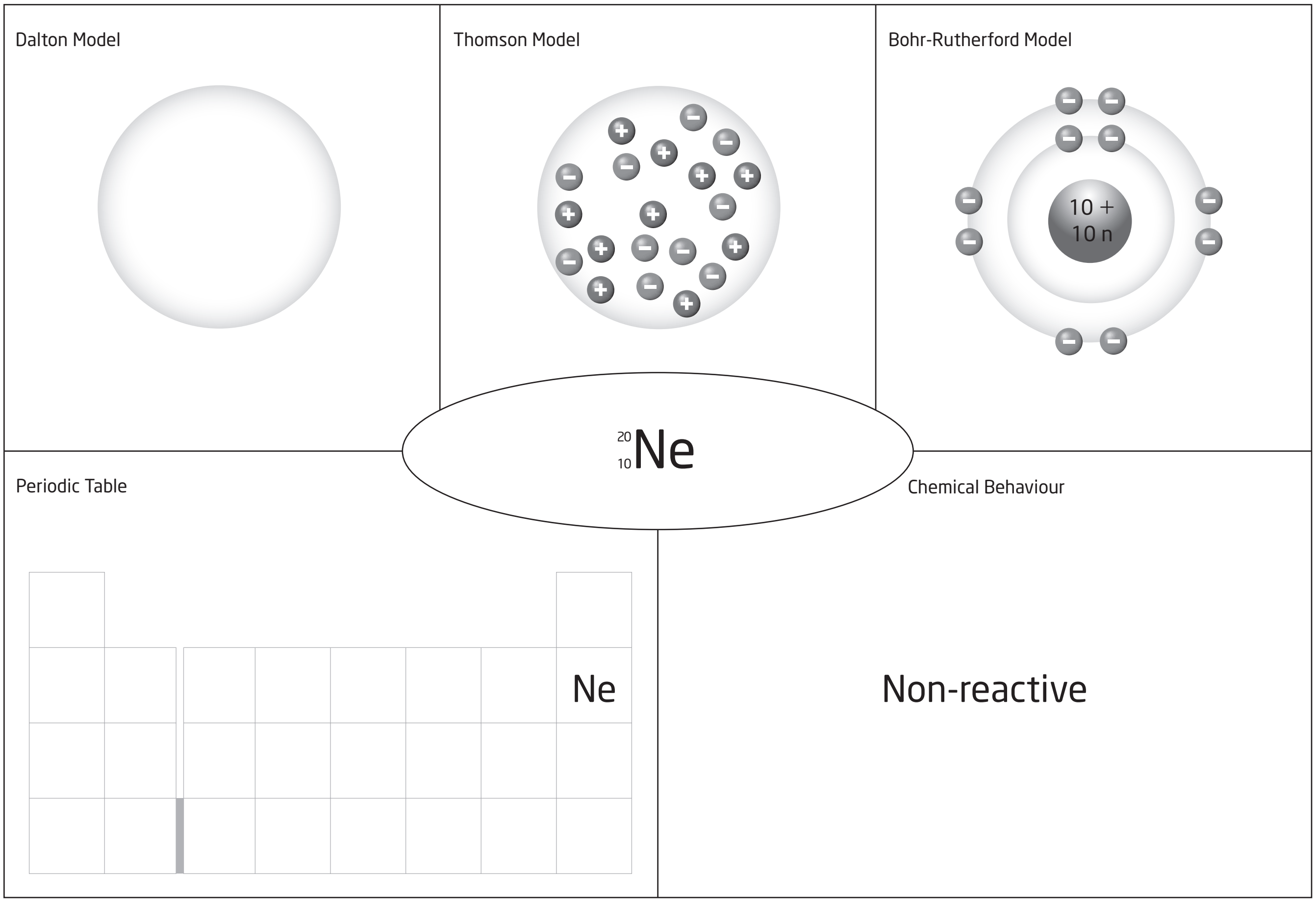
   Reading down: Lithium is less reactive then sodium; sodium is less reactive than potassium; magnesium is less reactive than calcium; calcium is less reactive than strontium.

Chapter Review Answers (Student textbook pages 216 and 217)

Please see also **BLM 5-16 Chapter 5 Review (Alternative Format).**

Make Your Own Summary

This chapter is a series of graphic representations: pictures of the evolving model of the atom, pictures of the Bohr-Rutherford model of the atom, the periodic table itself, and finally the periodic table combined with the Bohr-Rutherford atom. A graphic organizer should compare and contrast all of these representations. Here is one example:



Each student can choose one element, and represent it in six different ways. Students can compare, contrast, and cross-reference all six representations. Students who are successful with one element can probably be successful with others.

Reviewing Key Terms

1. valence electron
2. group
3. non-metal
4. periodic table
5. atomic number
6. nucleus
7. electrons
8. mass number

Knowledge and Understanding

9. Rutherford identified the nucleus. Since some of the positively charged particles were repelled backward in his experiment, Rutherford inferred that a positively charged nucleus repelled them.
10. Protons (positive) and neutrons (neutral) have nearly the same mass and are found in the nucleus. Electrons (negative) have a very low mass, and fly around the nucleus.
11. the number of protons, which determines both the identity of the element and the number of electrons in the neutral atom

12. **a.** They have the same number of protons, so they are the same element: lithium.
   b. The atom on the left has a mass number of six: lithium-6. The atom on the right has a mass number of seven: lithium-7.

13. **a.** three protons, four neutrons, three electrons; metal
   b. 15 protons, 15 neutrons, 15 electrons; non-metal
   c. 13 protons, 15 neutrons, 13 electrons; metal
   d. six protons, seven neutrons, six electrons; non-metal
   e. 14 protons, 14 neutrons, 14 electrons; metalloid
   f. 17 protons, 18 neutrons, 17 electrons; non-metal

14. Mendeleev organized every known element in a list, by mass. He found that certain properties appeared at regular intervals. He organized the similar properties, and he developed a table of elements that repeated in a periodic way.

15. Non-metals are typically not shiny, malleable, or ductile, and are poor conductors of heat and electricity. They are usually gases or brittle solids at room temperature. Non-metals are located on the right side of the periodic table.

16. The number of valence electrons is two in each atom as you move down Group 2.

17. Having a full valence energy level causes atoms to be non-reactive.

18. **a.** one
   b. three
   c. seven
   d. two
   e. five
   f. two
   g. four
   h. six

19. An atom's size is determined by the distance from the centre of the nucleus to the outermost electrons.

20. **a.** sodium
   b. bromine
   c. nitrogen

Thinking and Investigation

21. Rubidium is larger than potassium, so it loses its electrons more easily.

22. Group 14 and Group 15 would likely have elements that have the widest range of properties because these groups consist of roughly equal numbers of metals and non-metals.

23. Rutherford would not have seen that some particles were deflected back toward the source. Lacking that information, he would have concluded that Thomson's model was correct. There would have been no experimental evidence to support the idea of a nucleus.

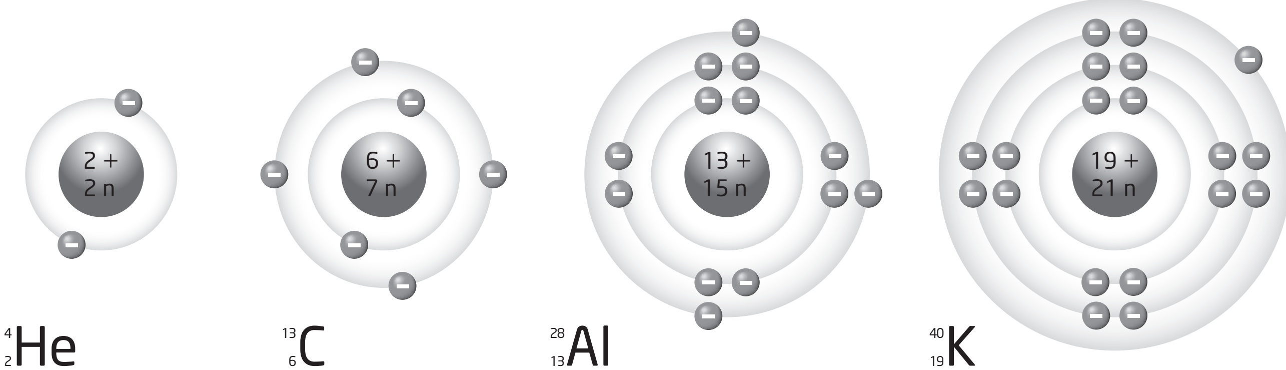
24. The atoms have the same mass number. The total number of protons and neutrons equals 40 in each case. However, argon has 18 protons and 22 neutrons, potassium has 19 protons and 21 neutrons, and calcium has 20 protons and 20 neutrons.

25. Thomson was able to conclude that there was a positive charge distributed within the atom; Rutherford had evidence that the positive charge was in a dense centre called the nucleus.

Communication

26. **a.** Rutherford model: Students' drawings should be similar to Figure 5.6, on page 183, and should reflect an atom as mostly empty space, with a small, dense, positively charged nucleus in the centre. The nucleus contains most of the mass of the atom, and electrons move around the nucleus.
   b. Bohr model: Students' drawings should be similar to Figure 5.7, on page 184, and should reflect an atom as mostly empty space. A small, dense, positively charged nucleus that contains most of the mass of the atom is at the centre of the atom. Electrons occupy energy levels outside of the nucleus.
   c. Thomson model: Students' drawings should be similar to Figure 5.4, on page 181, and should show negatively charged electrons embedded throughout a mass of positively charged material.

27.



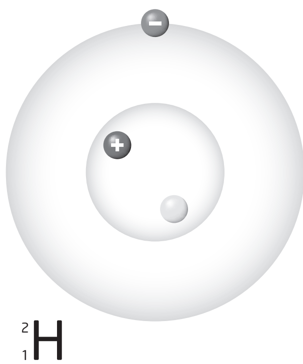
28. Students' paragraphs will vary, but should include the ideas that iron is present in all body cells, and in blood where it is necessary for transporting oxygen through the body; copper, zinc, magnesium, and calcium are essential for plants and animals to live; multiple blood transfusions can result in people accumulating too much iron, which can severely damage the heart and liver; mercury has contaminated drinking water and accumulated in fish as a result of burning waste materials and fossil fuels, and other industrial operations, and people who eat the fish or drink the water can become very ill.

29. Gold is resistant to corrosion and can reflect infrared radiation, so it is used as a coating for space vehicles.

Application

30. You can use heat and chemical solutions to isolate elements, like gold, from their ores, and the elements themselves will not be altered.

31. a.



b. Heavy water contains two deuterium atoms instead of regular hydrogen atoms, so it is slightly more massive than ordinary water.

c. The extra neutrons in the deuterium slow down the neutrons produced in the nuclear reaction. This moderation is required for the nuclear reaction to take place; if the neutrons move too quickly, the nuclear reaction will not occur.

Chapter 6 Understanding the Properties of Compounds

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- Two weeks before completing Activity 6-1, on page 219 of the student textbook, buy sufficient resealable plastic food bags, and ice.
- Two weeks before completing Inquiry Investigation 6-A, on page 249 of the student textbook, buy 45 uncoated round steel nails for each class.
- One month before completing Inquiry Investigation 6-B, on page 250 of the student textbook, check for supplies of appropriate ionic and covalent compounds, and purchase some if necessary.
- Students can review the Key Terms in Chapter 6 using **BLM 6-1 Chapter 6 Key Terms.**

In this chapter, students will build on their understanding of metal and non-metal elements as they relate to ionic and covalent compounds. Students will study the nature of bonding, the properties of each class of substance, and the methods of modelling both kinds of bonding.

Using the Chapter Opener (Student textbook pages 218 and 219)

- Provide students with climbing rope, a helmet, a climbing shoe, a climbing belt, granite, limestone, chalk, and metal alloy pitons and links to examine as they read the text box related to the opening photograph.
- Support the STSE-focussed introduction using a variety of paints and paint solvents as examples of compounds that have a social, an environmental, and an economic impact. Many petroleum-based paints and solvents are environmentally hazardous, and are banned in some municipalities.
- Paints provide an interesting introduction to the focus on properties of compounds in this chapter. Pigments range from minerals, to metal oxides, to organic dyes. Binders range from natural glues like egg and linseed oil to covalent polymers like acrylic and epoxy. Solvents range from water to petroleum spirits to sophisticated liquids such as acetone.

Activity 6-1 Bouncing Glue (Student textbook page 219)

Pedagogical Purpose

In this activity, students gain first-hand experience with properties that change as substances are combined. They also consider the STSE implications of the new properties.

Planning		
Materials	10 mL of white glue 100 mL beaker Wooden stir stick 10 mL of 4% borax solution	10 mL of water Tablespoon Food colouring
Time	Preparation: 20 min	Class time: 20 min
Safety	This small amount of borax can cause skin irritation, but is not acutely toxic. Have students wear safety goggles and a lab apron. Remind students to clean up and spills immediately, and to inform you.	

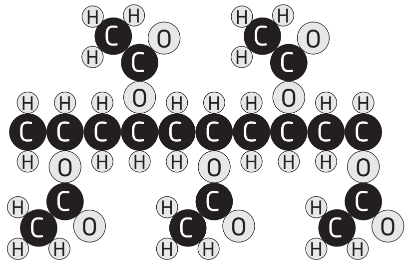
Background

When boron loses three electrons, it forms the B^{3+} ion. In water, it attracts four OH^- groups to itself, forming $B(OH)_4^-$ ion.

White glue is an emulsion of polyvinyl acetate in water. Polyvinyl acetate is a long chain of carbon molecules, with one vinegar molecule attached to every other carbon in the chain. The oxygen atoms in the vinegar molecule are the sticky points of the white glue, because they can form *hydrogen bonds* with any -OH groups on plant fibres such as wood, paper, and cotton.

When white glue is mixed with borax solution, the four (OH) groups around each boron atom link with four acetates in the glue. This process causes the glue to form a tangled gel. When full of water, it feels like slime. As the water is squeezed out, it behaves more like rubber.

polyvinyl acetate



Activity Notes and Troubleshooting

- The borax binds with the polyvinyl acetate quite quickly.
- To make 150 mL of 4 percent borax, dissolve 6 g of borax in 150 mL of water. Adding more borax will not improve the reaction.
- The borax is very tightly bound to the polyvinyl acetate. Handling the slime presents no health risk. Instruct students to wash their hands after the activity.

Additional Support

- ELL Explain what is meant by *knead* and by *same* and *different*. Some students may not have words in their first language for *slime* and *bounce* or have any experience with Silly Putty. After the activity, ask them to describe things that have those properties.
- Enrichment—Issue this challenge: Tell students that boron (in borax) has 4 -OH groups. A sugar molecule has 5 -OH groups and a citric acid molecule has 3 -OH groups. Have students carry out an experiment to determine if sugar or citric acid causes white glue to form slime.

Answers

1. Differences in glue balls may be due to the amount of food colouring used or the amount of liquid squeezed out.
2. Silly Putty

Study Toolkit		
Strategy	**Page Reference**	**Additional Support**
Making Inferences	Student textbook page 226: Solubility and Plant Fertilizers Prompt students to recall experiences related to fertilizers; for example, burnt lawn, nutrients needed by their own bodies. The inferences they can draw from the textbook depend on their experience. Student textbook page 245: Ball-and-Stick Models Model cars, airplanes, houses, and dolls provide students with experiences from which they can infer the usefulness of models.	Student textbook page 224: What Does Sodium Fluoride Do? Inquiry Investigation 6-B, student textbook page 250: Students use the textbook theory and lab experience to infer the identities of the chemicals. **BLM G-4 Making Observations and Inferences** English language learners may take reading between the lines literally. Use everyday experiences to show what the phrase means.
Monitoring Comprehension	Student textbook page 227: Conductivity Students will need sticky notes. Text resources, dictionaries, and similar resources are helpful. Some students need pictures to support comprehension.	Student textbook page 236: The Properties of Covalent Compounds The properties of covalent compounds are easily misunderstood.
Creating a Word Map	Student textbook page 234: Molecules This technique is helpful to understand the meaning of words for which students have many associations. Use students' word maps to test their understanding.	Student textbook page 225: Solubility Word maps can expose misunderstandings. Invite English language learners to add explanations in their first language.

Section 6.1 Ionic Compounds (Student textbook pages 221 to 231)

Specific Expectations

- **C1.2** assess social, environmental, and economic impacts of the use of common elements or compounds
- **C3.4** describe the characteristic physical and chemical properties of common elements and compounds

In this section, students will learn how metal atoms plus non-metal atoms form ionic crystals, and how the ionic bond is reflected in such visible properties of ionic compounds as their crystalline structure, their solubility, and the electrical conductivity of their solutions.

Common Misconceptions

- **Students tend to think of a *bond* as a singular thing, like a handcuff.** The ionic bond is spread out over many atoms: each Na^+ ion is adjacent to, and attracted to, six Cl^- ions in sodium chloride. There is no single *ionic bond* between just two ions. A physical model of an ionic crystal, for example, a *wire-and-ball* model, would help students visualize this concept.
- **Students tend to believe that the individual particles of a substance have the same properties as the substance itself.** They might speak about a sodium ion having a high melting point, being crystalline, being soluble, or being a good conductor. Point out that the bulk ionic compound has these properties, but the individual ions are simple particles. The bulk properties are the result of attractions between the individual particle ions. Remind students that the properties of bouncing glue were different from the properties of either of the ingredients that made up the glue.

Background Knowledge

Ionic bonding involves two distinct physical processes, and two pedagogically important changes of category. The first process is the "loss" and "gain" of electrons by the metal and non-metal, respectively. This process results in a change of category: the atoms are changed into ions. The second physical process is the mutual attraction of the resulting ions. The corresponding change of category is that individual particles are organized into a crystal lattice with a set of properties that is different from the properties of the ions. Many students find that ionic bonding is more difficult to learn than covalent bonding. You might consider teaching covalent bonding first.

Literacy Support

Using the Images

- On the chalkboard, draw the Bohr-Rutherford diagram shown in Figure 6.2, on page 222, but without electrons. Use magnets to model the electrons. Move the electrons to correspond to the diagram (or have a student do it). Label the electric charges on the electrons and the nucleus. Add up the charges: the *total* of the positive and negative charges is the ionic charge.
- For Figure 6.3, on page 222, use a Bohr-Rutherford diagram to remind students *why* Mg forms a +2 ion.
- ELL Many students will need to see Figure 6.4, on page 223, "worked out" by you before they explain it in English. With chalk, draw the Bohr-Rutherford diagrams with no electrons on a black lab bench or the chalkboard. Have students move magnets or other objects around to model the changes that occur in the diagram. Have students use words or actions to describe what is happening. This one diagram represents two of the main ideas of this section. By acting it out with magnets first, students will be better prepared to understand the text in this section. As students engage in the activity introduce key vocabulary that will be used in the text.

Using the Text

Before Reading

- Ask students, "What are the major ideas that you are going to learn about in this section?" Have students preview pages 221 to 230, looking at headings, subheadings, figures, captions, key terms, and marginal notes for three to four minutes, and then write one sentence or a phrase to describe each idea that they are going to study. See Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook.

During Reading

- Review Study Toolkit 2, Reading Effectively: Monitoring Comprehension, on page 564 of the student textbook, with students. Provide students with sticky notes on which to summarize each chunk of text. Students can mark each sticky note with either a checkmark (✓) to indicate understanding, a question mark (?) to indicate that they are not sure whether they understand, or an X, to indicate the need for explanation. Each mark leads students to one course of action as they work out the meaning of the text. At the end, they will have 8 to 10 summaries on sticky notes. Alternatively students can use **BLM 6-2 Reading Strategy: Ionic Compounds,** to monitor their comprehension.
  - ELL You may want to meet with students after they read each chunk to help clear up any misunderstandings. Encourage English language learners to ask for help when they are experiencing difficulty.

After Reading

- Have students organize and edit their notes into a single summary.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check question 3, page 224	Students note that sodium has one valence electron, and loses it to chlorine so that both atoms have full shells. Ions then attract.	Use physical models (for example, chalkboard, pieces of paper, and so on) to illustrate. Provide parallel exercises using different elements. (See **BLM 6-3 Ionic Bonding.**)
Learning Check questions 5 and 6, page 227	Students' drawings indicate a crystal lattice that disintegrates upon dissolving in a polar solvent like water.	Provide a framework, so that students can work out the process of dissolving, and explain conductivity. See **BLM 6-4 Ionic Compounds,** or **BLM 6-5 Ionic Compounds (Alternative Version).**
Section 6.1 Review question 6, page 231	Students explain that ions in a crystal lattice cannot move, so no electric current can flow. When dissolved, the same ions can move, so electric current is possible.	Use **BLM 6-4 Ionic Compounds,** or **BLM 6-5 Ionic Compounds (Alternative Version),** to provide a framework for students to work out the process of dissolving and the nature of an ionic solution.

Instructional Strategies

- Provide crystals of sodium chloride to each student. Large, pure crystals can be found in high-quality water softener salt. Sometimes sidewalk salt contains good-quality crystals. Tell students that the sodium chloride they are holding is a very common ionic compound. What properties of sodium chloride have they observed?
- There are several classroom demonstrations that graphically illustrate ionic bonding and the properties of ionic compounds:
  - Grip a strip of magnesium with tongs and ignite it in a Bunsen burner flame. (Caution: Shield students from infrared radiation by holding a piece of paper between the magnesium and the students.) Pass around the cooled ionic product, MgO.

    - React 50 mL of 1.0 HCl with an excess of magnesium flakes (about one half of a teaspoon). When the reaction is complete, pour the clear liquid into a clean beaker, and heat the solution until it has evaporated to dryness. Crystals of $MgCl_2$ appear.
    - NaCl, MgO, and $MgCl_2$ can all be tested for ionic properties: crystalline appearance, solubility in water, and conductivity of solution. MgO is the least soluble, and a microscope is needed to see the crystals.
- On the chalkboard, create Bohr-Rutherford diagrams with magnetic “electrons,” so that students can follow the reactions by moving the electrons around on the chalkboard drawing.
- ELL Add ions and ionic bonds to the concept map you began with English language learners in Chapter 4.
- Inquiry Investigation 6-A, What Causes Rusting of Iron Nails?, on page 249 of the student textbook, allows students to investigate a real-world example of ionic bonding.
- ELL Enrichment—Have students consider the advantages and disadvantages of different substitutes for road salt using **BLM 6-6 What Are the Alternatives to Road Salt?** Ensure that English language learners understand the terms *advantage* and *disadvantage.* Use simple examples and the symbols + and – to illustrate.

Activity 6-2 Making Ice Cream (Student textbook page 229)

Pedagogical Purpose
Students know that salt is soluble in water, and that salt melts ice. They may not know how salt and water are related. This activity provides dramatic evidence that dissolved salt lowers the melting point of water.

Planning		
Materials	Measuring cups and spoons 5 mL of sugar 3 drops of vanilla extract 500 mL of ice 1 L resealable plastic bag Sheet of newspaper	Plastic spoons 60 mL of milk 250 mL resealable plastic bag 150 mL of rock salt (sodium chloride) Thermometer
Time	Preparation: 30 min	Class time: 60 min
Safety	Keep lab equipment far from edible materials. Remind students not to eat any ice cream until you have told them that they can. Students should wear safety goggles.	

Background
Dissolved material *always* lowers the melting point of a pure substance; the greater the amount of dissolved material, the greater the melting point depression. But why does adding salt both *melt* the ice and *make it colder* at the same time?

In an ice cube at a temperature of 0°C, water molecules are constantly breaking off the crystal (melting) and sticking back onto the crystal (freezing). When salt is added, the water molecules break off, but because of melting point depression, they do not freeze back onto the crystal. Every gram of ice that melts in this way takes 330 Joules of heat energy from the surrounding ice and water (and milk!), making them colder.

Activity Notes and Troubleshooting
- Cover the desktop surfaces with newspaper to prevent contamination of the materials. Provide one station to dispense the plastic bags, milk, sugar, and vanilla. Supervise that station to be sure that students do not accidentally contaminate their ice cream.
- Tell students to be certain to seal the 250 mL bag carefully, to prevent salt from ruining their ice cream.

- If students are to eat the ice cream, consider using water softener salt. It is purer.
- Do not allow "double dipping," as it may spread illnesses.
- In the time that students are rocking their ice cream, discuss anything they did not understand in this section. They will need to pause every 5 min to check the temperature.

Additional Support

- ELL Demonstrate this complex set of instructions to be sure that students understand how to proceed.
- As a challenge, ask what would happen if a grain of salt got into the ice cream. Have students explain their answers. (Salt will melt ice cream just as effectively as it melts ice.)

Answers

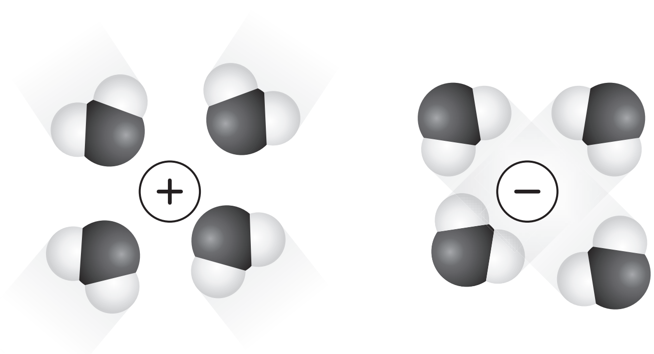
1. Answers will vary. The lowest possible temperature is about –20°C.
2. Sodium chloride was added to lower the melting point of the ice.

Learning Check Answers (Student textbook page 224)

1. metals and non-metals
2. positive ion
3. The sodium atom had one valence electron; the chlorine atom had seven valence electrons and room for one more. The sodium atom lost its valence electron, becoming Na^+; the chlorine atom gained that electron, becoming Cl^-. The Na^+ and Cl^- ions attracted each other, becoming NaCl.
4. Sample answer: Clothes fresh out of the dryer stick together.

Learning Check Answers (Student textbook page 227)

5. Students' sketches should resemble sodium chloride shown in Figure 6.6, on page 225, with F instead of Cl.
6. water; See diagram below.



7. Body fluids contain dissolved salt and other ionic compounds. These electrolyte solutions conduct electricity.
8. Sample answers: sodium chloride (table salt); sodium fluoride (in toothpaste); calcium carbonate (in chalk)

Section 6.1 Review Answers (Student textbook page 231)

Please also see **BLM 6-7 Section 6.1 Review (Alternative Format).**

1. If an atom attracts and holds an extra electron, the atom becomes a negative ion.

2. **a.** ionic
b. covalent
c. covalent
d. ionic

3. No. Both elements are non-metals.

4. Ionic compounds are large crystals in which many ions are tightly packed. The ions are strongly attracted, and are not easily separated to form a liquid.

5. Most solid fertilizers are ionic compounds of potassium, nitrogen, and phosphorus.

6. The ions in a solid ionic crystal are locked in place, and cannot move. If the crystal is dissolved in water, the ions can move in an electric current.

7. Salt can reach streams by surface run-off, sinking into groundwater, and blowing as airborne dust.

8. Salt blows in from the Atlantic Ocean. In the Northwest Territories, temperatures are so cold that salt is not used to melt ice.

Section 6.2 Covalent Compounds (Student textbook pages 232 to 241)

In this section, students will learn how non-metal atoms form covalent bonds. They will study how the molecular structure of covalent compounds provides a wide variety of physical properties, including their lack of electrical conductivity.

Common Misconceptions

- **Students tend to think of a *chemical bond* as a physical thing, like tape or string.** It is very important to stress that the chemical bond is a set of attractions among atoms and valence electrons. Remind students of these properties whenever they appear to be describing a covalent bond as a material thing.
- **In their habit of thinking of abstract things as concrete material objects, students might think of *breaking a covalent bond* as the physical destruction of a thing.** Emphasize that a covalent bond is the result of four attractions (two electrons and two atoms), and that breaking a bond is any process that reduces those attractions to zero. The electrons and the atoms still exist.

Background Knowledge

Non-metal atoms strongly attract their own electrons. If they have room in their valence shells, they can strongly attract other atoms' electrons as well. When two non-metal atoms have "room for one more," then both of these atoms can attract one of the other's valence electrons into their own valence energy level, without letting go of their own electron. This "double attraction" is a covalent bond.

Literacy Support

Using the Images

- Figure 6.16, on page 233, illustrates the formation of a covalent bond. Draw the Bohr-Rutherford diagram in this figure on the chalkboard, without electrons. Use magnets to model the electrons. Move the electrons to correspond to the diagram. Label the shared pair of electrons, and identify it as the covalent bond.
- ELL Many students will need to see Figure 6.18, on page 234, "worked out." With chalk, draw the Bohr-Rutherford diagrams without electrons on a black lab bench or the chalkboard. Have students move magnets or other objects around to show how the shared pairs of electrons form. Encourage students to use words to describe their model, or put some of the key terms on cards and have students use the cards as they explain what is happening.

Using the Text

Before Reading

- Ask students, "What major ideas are you going to learn about in this section?" Have students preview pages 232 to 240, looking at headings, subheadings, figures, captions, Key Terms, and marginal notes. When they are finished, have them write one sentence or a phrase to name each idea. (See Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook, as an example.)

During Reading

- Review Study Toolkit 2, Reading Effectively: Monitoring Comprehension, on page 564 of the student textbook, with students. Provide students with sticky notes on which to summarize each chunk of text. Students can mark each sticky note with either a checkmark (✓) to indicate understanding, a question mark (?) to indicate that they are not sure whether they understand, or an X, to indicate the need for explanation. Each mark leads students to one course of action as they work out the meaning of the text. At the end, they will have 8 to 10 summaries on sticky notes. Alternatively, students can use **BLM 6-8 Reading Strategy: Covalent Compounds.**

Specific Expectations

- **C1.1** assess the usefulness of and/or the hazards associated with common elements or compounds in terms of their physical and chemical properties
- **C3.4** describe the characteristic physical and chemical properties of common elements and compounds

- ELL Some English language learners may need to be guided through reading this information. Draw their attention first to the visuals and print key terms as you discuss them with students. Explain the key concepts that are described in the section and then have students read. Partner reading is also a very supportive strategy for English language learners who are stumped by lengthy sentences and abstract language

After Reading

- Have students organize and edit their notes into a single summary.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions 1 and 2, page 237	Students explain that non-metals strongly attract electrons. When two non-metals attract each other's electrons and share them, they form a covalent bond.	Use physical models (for example, chalkboard, pieces of paper, and so on) to illustrate. Provide parallel exercises, with different elements. (See **BLM 6-9 Covalent Bonding.**)
Learning Check question 4, page 237	Students explain that the electrons in a covalent bond are strongly attracted to the non-metal atoms, and are not free to move–that is, to conduct a current.	Use the bodily-kinesthetic activities in the Instructional Strategies below.

Instructional Strategies

- Choose two students to model two non-metal atoms. Give each student one tennis ball "electron." "Test" the students by trying to pull away the electron. The students should hold the "electron" tightly enough that you cannot easily pull it away. Now instruct the students to attempt to pull the other student's electron away, without letting go of their own "electron." Two non-metal atoms are covalently bonded by one shared pair of electrons. To help English language learners build vocabulary, print the words on the board as you describe what is happening.
- DI Relate the bodily-kinesthetic demonstration above to ionic bonding. Have two students each hold one tennis ball "electron." One student (the "non-metal") takes the "electron" from the other student (the "metal"). The two "ions" are then oppositely charged, and attracted to each other. Note that ions can move, and carry charge from place to place (that is, conduct an electric current).
- ELL Provide students with a variety of covalent compounds, for example, a polyethylene bag, polypropylene rope, vegetable oil, essential oils, and so on. Ask students what properties the compounds share. Point out that many covalent compounds are easy to melt, do not dissolve in water (are oily), and do not conduct electricity.
- The Case Study on pages 238 and 239 of the student textbook provides an opportunity for students to consider points of view involving STSE decisions. Make sure that English language learners understand what is meant by *biodegradable*.
- In Making a Difference on page 240 of the student textbook, students will read about the far-reaching impact of a high school student's concern with the impact of various compounds on the environment.
- Inquiry Investigation 6-B, Properties of Ionic and Covalent Compounds (on student textbook pages 250 and 251), provides students with an opportunity to review what they have learned about both types of compounds.
- In Data Analysis Investigation 6-C, Classification of Household Substances (on student textbook page 252), students apply what they have learned to classify common household substances as ionic or covalent compounds. Most of this Investigation could be completed at home.

Activity 6-3 Cornstarch Plastic (Student textbook page 240)

Pedagogical Purpose

Students experience two common, but very different, covalent compounds in this activity. Both water and starch are covalent molecules, but their different structures provide very different properties. When they interact with each other, they display more surprising properties.

Planning		
Materials	75 mL of cornstarch 45 mL of water Graduated cylinder	250 mL beaker Sturdy spoon or stir stick
Time	Preparation: 15 min	Class Time: 30 min
Safety	Corn starch dust can be very uncomfortable if inhaled. Remind students not to make clouds of dust. Ensure that students wear lab aprons and goggles.	

Background

Hydrogen and oxygen are covalently bonded to make water molecules. The individual water molecules are attracted to each other by hydrogen bonds. The starch molecule consists of hundreds of sugar molecules bonded together in a long chain. Sugar is covered with -OH groups, so it is attracted to water molecules (see Activity 6-1, on page 219 of the student textbook).

If a student lets the starch-water mixture rest, it will flow like a fluid. The long chains of starch will have time to slide past each other. If, however, a student tries to force a rapid change, the starch molecules cannot untangle. Think of a pot of tangled spaghetti noodles: if you grab some and yank on them, the whole pot of noodles will come out in one clump. If you gently wiggle the noodles free, you can separate enough for just one serving.

Activity Notes and Troubleshooting

- Add the water to the starch. It mixes much more easily, and is easier to adjust.
- Do not stir too vigorously. Use a steady motion.

Additional Support

- Have a small pot of cooked, drained spaghetti noodles on hand to demonstrate the behaviour of long, tangled strands in response to a slow, gentle force and to a fast, large force.
- **ELL** This lab is particularly complex for English language learners, because it involves many different levels:
  1. the odd behaviour of the starch
  2. understanding the molecular structure of the starch
  3. imagining the behaviour of tangled starch molecules

  Give students plenty of time to develop their understanding. Use diagrams to reinforce these concepts.

- ELL Suggest that students make short videos of the experiment. They can then collaborate to make short videos of their own explanations, using whatever means they wish (for example, animation, a bodily-kinesthetic activity, a speech, or a dialogue). Model recording their observations, reviewing key vocabulary as you write.
- Enrichment—Have students consider this question: If the cornstarch/water mixture is a model for soil, how would soil behave during an earthquake? (While soil particles can move past one another when a gentle force is applied, when a great force like an earthquake is applied, the soil may break, leaving a deep crack.)
- ELL Invite English language learners to work with a classmate when completing the Learning Check questions. Encourage them to use diagrams and notes that they have kept to guide them in their discussions.

Answers

1. The mixture flows like water, until it is level and smooth.
2. It breaks or shatters, with the break appearing dry.
3. Students' answers will vary. Accept any reasonable answers. A safety catch releases with a gentle pull, but holds with a hard shock. A transmission drive allows a vehicle to idle slowly, but transmits power to the wheels when cranked harder.

Learning Check Answers (Student textbook page 237)

1. non-metals
2. Valence electrons are shared between two non-metal atoms.
3. **a.** one silicon and four chlorine atoms
   b. one sulfur and six fluorine atoms
4. Covalent compounds are usually poor conductors of electricity.

Section 6.2 Review Answers (Student textbook page 241)

Please see also **BLM 6-10 Section 6.2 Review (Alternative Format).**

1. **a.** covalent
   b. ionic
   c. covalent
   d. covalent
2. Metals lose electrons too easily, and would not form a covalent bond.
3. *Co* usually means shared. *Valent* refers to valence electrons. Therefore a covalent bond involves shared valence electrons.
4. Yes. Hydrogen and sulfur have shared valence electrons so that both of them have filled valence shells.
5. Tri-angle has three angles. Octo-pus has eight tentacles. Penta-gon has five sides. A dec-ade has 10 years.
6. Forces between individual ions are strong, so they only melt at high temperatures. Forces between covalent molecules are weak, so they melt at lower temperatures.
7. Covalent compounds do not have free electrons, so they do not conduct electricity.
8. Students' answers will vary. Some artificial polymers are not biodegradable, and tend to accumulate in the environment. Other polymers are necessary for living organisms (proteins) or can be used to improve safety, such as seat belts and tires.

Section 6.3 Modelling Compounds (Student textbook pages 242 to 248)

In this section, students will deepen their understanding of a scientific *model*. They will first construct Bohr-Rutherford models on paper, then ball-and-stick models and space-filling models using kits. Finally, they will compare and contrast the different kinds of models.

Specific Expectations

- **C 2.5** construct molecular models to represent simple molecules (e.g., O_2, CO_2, H_2O, NH_3, CH_4)

Common Misconceptions

- **Students tend to conceptualize abstract concepts like bonds in terms of material substances.** When you present a ball-and-stick model of water, for example, they may think of a bond as a mechanical link, like a stick. Be aware of this misconception. Take care to emphasize that the bond is not a material thing like tape or a string.
- **Because of their experiences with model cars, airplanes, animals, and people, students are likely to think of a *model* as a smaller or larger replica of the real thing.** Knowing this, emphasize that every scientific model is "a representation that is useful" because it behaves in some ways like the hidden reality. A scientific model is never "the whole truth."

Background Knowledge

When Dalton first conceived of atoms as individual particles, he had to conclude that something held the atoms together in chemical compounds. Models of chemical bonding have evolved from the time of Dalton. We have a much more detailed model of the structure of the atom, and how the electrons are involved in bonding. The Bohr-Rutherford diagram provides a very limited, but useful, image of chemical bonding. Dalton would have understood the ball-and-stick and the space-filling models. Students today find them intuitively useful and helpful to display bond angles and bond lengths—features they have not likely considered before.

Literacy Support

Using the Images

- ELL The diagrams convey most of the important information in this section. English language learners in particular will benefit from examining the diagrams in the textbook and the models that you prepare before reading the text. As they examine the diagrams, use the language of the text with them.
- Review Figures 6.27 and 6.28, on page 243, with students. Explain that they are *scientific models* of bonding, because they represent real atoms in a way that can help us to explain and predict the behaviour of elements as they form chemical bonds. Have students identify which figure shows covalent bonding and which shows an ionic bond. How do they know?
- Build the ball-and-stick models of the three compounds in Figure 6.30, on page 245. Use a fine-point permanent marker to put two dots (representing electrons) on each "bond" (stick). These dots can help students to bridge the gap between the Bohr-Rutherford diagram and the ball-and-stick model.
- ELL To help students understand Figures 6.30 and 6.31, on pages 245 and 247, prepare large ball-and-stick models and space-filling models of water and one or two other substances. The large models often make such features as bond angles, bond lengths, and atomic volumes much more accessible and understandable to students than small models do.

Using the Text

Before Reading

- Ask students, "What are the major ideas that you are going to learn about in this section?" Have students preview pages 242 to 247 of the student textbook, looking at headings, subheadings, figures, captions, and marginal notes for three to four minutes. When they are finished, have them write one sentence or a phrase to name each idea. (See Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook, as an example.)

During Reading

- Review Study Toolkit 2, Reading Effectively: Monitoring Comprehension, on page 564 of the student textbook, with students. Provide students with sticky notes on which to summarize each chunk of text. Students can mark each sticky note with either a checkmark (✓) to indicate understanding, a question mark (?) to indicate that they are not sure whether they understand, or an X, to indicate the need for explanation. Each mark leads students to one course of action as they work out the meaning of the text. At the end, they will have four to five summaries on sticky notes. Alternatively, students can use **BLM 6-11 Reading Strategy: Modelling Compounds.**

After Reading

- Have students organize and edit their notes into a single summary. They should check to make sure their notes include the purpose or advantages of each type of model.
  - ELL English language learners may benefit form doing this activity with you, or after you model the process of summarizing key information.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check question 3, page 246	Students demonstrate awareness of electron arrangement, bond angle, bond length, atomic size, and how each model displays, or fails to display, each feature.	Provide students with modelling clay and toothpicks. Instruct students to start with a Bohr-Rutherford diagram, and build plausible ball-and-stick, and space-filling, models of the same compound.
Learning Check question 4, page 246	Students describe several advantages and several limitations of each model type.	Provide students with a real model of an animal, a car, a home, and so on. Repeat the exercise with the concrete object in view.

Instructional Strategies

- Choose several common substances, for example, water, methanol, propane, salt. For each substance, make a large Bohr-Rutherford model, a ball-and-stick model, and a space-filling model, in corresponding sizes. Students find it much easier to appreciate the characteristics of compounds when they use large models. Have students match up the models that show the same compound.
- Decide on one complex compound, such as glucose, chlorophyll, Vitamin-D, or some other substance. Make corresponding Bohr-Rutherford, ball-and-stick, and space-filling models. The value of the different model types is more easily appreciated when seen side-by side.
- Twenty or thirty space-filling models of water could be used to show how a small crystal of NaCl dissolves. This activity would provide a marked distinction between the behaviour of ionic and covalent substances as modelled by the three model types.

Activity 6-4 Representing Compounds Using Bohr-Rutherford Models

(Student textbook page 244)

Pedagogical Purpose

Representing the bonding process is a skill, and it requires practice to learn. This activity provides students with the opportunity to learn the skill, and it provides a model to use to assign further practice.

Planning		
Materials	Bohr-Rutherford models of NaCl, H_2O, KCl, and CO_2 (in Figures 6.4, 6.18, 6.27, and 6.28)	
Time	No preparation time is needed.	Class time: 30 min

Background

The most important feature of the Bohr-Rutherford diagrams is the movement of the valence electrons. In each bond, the non-metal atom attracts and holds electrons from a second atom. If the second atom is a metal, the non-metal completely removes the valence electron from the metal, creating two ions. If the second atom is a non-metal, then both atoms attract and hold each others' electrons, forming a covalent bond.

Activity Notes and Troubleshooting

- A complete solution to each question requires at least two diagrams: a *before* diagram, in which the intact atoms are close to each other; and an *after* diagram, in which all of the atoms settle down to their final configuration. The motion of the electrons can be depicted with arrows.

Additional Support

- Give students many opportunities to model compounds and bonding before doing this activity. See "Instructional Strategies" above.
- ELL *Sharing* and *taking* are anthropomorphic metaphors used to support students' understanding of covalent and ionic bonding. Act out sharing and taking so that students have a clear idea of these concepts before applying them metaphorically to chemical bonding.
- If necessary, review how to use information in the periodic table to decide what a Bohr-Rutherford diagram would look like.

Answers

1. It has room for two more (Group 16).
2. It must have three single (unpaired) electrons (Group 15).
3. the number of electrons in the valence shell

Activity 6-5 Ball-and-Stick Models (Student textbook page 246)

Pedagogical Purpose

In science, there are many different representations of bonding. Therefore, students must learn how to "translate" among various representations, including the models studied here.

Planning		
Materials	Molecular model kit	Sharp permanent markers (optional)
Time	Preparation: 5 min	Class time: 60 min
Safety	Remind students to handle the pieces carefully, and to keep track of small pieces.	

Background

Ball-and-stick models can really only be used to represent covalent molecules. Each "stick" represents one chemical bond—that is, one shared pair of electrons. In the molecule, these electron pairs are actually spread out over a large volume. Each pair repels the others, and they move as far apart from each other as possible. Four covalent pairs repel each other into the geometry of a tetrahedron. Most molecular model kits reflect this phenomenon.

Activity Notes and Troubleshooting

- Check students' Bohr-Rutherford diagrams before they proceed, to ensure that students have placed the correct numbers of electrons in the valence shells.
- You might wish to use a fine-point permanent marker to place two black dots on each "stick," to remind students that a bond is a covalently shared pair of electrons.
- Be prepared to tackle "double bonds," in which two atoms share two pairs of electrons. Oxygen and carbon often form double bonds, for example, oxygen gas (O_2) and carbon dioxide (CO_2).
- Additional molecules (single bonds) that students can easily build include ethane (C_2H_6), propane (C_3H_8), methanol (CH_3OH), cyclohexane (C_6H_{12}), and glucose ($C_6H_{12}O_6$).

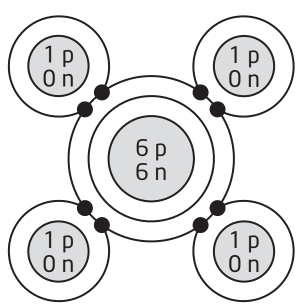
Additional Support

- ELL This activity makes few language demands. Use it to reinforce Bohr-Rutherford bonding diagrams, which are much more difficult to create than ball-and-stick models. Prepare Bohr-Rutherford bonding diagrams of H_2O, O_2, CO_2, NH_3, and CH_4, and point out how the bonding is represented in both kinds of models.
- Enrichment—Have students build models of more double bonded molecules, for example, ethene (C_2H_4), formaldehyde (CH_2O), propene (C_3H_6), and benzene (C_6H_6).

Answers

1. Ball-and-stick models provide the three-dimensional shape of the molecule.
2. Bohr-Rutherford: two-dimensional; shows electrons; shows whole atom; shows bonding
   Ball-and-stick: three-dimensional; hides electrons; shows only bonds; shows bonding

Learning Check Answers (Student textbook page 246)

1. It is drawn on a flat sheet of paper with only two dimensions: length and width.
2. 

3. three-dimensional shape of the molecule
4. Answers should describe a model, such as a map or a model airplane, and should include a table that correctly identifies the pros and cons of the model.

Section 6.3 Review Answers (Student textbook pages 248)

Please see also **BLM 6-12 Section 6.3 Review (Alternative Format).**

1. Bohr-Rutherford model
2. Eight valence electrons are in covalent bonds; 24 valence electrons are not in bonds.
3. ball-and-stick models and space-filling models
4. ball-and-stick model
5. Students' answers will vary. The information is the same as in the answers for questions 6, 7, and 8 below. The answer should be in the form of a table, or a well-organized paragraph.
6. Students' answers will vary. Two-dimensional models are easy to draw, and they show the arrangement of electrons in the compound. Three-dimensional models do not show electrons, but they more accurately show the correct arrangement of atoms.
7. The covalent model kit is more expensive, but has the correct angles between the bonds and the correct number of bonds for each atom. The gumdrops and toothpicks are cheap and available, but are not as accurate as models made with the kit.
8. The size and shape of a medication molecule are important. The space-filling model or other three-dimensional model would be the best, because it shows the relative sizes and arrangement of atoms.

Inquiry Investigation 6-A What Causes Rusting of Iron Nails?

(Student textbook page 249)

Pedagogical Purpose

Students investigate a common example of ionic bonding and its implications.

Planning		
Materials	Fine sandpaper 3 clean, dry test tubes Water Test-tube rack **BLM 6-13 Inquiry Investigation 6-A What Causes Rusting of Iron Nails?** (optional)	3 clean, dry nails 3 clean, dry rubber stoppers Table salt
Time	Setup: 45 min	Observation: 15 min
Safety	Students should wear goggles and a lab apron. Remind students to agitate the test tubes safely, and to clean up any spills immediately.	

Background

Rusting is a complex chemical change that involves many different processes. The condensed equations below are beyond students' level, but may be helpful to you. Dissolved oxygen reacts with the iron and water to make "green rust," iron II hydroxide:

$2 Fe + O_2 + 2H_2O \rightarrow 2 Fe(OH)_2$

Iron II hydroxide reacts with more water and oxygen to make "red rust," iron III hydroxide:

$4 Fe(OH)_2 + O_2 + H_2O \rightarrow 4 Fe(OH)_3$

Both reactions actually involve several steps, and are accelerated by the presence of dissolved ions, like sodium chloride. Formation of rust requires exposed iron, oxygen gas, liquid water, and dissolved electrolytes like salt. If any of the four factors are missing, the reaction is slowed or stopped.

Activity Notes and Troubleshooting

- Using clean iron is important! The day before distributing the nails, soak them in hot water with a little detergent to remove grease. Then rinse them with clean hot water, and let them dry on a paper towel.
- Rusting nails leave stains on glass. Use older test tubes.

Additional Support

- **ELL** Have one student read the procedure steps, while another student demonstrates the procedure to the rest of the students, so that everyone in the class understands the procedure. Note and explain new vocabulary, such as *stopper, expose, control*, and *condition*.
- **ELL** Encourage students to explain the procedure before the experiment by drawing diagrams, with arrows and small notes, to show what will be done to the nails.
- For a challenge, some students may wish to design a new set of experiments to test the effectiveness of coating the nails with oil, paint, and so on, to resist rusting.
- Enrichment—For a student inquiry, run a trial of three nails, test tubes, and stoppers (as in the textbook), but flush the test tubes with an inert gas such as nitrogen or carbon dioxide, to remove the oxygen, before stoppering them.
- Enrichment—For a teacher demonstration, add other salts to the test tubes, such as sodium nitrate or potassium chlorate.

Answers

Analyze and Interpret

1. the dry iron nail
2. Salt and water had the greatest rusting; the dry nail had the least rusting.

Conclude and Communicate

3. Clean iron tools before storing them in a dry place. A warm storage area reduces water condensation.

Extend Your Inquiry and Research Skills

4. Oxygen is necessary for rusting to occur. Students should include a control with oxygen, and variations without oxygen.

Inquiry Investigation 6-B Properties of Ionic and Covalent Compounds (Student textbook pages 250 and 251)

Pedagogical Purpose

This activity challenges students to identify covalent and ionic compounds, based on their observable properties.

Planning		
Materials	6 test tubes Glass plate of watch glass Plastic water bottle Aluminum foil Conductivity tester **BLM 6-14 Inquiry Investigation 6-B Properties of Ionic and Covalent Compounds** (optional)	6 samples of compounds (See Activity Notes for suggestions.) Scoop Hot plate Distilled water Tongs
Time	Preparation: 30 min	Class time: 70 min
Safety	Ensure students wear safety goggles and a lab apron, as well as gloves. Ensure students do not smell directly when testing for odour. They should avoid inhaling any gas by taking a deep breath and holding it, wafting some air from near the mouth of the test tube toward their nose, and then breathing out. Remind students to be careful with the hot plate, to not leave it turned on for more than 2 min, to allow it to cool for 15 min before moving it, and to unplug it by pulling on the plug and not the cord. Ensure students keep their workplace clean and dry.	

Background

A typical ionic compound is odourless; is brittle, and can be crushed to gritty powder; is medium hard; will melt at high temperature; will dissolve in water; can conduct electricity in solution. Students should score these properties with a 0 on the table.
A typical covalent compound has odour; is soft or a liquid; can be crushed like wax or butter; is soft; will melt at low temperature; cannot dissolve in water; does not conduct electricity. Students should score these properties with a 1 on the table.

Activity Notes and Troubleshooting

- Emphasize the scoring system: ionic behaviours score 0, covalent behaviours score 1.
- Each sample must be as small as possible, yet large enough to perform all of the tests. Three crystals should be enough: smell one, then crush it; test hardness, then melt it; dissolve one, then test conductivity.
- Suggested ionic compounds are sodium chloride, copper sulfate, alum, ferrous ammonium sulfate, and ammonium chloride.
- Suggested covalent compounds are menthol; oil of wintergreen; polypropylene rope; vegetable oil; thymol; and essential oils such as geranium, rose, and so on.

Additional Support

- ELL This complex activity requires students to match a 6 × 6 matrix of substances and tests to six properties. Expressing and comprehending this task in words is very difficult. Provide students with blank tables, and with lists of ionic and covalent properties. Model one test of six processes and then complete the appropriate part of the matrix. If they understand the task have students continue on their own.

- To reinforce the purpose of this activity, provide some physical models of ionic crystals, and small covalent molecules. Refer to these models as you discuss the properties of the compounds being tested.
- Enrichment—Provide students with some ambiguous materials to investigate: covalently bonded quartz, or glass $(SiO_2)_n$; citric acid, a covalent ionic solid; fools' gold (FeS_2); and ammonium carbonate $[(NH_4)_2CO_3]$.

Answers

Analyze and Interpret

1. Representative ionic compounds, such as potassium iodide, have a total score of 0; representative covalent compounds, such as camphor, have a total score of 6.
2. Answers will vary. Students should base their conclusions on observed patterns of properties, for example, which substances behaved in a similar way and which property seemed most typical of ionic compounds.

Conclude and Communicate

3. The names of ionic substances have a *metal-non-metal-ide* structure. Many covalent compounds have colloquial names like camphor, wax, and so on.

Extend Your Inquiry and Research Skills

4. Students' answers will vary. Accept any well-defended answers.
5. Many sports drinks contain salts, which are ionic compounds. Conductivity would be an effective test.

Data Analysis Investigation 6-C Classification of Household Substances (Student textbook page 252)

Pedagogical Purpose

Students will apply concepts learned in sections 6.1 and 6.2, and in Inquiry Investigation 6-B, on pages 250 and 251, to interpret a table of data. This activity will help students consolidate the material they learned in Chapter 6.

Planning		
Materials	**BLM 6-15 Data Analysis Investigation 6-C Classification of Household Substances** (optional)	
Time	No preparation time is needed.	Class time: 15 min

Background

In the science lab, teachers can choose chemicals of exceptional purity to represent the clearest cases of ionic or covalent compounds. In the home, matters are not always so clear. Yet, if students are unable to apply the classroom knowledge to their everyday world, they are likely to forget their learning.

Baking soda and sugar are quite pure; salt is less pure. Cooking oil is a mixture of oils, not a pure substance. Wax consists of perhaps 10 petroleum compounds. Lip balm is a mixture of many covalent compounds, including wax. Dishwasher soap (powder) is a mixture of sodium carbonate, borax, and other ionic compounds.

Sugar and baking soda both display anomalous behaviour. Sugar is a crystal, but it is covalent. It dissolves in water, but it does not conduct electricity. Baking soda is an ionic compound that decomposes before it melts.

Activity Notes and Troubleshooting

- Refer students to the scoring system used in Inquiry Investigation 6-B, on pages 250 and 251. Have them use it to classify the substances in this investigation.

Additional Support

- **ELL** Display samples of each of the household substances in their original packaging, so that students can connect the name to the consumer product. Ensure that students understand the meanings of *qualitative* and *quantitative*.
- **DI** Demonstrate the three tests on the six substances. The physical experience of the tests may be more meaningful than written or spoken words, especially to bodily-kinesthetic and spatial learners.

Answers

Analyze and Interpret

1. high vs. low melting points; soluble vs. insoluble in water; conductive vs. non-conductive in water
2. ionic: baking soda, table salt, dishwasher soap (powder); covalent: cooking oil, lip balm, wax; not clear: sugar

Conclude and Communicate

3. Sugar is not easy to classify. It has a distinct crystalline structure, but melts at a relatively low temperature. It dissolves in water, but does not conduct electricity.

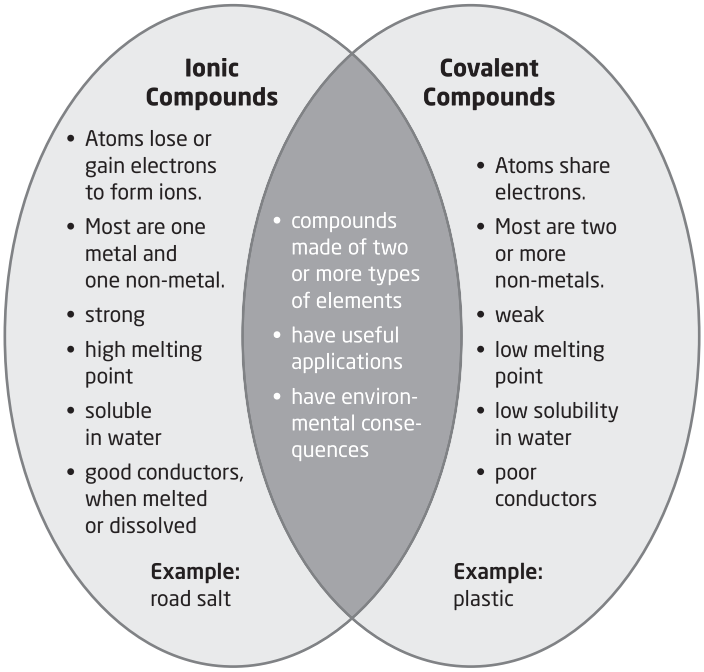
Extend Your Inquiry and Research Skills

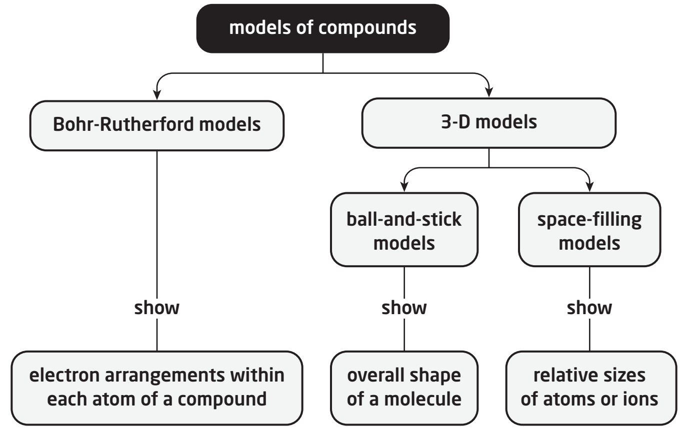
4. Students' answers will vary. Accept any reasonable answers with students' explanations.

Chapter Review Answers (Student textbook pages 254 and 255)

Please see also **BLM 6-16 Chapter 6 Review (Alternative Format).**

Make Your Own Summary





Reviewing Key Terms

1. **f.** ion
2. **g.** chemical bond
3. **a.** covalent bond
4. **c.** molecule
5. **b.** ionic bond
6. **e.** covalent compound
7. **d.** ionic compound

Knowledge and Understanding

8. A more stable atom has a full valence shell of electrons.
9. **a.** Mg^{2+} lost 2 e^-.
   b. Al^{3+} lost 3 e^-.
   c. S^{2-} gained 2 e^-.
   d. I^- gained 1 e^-.
10. A metal and a non-metal make up an ionic compound. Two or more non-metals make up a covalent compound.
11. Students' answers may vary; carbon dioxide, water
12. Students' answers may vary; sodium chloride, calcium carbonate
13. **a.** H_2O, covalent
    b. CO_2, covalent
    c. NaCl, ionic
    d. OF_2, covalent
14. **a.** Strontium bromide, ionic
    b. carbon disulfide, covalent
15. Students' answers will vary. Tables should be well organized. A sample answer is given below.

	Carbon Dioxide	Sodium Chloride
Similarities	Clear Colourless Compound	Clear Colourless Compound
Differences	Gas Slightly soluble in water Solution conducts weakly	Solid Highly soluble in water Solution conducts well

16. In an ionic bond, electrons are transferred from a metal to a non-metal, forming two kinds of ions that attract each other into a crystal lattice. In a covalent bond, electrons are shared between two atoms.
17. **a.** 2
    b. 5
    c. 6
    d. 9
18. **a.** ball-and-stick; space filling; Bohr-Rutherford
    b. ball-and-stick; space-filling
    c. Bohr-Rutherford

19. a. sodium chloride; dissolves readily, lowers melting point of water
b. environmental damage to water, soil, and plants

Thinking and Investigating

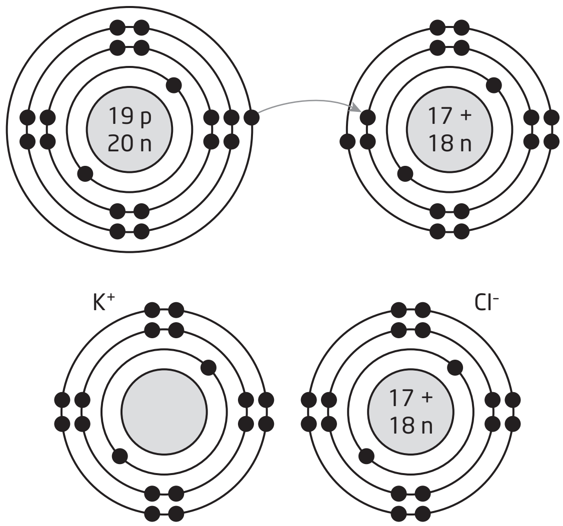
20. equal; The number of electrons lost by the metal atoms must have been gained by the non-metal atoms.

21. Ionic bonds are strong; crystal lattice cannot be shaken apart easily.

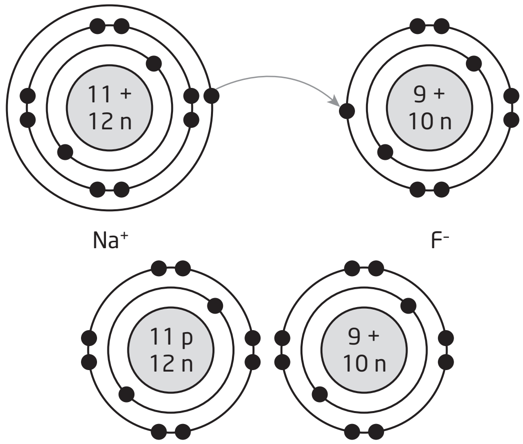
22. Covalent bonds are strong; the forces between molecules are often weak.

Communication

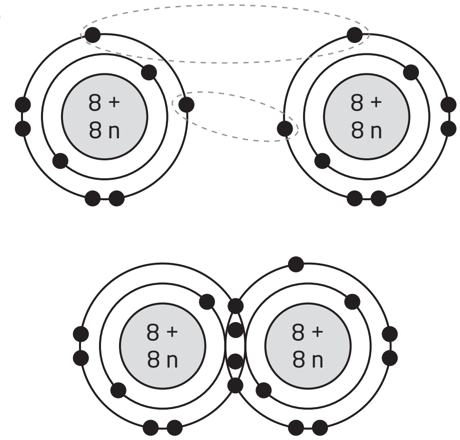
23. a.



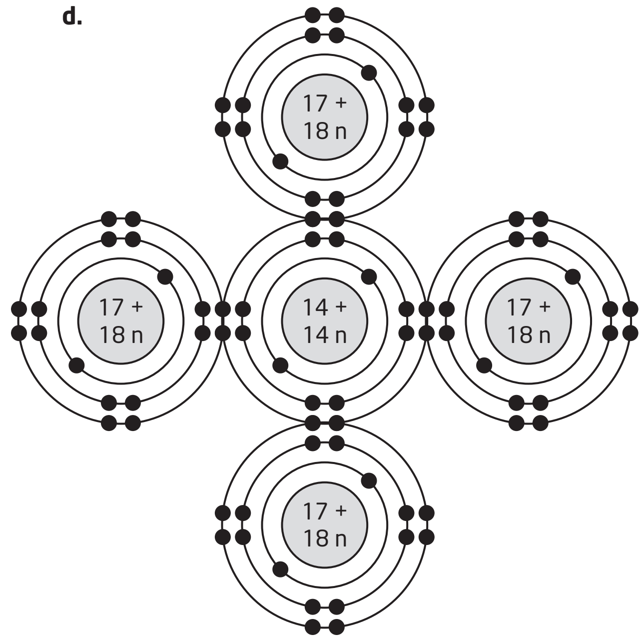
b.



c.



d.



24. The letter must contain this argument: When dissolved in water, an electrolyte dissociates into ions, and is capable of conducting electricity. A covalent molecule is unlikely to dissociate into ions; therefore, it cannot be an electrolyte.

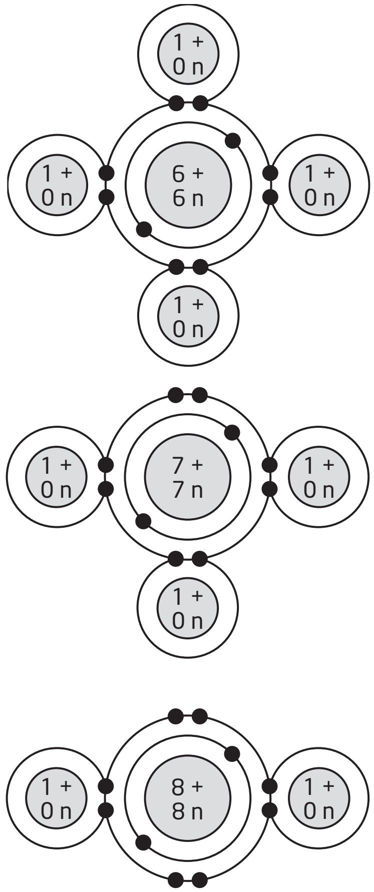
25. Sample positive effects: plastics can be inexpensive, durable, easy to manufacture, chemically inert, designed with special properties, recyclable, light, strong, and so on. Sample negative aspects: plastics can be energy inefficient, designed to be discarded, unable to break down in environment, decompose into harmful chemicals, and so on.

Application

26. a. Insoluble fertilizer could not be taken up by plants.
b. Ineffective fertilizer would be costly and economically detrimental to farmers.

27. Ionic compounds have high melting points: calcium chloride (+772°C). Covalent compounds often have low melting points: sulfur dichloride (-121°C).

28. a.



b. Electron Arrangements and Bond Angles

Compound	Formula	Number of Valence Electrons in Covalent Bonds	Number of Valence Electrons Not in Covalent Bonds	Bond Angle
Methane (main component of natural gas)	CH_4	8	0	109.5°
Ammonia (used as a fertilizer)	NH_3	6	2	107.0°
Water (necessary for living organisms)	H_2O	4	4	104.5°

c. Four identical bonds are always 109.5° apart, in a *tetrahedral* angle. When one non-bonded pair is present, the remaining bonds are forced together, to 107.0°. If two non-bonded electron pairs are present, then the bond angle is reduced to a 104.5° angle.

Unit 2 Projects

Inquiry Investigation
Rust Prevention

Pedagogical Purpose

This activity requires students to demonstrate familiarity with a large number of concepts covered in the unit, especially physical and chemical change, the properties of elements and compounds, and ionic and covalent bonding. Students must also demonstrate the ability to plan and execute a complex experiment, keep records, and interpret and communicate findings.

Planning		
Materials	Uncoated steel nails (99.7% iron) Pieces of sheet steel from auto body shop Steel wool to clean iron Test tubes with stoppers Solution of copper sulfate	A variety of coatings (students supply) Other metals, such as copper wire, magnesium strips, aluminum foil, zinc salt **BLM A-46 Unit 2 Inquiry Project Rubric G-7 Design Your Own Investigation** (optional) **BLM A-3 Designing an Experiment Checklist** (optional)
Time	Preparation: 20 min	Class time: 2 or 3 days
Safety	Students must present their plans for approval before proceeding. Students should wear eye protection and skin protection at all times.	

Background

Coatings can prevent rusting by not allowing the iron to have contact with water and air. Coating with metals that are more active than iron, such as zinc or magnesium, prevents rusting by supplying their electrons to oxygen, and setting up a small electrical field that slows further oxidation. Contact with metals that are less active than iron, such as copper, causes the opposite effect: increasing oxidation of the iron. Metal plating, such as chromium or nickel, provides a surface that is less active than iron, and resists rusting.

Activity Notes and Troubleshooting

- Remind students to set up appropriate controls for their experiment.
- Commercial automotive anti-rust coatings from various sources could be compared. Most building supply and hardware stores have anti-rust paints and coatings.
- Be prepared for students to invent a variety of tests and experiments.
- Students can use **BLM G-7 Design Your Own Investigation; BLM A-3 Designing an Experiment Checklist;** and **BLM A-46 Unit 2 Inquiry Project Rubric** to help them plan their project.
- Encourage students to have a classmate check their completed project to ensure that it meets the assessment criteria.

Additional Support

- Use a bicycle to provide examples of rust-prevention strategies: grease on the chain, paint on the frame, plastic covering on the cables, chromium plating on the handlebars. Use these parts to suggest the kinds of things that students could investigate.
- Many students have relatives whose work involves some measure of rust protection. Try to accommodate these students as they pursue experiments related to those workplaces.

- Extension—Simple nickel and copper plating stations can be set up to test the effect of plating as a rust protection.

Rubric

ACHIEVEMENT CHART CATEGORY	Level 1	Level 2	Level 3	Level 4
Thinking & Investigation	Conducts the experiment, carrying out the procedure safely and recording data accurately with limited effectiveness. Supports or refutes predictions for each variable with limited clarity. Identifies sources of uncertainty with limited accuracy.	Conducts the experiment, carrying out the procedure safely and recording data accurately with some effectiveness. Supports or refutes predictions for each variable with some clarity. Identifies sources of uncertainty with some accuracy.	Conducts the experiment, carrying out the procedure safely and recording data accurately with considerable effectiveness. Supports or refutes predictions for each variable with considerable clarity. Identifies sources of uncertainty with considerable accuracy.	Conducts the experiment, carrying out the procedure safely and recording data accurately in a highly effective manner. Supports or refutes predictions for each variable with a high degree of clarity. Identifies sources of uncertainty with a high degree of accuracy.
Communication	Results are communicated with limited effectiveness.	Results are communicated with some effectiveness.	Results are communicated with considerable effectiveness.	Results are communicated with a high degree of effectiveness.
Application	Makes connections between science, technology, society and the environment with limited effectiveness.	Makes connections between science, technology, society and the environment with some effectiveness.	Makes connections between science, technology, society and the environment with considerable effectiveness.	Makes connections between science, technology, society and the environment with a high degree of effectiveness.

An Issue to Analyze
The Impact of Metal Mining

Pedagogical Purpose

This activity requires students to demonstrate familiarity with concepts covered in the unit, especially physical and chemical change, the properties of elements and compounds, and ionic and covalent bonding. Students must also apply those concepts to the analysis of a social/environmental problem, and generate possible solutions to the problem.

Planning	
Materials	Research resources **BLM A-47 Unit 2 An Issue to Analyze Rubric** (optional) **BLM G-14 Debating Procedures** (optional) **BLM G-15 Debate Organizer** (optional) **BLM G-12 Scientific Research Planner** (optional) **BLM G-17 Worksheet for Investigating Issues** (optional)
Time	2 or 3 days

Background

Mining requires the removal of large amounts of surface soil and rock. Where does the material go? What does it contain? How does it change the mineral content of surface water, and where does that water go? Refining metals involves many different chemical processes, all of which consume resources and generate waste materials. What are the environmental costs? Who bears them? This report requires students to integrate four areas of knowledge: mining technology, metal chemistry, environmental impacts, and social responses.

Activity Notes and Troubleshooting

- Refer students to Science Skills Toolkit 11, How to Do a Research-Based Project, on pages 552 and 553 of the student textbook. The blackline masters listed above can also provide support for students.
- Students need time and resources to do the following:
  - plan an investigation of important points of the issue, and propose a thesis
  - explore a particular mining issue, collecting enough information
  - process the information, generate new questions, and revise the thesis
  - create a product to communicate findings
- Students will need help and direction to find resources that relate the particular mining issue to the concepts of physical and chemical properties, and chemical change.
- Encourage students to have a classmate read their project to ensure that it meets the assessment criteria.
- Use **BLM A-37 Unit 2 An Issue to Analyze Rubric,** to guide and assess students' work.

Additional Support

- If students need direction to plan and implement a research-based project, provide copies of one or more of the blackline masters listed above. You could gather a group to discuss possible responses.
- ELL Resource extraction issues arise all over the world. English language learners may be able to use their familiarity with a mining issue that impacts their country of origin. Some students, however, may have little or no exposure to mining. A visual such as a short documentary on mining would provide them with background information.

- A variety of product types should be encouraged. Video productions, photograph montages, interviews, and debates can provide students with opportunities that match their abilities and interests.

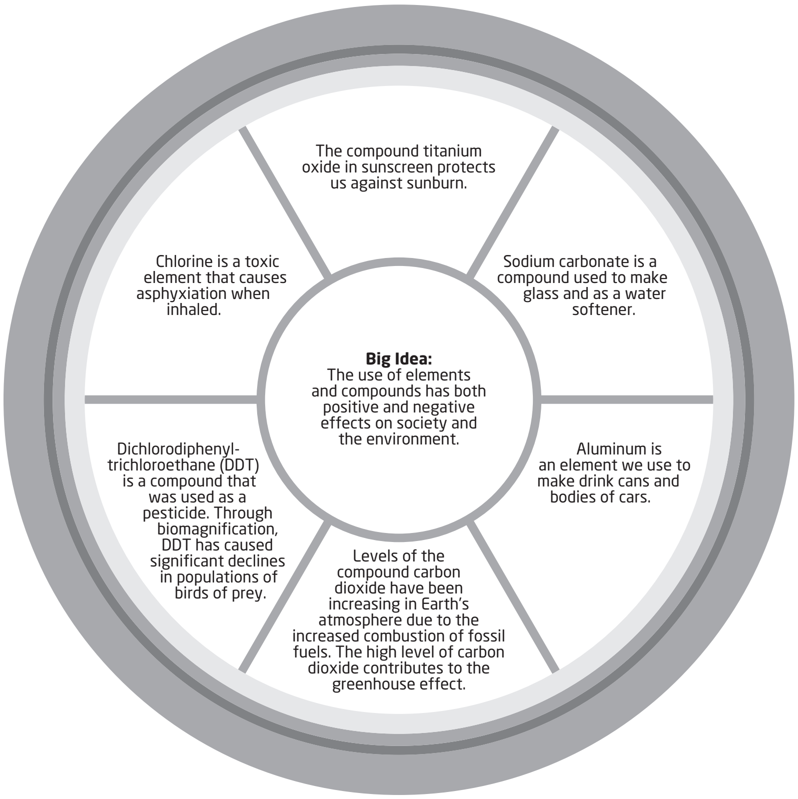
Rubric

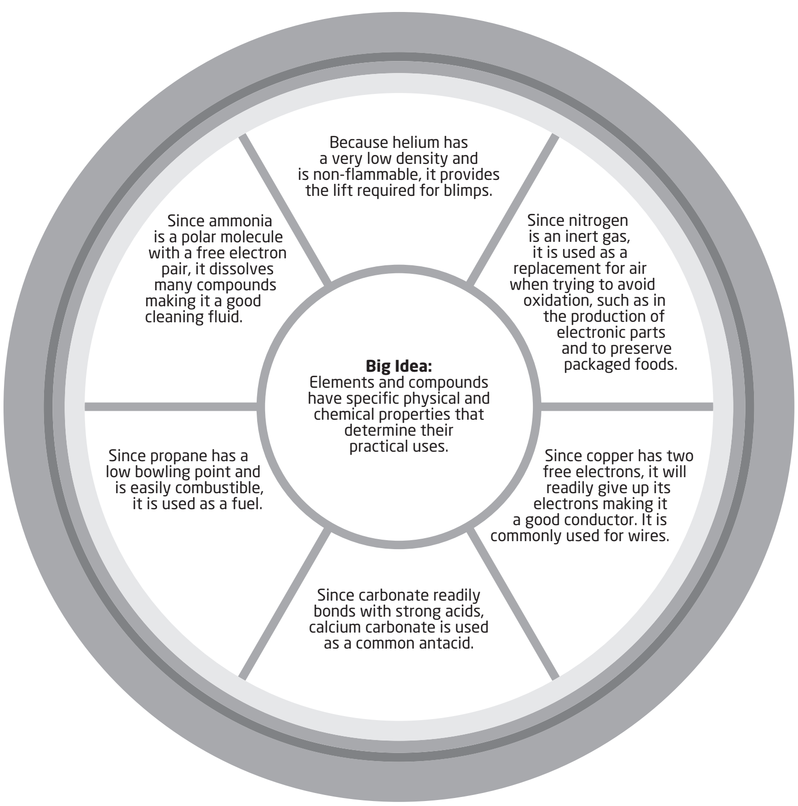
ACHIEVEMENT CHART CATEGORY	Level 1	Level 2	Level 3	Level 4
Knowledge & Understanding	Demonstrates limited knowledge of specific issues related to metal mining.	Demonstrates some knowledge of specific issues related to metal mining.	Demonstrates considerable knowledge of specific issues related to metal mining.	Demonstrates a high degree of knowledge of specific issues related to metal mining.
Thinking and Investigation	Formulates research questions with limited effectiveness.	Formulates research questions with some effectiveness.	Formulates research questions with considerable effectiveness.	Formulates research questions with a high degree of effectiveness.
Communication	Communicates a position on the issue with supporting evidence, using appropriate scientific vocabulary, with limited effectiveness and clarity.	Communicates a position on the issue with supporting evidence, using appropriate scientific vocabulary, with some effectiveness and clarity.	Communicates a position on the issue with supporting evidence, using appropriate scientific vocabulary, with considerable effectiveness and clarity.	Communicates a position on the issue with supporting evidence, using appropriate scientific vocabulary, with a high degree of effectiveness and clarity.
Application	Identifies a position on the issue with support from various perspectives and stakeholders with limited effectiveness. If necessary, proposes alternative course of practical application and provides rationale with limited effectiveness.	Identifies a position on the issue with support from various perspectives and stakeholders with some effectiveness. If necessary, proposes alternative course of practical application and provides rationale with some effectiveness.	Identifies a position on the issue with support from various perspectives and stakeholders with considerable effectiveness. If necessary, proposes alternative course of practical application and provides rationale with considerable effectiveness.	Identifies a position on the issue with support from various perspectives and stakeholders with a high degree of effectiveness. If necessary, proposes alternative course of practical application and provides rationale with a high degree of effectiveness.

Unit 2 Review Answers (Student textbook pages 260 to 263)

Connect to the Big Ideas

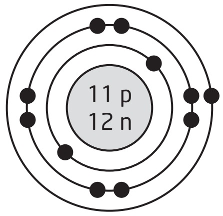
Connect to the Big Ideas answers are also available as a Blackline master on the accompanying CD.



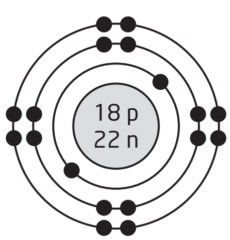


Knowledge and Understanding

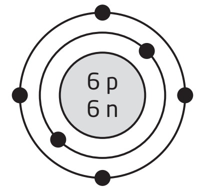
1. **b.**
2. **c.**
3. **a.**
4. **d.**
5. **a.**
6. **a.** Boiling point is the temperature at which a pure substance boils at atmospheric pressure. The boiling point of water is 100°C.
   b. Electrical conductivity is the ability of a substance to conduct electricity. Salt water has high conductivity.
   c. Solubility is the ability of a substance to dissolve. Salt is soluble (36 g per 100 g of water); quartz is insoluble.
7. 2.5 g/cm^3
8. 19.7 g
9. Liquid B is less dense, and it floats (D = 0.92 g/cm^3). Liquid A is more dense, and it sinks (D = 1.36 g/cm^3).
10. Physical property: density 1.0 g/cm3; boiling point 100°C
    Chemical property: reacts with sodium
11. **a.** positive
    b. negative
    c. negative
12. An electron has a mass of about $\frac{1}{1836}$ the mass of a proton. A neutron is very slightly more massive than a proton.
13. Atoms with a full shell are non-reactive. Atoms with one or two electrons tend to lose them; atoms lacking one or two electrons tend to gain them.
14. **a.** Na



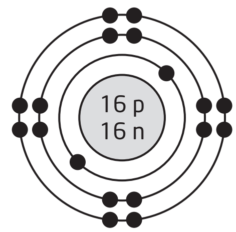
b. Ar



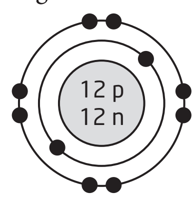
c. C



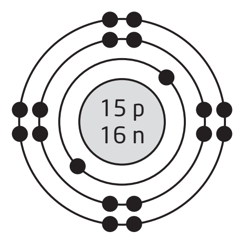
d. S^{2-}



e. Mg^{2+}



f. P^{3-}



15. **a.** 6 p, 7 n, 6 e
    b. 24 p, 28 n, 24 e
    c. 16 p, 16 n, 16 e
    d. 7 p, 7 n, 7 e
16. **a.** $^{14}_{6}C$
    b. $^{53}_{24}Cr$
    c. $^{33}_{16}S$
    d. $^{15}_{7}N$
17. atomic number: the number of protons in the nucleus; atomic mass number: the number of (protons + neutrons) in the nucleus; atomic mass: the average of the atomic mass of an element
18. As you read down the table, each element is larger because there are more layers of electrons.

Thinking and Investigation

19. a. Unplug the hot plate, and take the liquid off the hot plate before leaving the room.

b. Remove the test tube from the flame. Let the test tube cool, preferably in a wire test tube rack. Dispose of any chemicals as directed by the teacher. When it is cool, discard the test tube in the broken glass receptacle, tube down.

20. a. Place a lighted splint in the test tube. If hydrogen is present, it will ignite.

b. Place a glowing ember in the test tube. If oxygen is present, it will burst into flame.

c. Add limewater to the gas. If it is carbon dioxide, the limewater will turn white and milky.

21. Sodium reacts with water.

22. a. B, calcium, group 2

b. C, argon, has a full valence shell

c. A, oxygen, can attract two electrons

d. C, argon, is a noble gas, and was discovered last.

e. B, calcium, is the only metal.

23. a. neon

b. nitrogen

c. magnesium

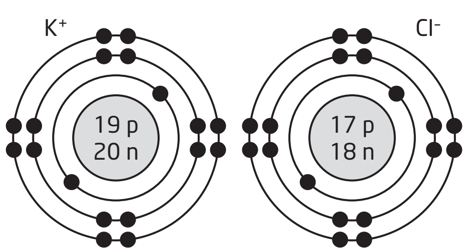
24. Compounds are composed of two or more elements in a fixed ratio.

25. Students' answers should include the following: ionic compounds involve a metal and a non-metal, involve the transfer of electrons, involve the formation of ions, are crystalline solids, may dissolve in water, have aqueous solutions, and are electrical conductors. Covalent compounds involve non-metals only, involve shared electrons, involve the formation of molecules, are often insoluble, and are poor conductors.

26. a. neutral atoms; protons and electrons are equal.

b. ionic; Element 19 (K) loses its only valence electron. Element 17 (Cl) gains one electron to complete its shell.

c.



d. potassium chloride

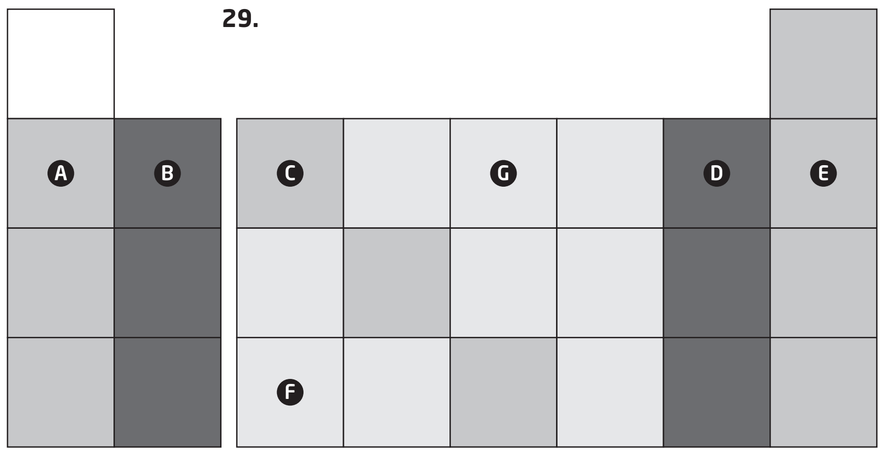
Communication

27. The models were developed in historical order:

Dalton	Thomson	Rutherford	Bohr
Every compound consisted of atoms of elements combined in fixed ratio by mass.	Every element could be made to emit cathode rays; later identified as electrons.	Alpha particles penetrated the atom; most passed right through. A very small number hit something very small, very massive, and positive.	Hydrogen gave off fixed colours of light. Electrons must revolve around hydrogen nucleus in fixed energy levels.

28. Students' answers will vary. There are up to nine different varieties of polyethylene, differing in molecular weight, side chain branching, and cross-linking.

29.



a. A, B, and F

b. G, D, and E

c. E

d. A

e. B

f. D

Application

30. a. A

b. C

c. F

31. Students' answers will vary. The best answers will discuss the sources of mercury, the organic compound of mercury, bio-accumulation of mercury, long lifetime of mercury contamination, direct and indirect health effects, and economic effects.

32. Students' answers will vary. Possible answer: Apply smallest possible amount, only at the time and place needed.

33. Space-filling models can show whether or not a drug will physically fit into a site on the DNA molecule.

Literacy Test Prep

Multiple Choice

34. **b.**

35. **d.**

36. **d.**

37. **a.**

38. **d.**

Written Answer

39. Students' answers must mention low density and strong, lightweight alloys. They should also mention workability, and that it does not corrode.