TOPIC 2.4

How do elements combine to form compounds?

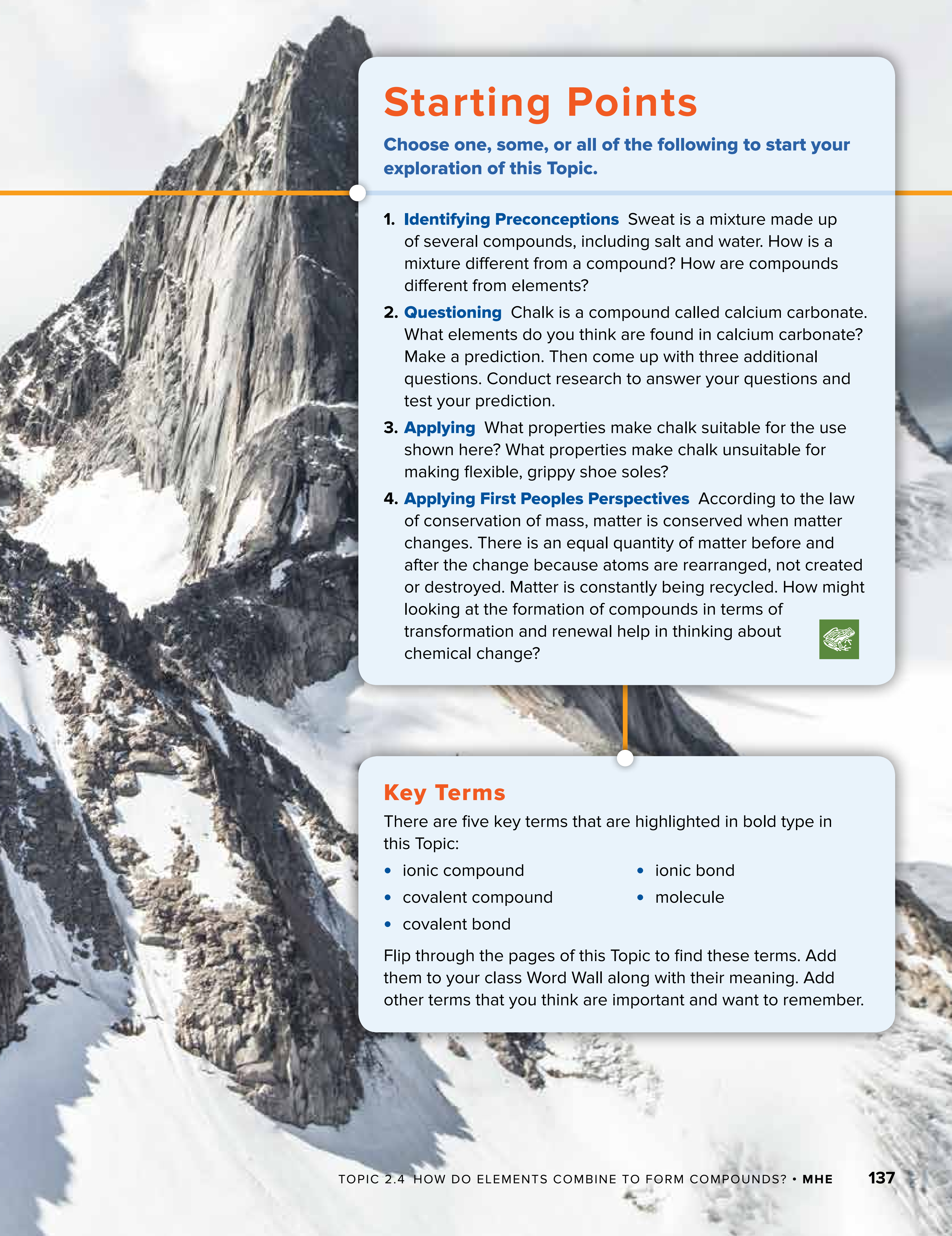
Key Concepts

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

Curricular Competencies

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

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



Starting Points

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

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

Key Terms

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

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

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

CONCEPT 1

Compounds account for the huge variety of matter on Earth.

Activity

What is it made of?

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

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

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

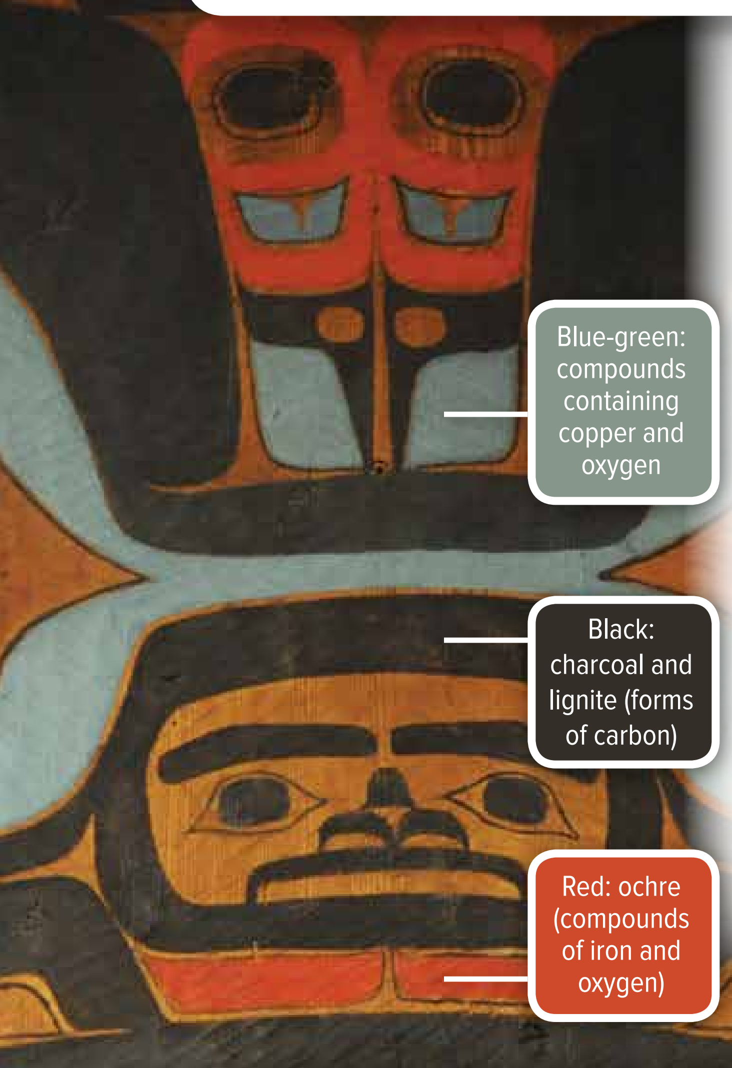
All of the compounds that exist on Earth are built from the elements of the periodic table. The periodic table lists 118 elements, and only 80 of these commonly form compounds. Yet there are 10 million known compounds—and scientists estimate that there could be billions of possible compounds. **Figure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

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

Before you leave this page . . .

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

AT ISSUE How can pigments influence art styles?



What's the Issue?

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

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

Dig Deeper

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

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

CONCEPT 2

Ionic compounds are made of ions.

Activity

Salt or Sugar?

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

ionic compound a compound made of oppositely charged ions

ionic bond a strong attraction that forms between oppositely charged ions

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

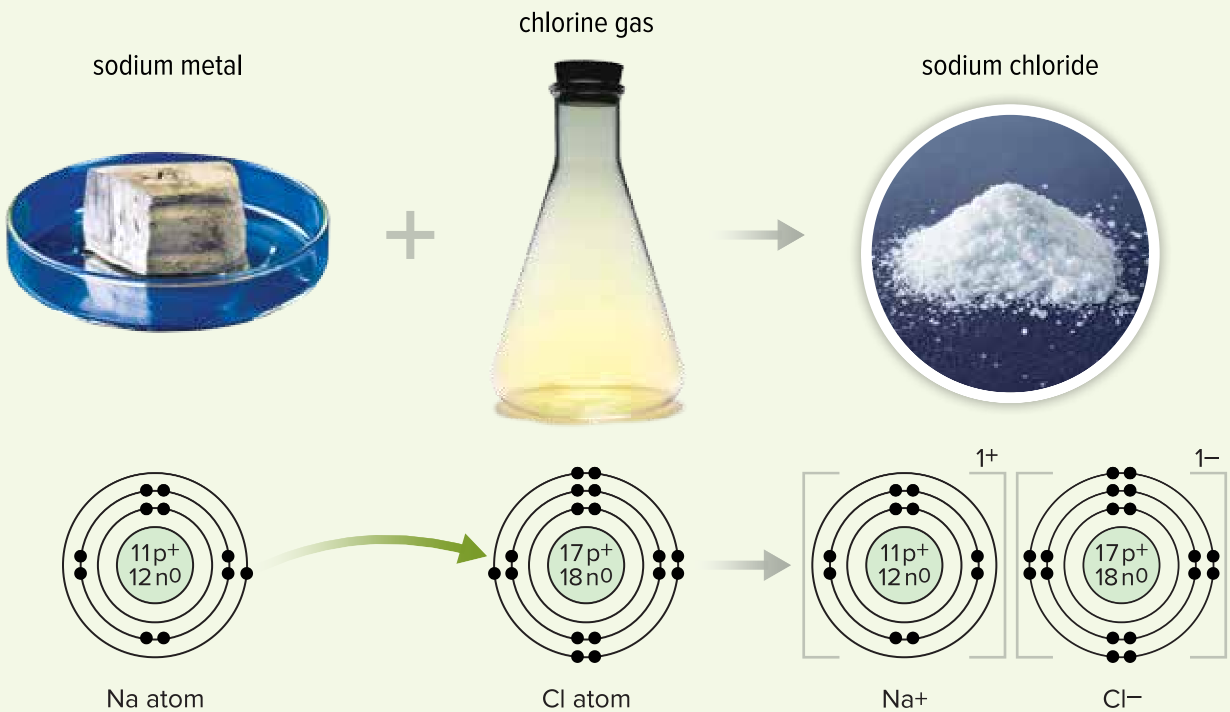
Formation of Ionic Compounds

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

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

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

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



Activity

Patterns in Ion Formation

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

11 1+
Na
sodium
23.0

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

The Structure of Ionic Compounds

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

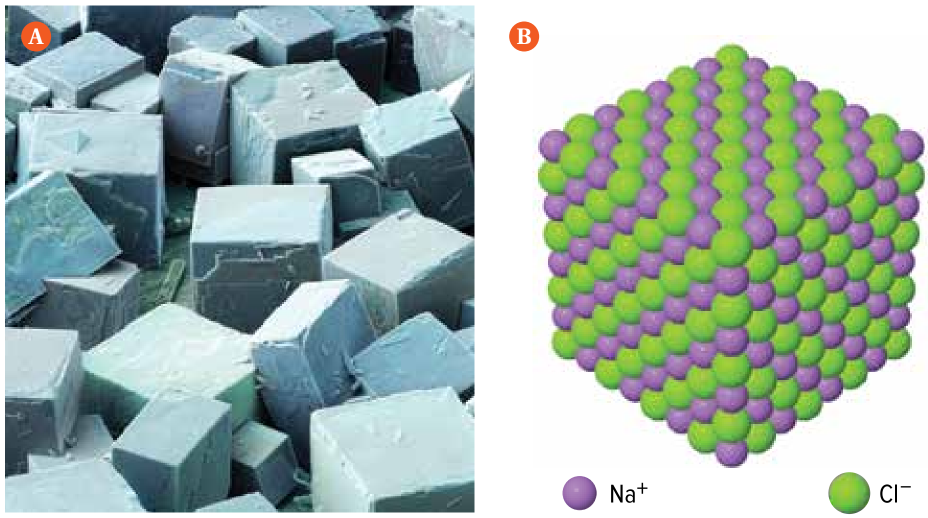


Figure 2.24 A This image shows the cubic structure of sodium chloride crystals. Each crystal contains millions and millions of sodium ions and chloride ions. B Sodium chloride crystals consist of sodium and chloride ions arranged in a repeating pattern. **Sodium chloride is made of charged particles,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

Properties of Ionic Compounds

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

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

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

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

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

A Distilled water does not conduct a current.

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

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

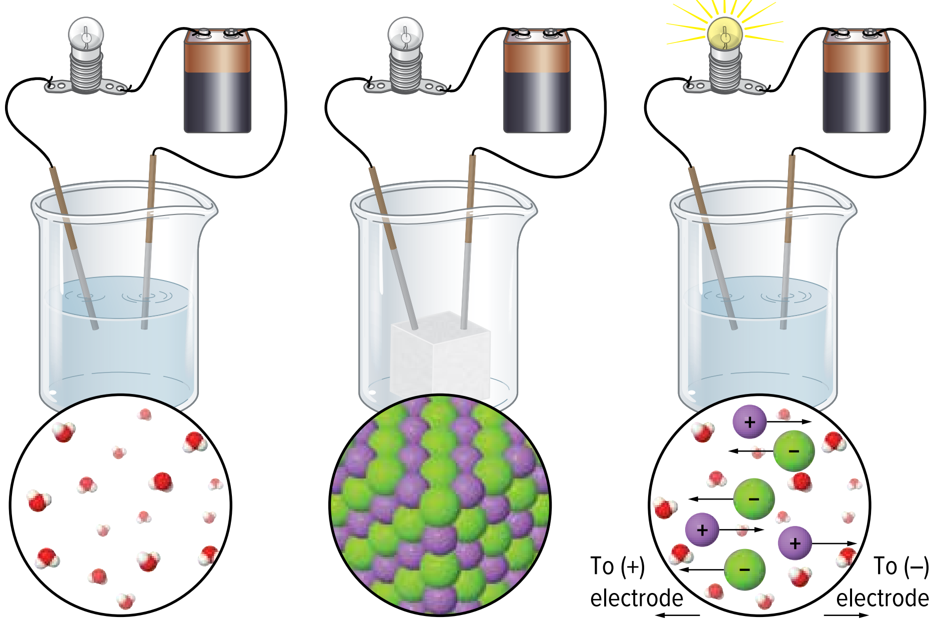
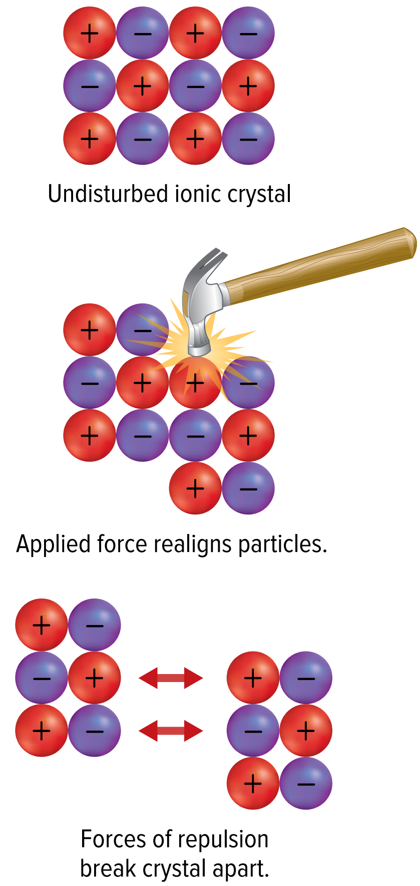


Figure 2.25 When a force strong enough to overcome the strong forces of attraction between oppositely charged ions is applied, ions with like charges come close together. They repel one another and the solid cracks.



Before you leave this page . . .

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

CONCEPT 3

Covalent compounds are made of molecules.

Activity

Model a Compound

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

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

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

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

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

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

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

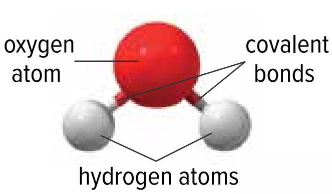
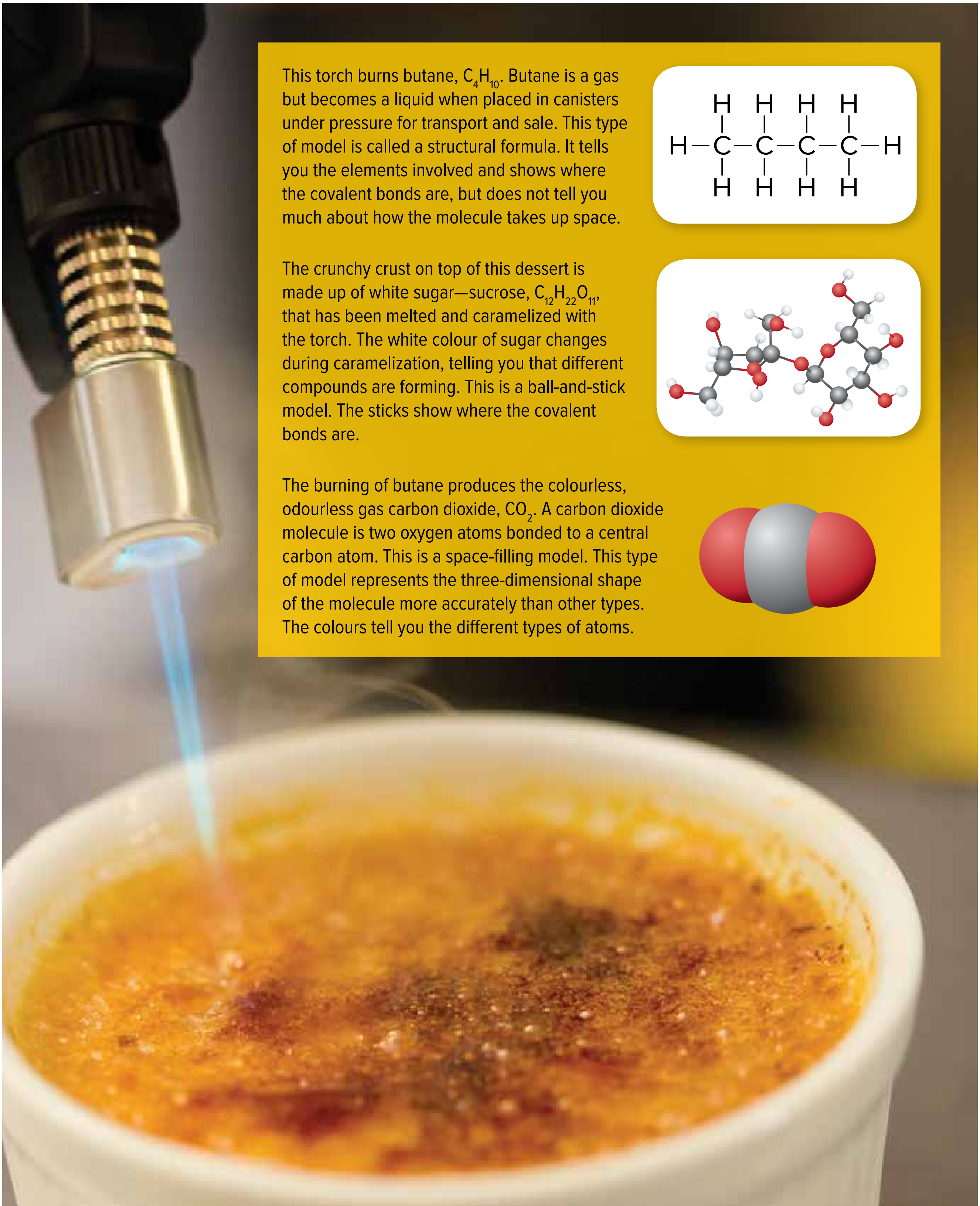


Figure 2.28 A covalent bond is like a tug-of-war in which both atoms attract the shared electrons.

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



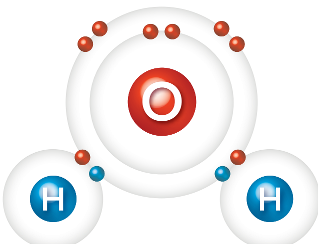
This torch burns butane, C_4H_{10}. Butane is a gas but becomes a liquid when placed in canisters under pressure for transport and sale. This type of model is called a structural formula. It tells you the elements involved and shows where the covalent bonds are, but does not tell you much about how the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

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

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

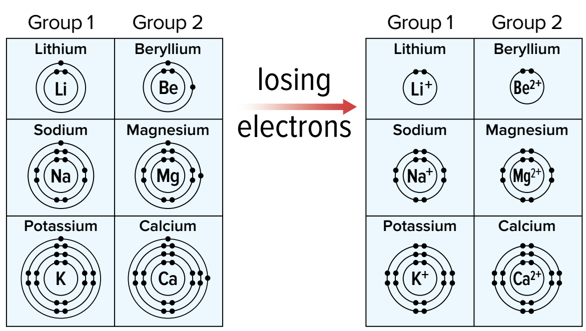
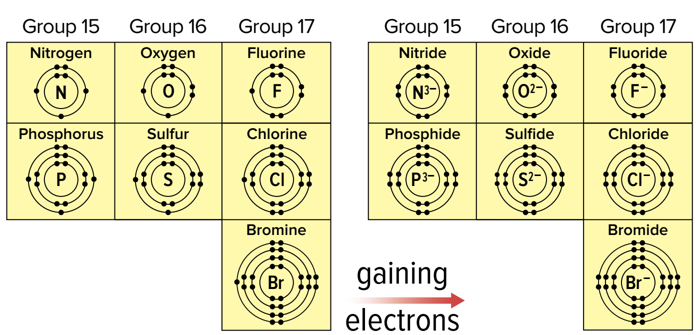
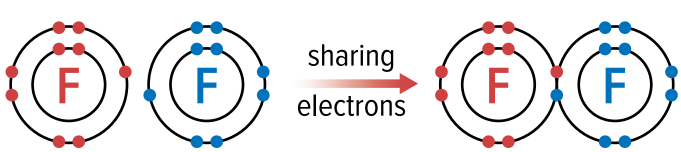
Achieving Stability by Sharing Electrons

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



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

Table 2.4 Three Ways That Atoms Become Stable

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

Properties of Covalent Compounds

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

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

Connect to Investigation 2-F on pages 152–153

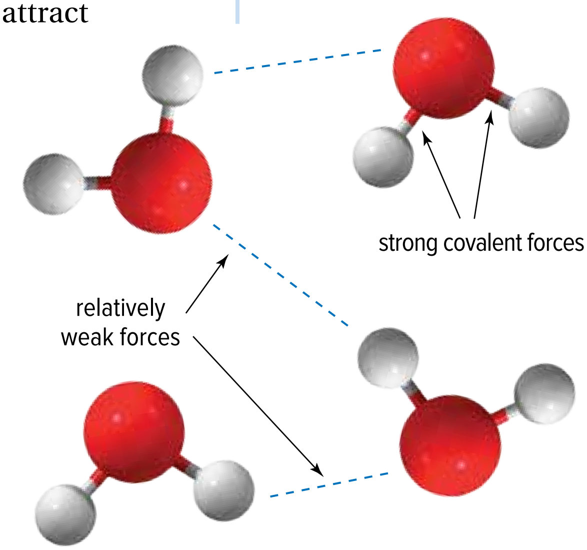


Figure 2.31 The forces that hold atoms together in molecules—covalent bonds—are very strong. Compared with these strong covalent bonds, the forces that hold one molecule to another in a liquid or solid are weak.

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

Before you leave this page . . .

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

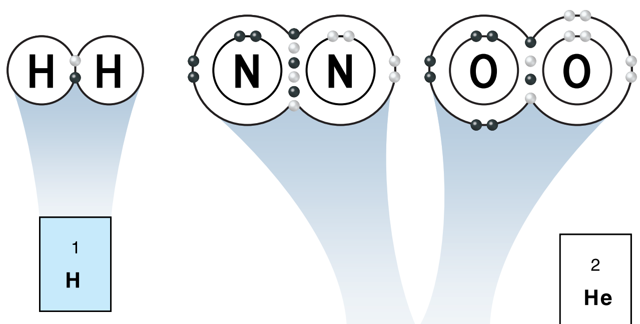
CONCEPT 4

Covalent bonding also occurs in elements and network solids.

Activity

Dare to Pair

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



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

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

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

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

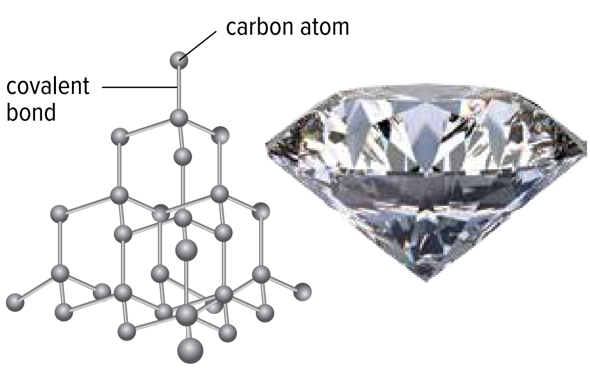
Network Solids

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

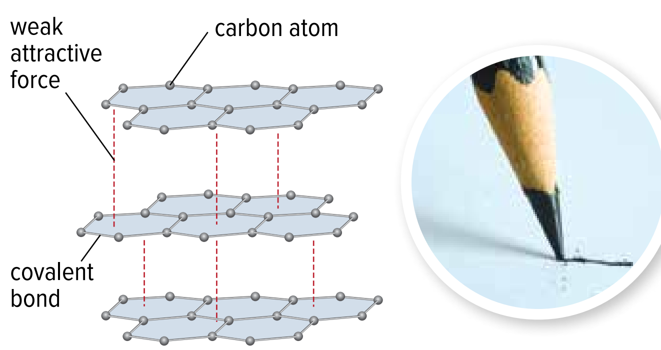
Figure 2.34 (A) Silicon dioxide, quartz, is a network solid. Its atoms are bonded into a regular, repeating structure by covalent bonds. This model shows a small part of the structure. In real quartz crystals like the ones shown in (B), billions of atoms are bonded together in this same repeating structure,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

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

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



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



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

Before you leave this page . . .

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

AT ISSUE

Is a synthetic diamond a real diamond?

What's the Issue?

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

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

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

Dig Deeper

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

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

Check Your Understanding of Topic 2.4

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

Understanding Key Ideas

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

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

3. Iodine, I_2, reacts with potassium, K, to form potassium iodide, KI. PA C
   a) What type of compound is formed? How do you know?
   b) Describe what is happening to the atoms of potassium and iodine and their electrons during bonding.

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

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

6. Seven elements exist as diatomic molecules. PA C
   a) List the seven elements.
   b) Why do the halogens exist as diatomic molecules while the noble gases do not?

7. Classify each of the following compounds as ionic or covalent. Briefly explain your answers. PA C
   a) lithium fluoride, LiF
   b) nitrogen triiodide, NI_3
   c) bromine dioxide, BrO_2
   d) barium iodide, BaI_2

Connecting Ideas

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

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

Making New Connections

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

Conductivity of Water Samples

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

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

INVESTIGATION

2-F

STRUCTURED INQUIRY

Skills and Strategies

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

Safety

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

What You Need

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

Properties of Ionic and Covalent Compounds

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

Question

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

Procedure

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

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

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

Crush/Hardness Test

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

Solubility Test

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

Melting Test

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

Conductivity Test

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

Process and Analyze

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

Evaluate and Communicate

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