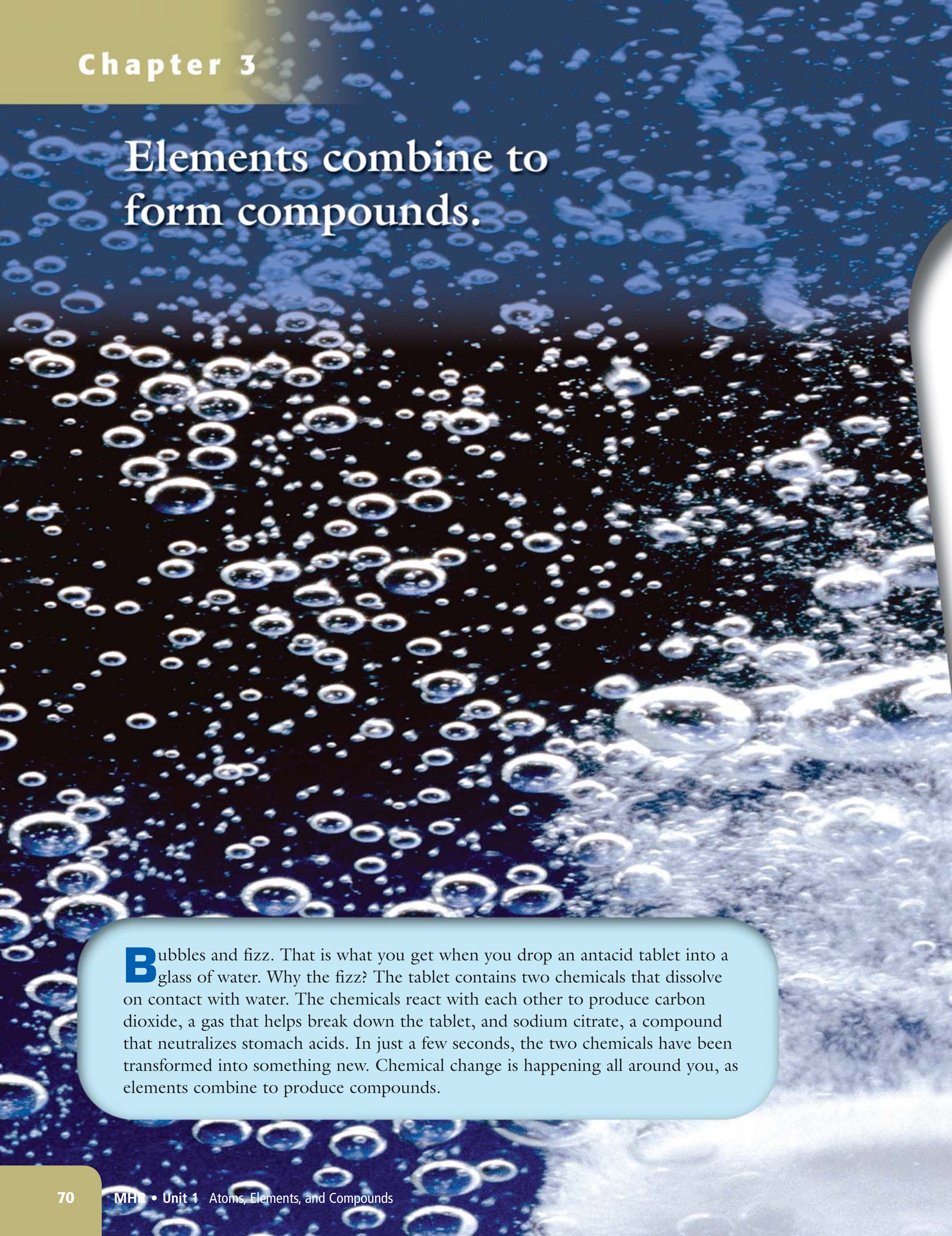
Chapter 3

Elements combine to form compounds.



Bubbles and fizz. That is what you get when you drop an antacid tablet into a glass of water. Why the fizz? The tablet contains two chemicals that dissolve on contact with water. The chemicals react with each other to produce carbon dioxide, a gas that helps break down the tablet, and sodium citrate, a compound that neutralizes stomach acids. In just a few seconds, the two chemicals have been transformed into something new. Chemical change is happening all around you, as elements combine to produce compounds.

FOLDABLES™
Reading & Study Skills

What You Will Learn

In this chapter, you will
- **distinguish** between covalent and ionic compounds
- **demonstrate** understanding of chemical names and formulas
- **differentiate** between chemical and physical change
- **describe** applications of chemical technology

Why It Is Important

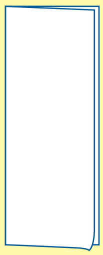
Almost everything in our world is made of compounds and mixtures of compounds. Our whole society depends on the production and wise use of compounds.

Skills You Will Use

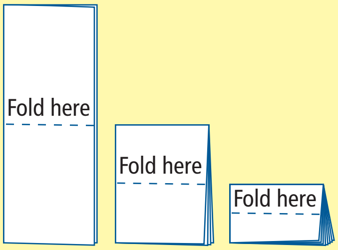
In this chapter, you will
- **write** chemical names given the chemical formulas
- **observe** changes in matter
- **communicate** your understanding of how substances are altered during chemical and physical changes

Make the following Foldable and use it to take notes on what you learn in Chapter 3.

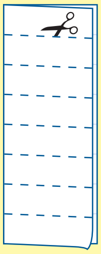
STEP 1 **Fold** a sheet of copy paper in half lengthwise (hot dog fold).



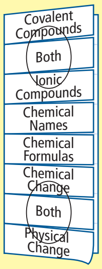
STEP 2 **Fold** in half to form two equal sections, fold in half again to form four equal sections, and in half again to form eight equal sections.



STEP 3 **Open** the folded paper and **cut** along the fold lines of one side only to form eight tabs.



STEP 4 **Label** the tabs as illustrated. **Draw** two circles as shown.



Similarities and Differences As you read this chapter, use your Foldable to find similarities and differences between covalent and ionic compounds and to differentiate between chemical and physical change.

3.1 Compounds

A compound is a pure substance made up of two or more kinds of elements that are chemically combined. When they combine, the atoms of one element make connections with the atoms of another element in very specific ways. Compounds are either covalent or ionic. In covalent compounds, atoms join together by sharing electrons. In ionic compounds, oppositely charged ions attract each other.

Key Terms

chemical bonds
covalent compound
ionic compound
molecule

Did You Know?

The elements magnesium and oxygen can combine to form a compound simply by being heated together. As they react, magnesium atoms give electrons to oxygen atoms. In the new compound, there is one ion of magnesium for every one ion of oxygen. As the photograph shows, this process releases a lot of light and heat.

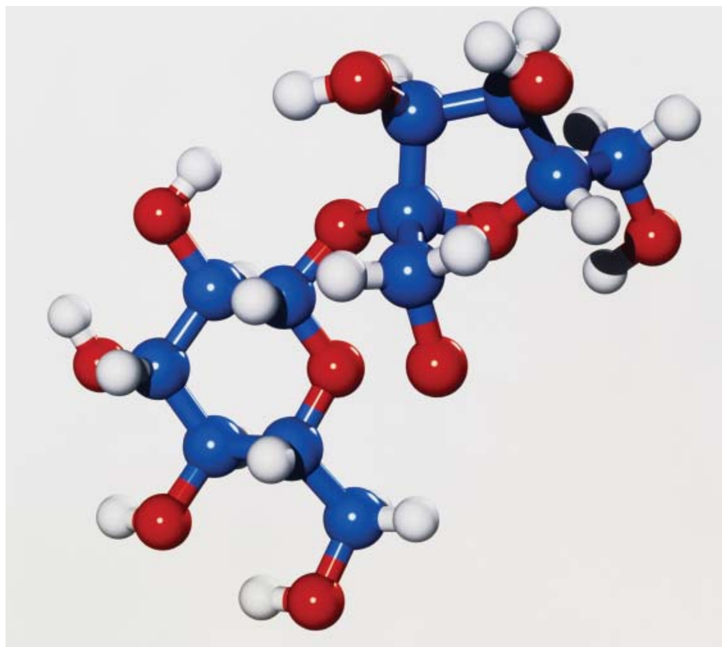


Figure 3.1 In this model of common table sugar ($C_{12}H_{22}O_{11}$), the carbon atoms are blue, oxygen atoms are red, and hydrogen atoms are white.

Imagine if you could see deep into the atomic structure of objects. You would see that a relatively simple substance, like table sugar, is composed of only one type of compound (Figure 3.1). A more complex example, such as a butterfly, might have between 100 000 and 1 million different kinds of compounds.

A compound is a pure substance made of more than one kind of element in which the atoms of the elements are joined together. By combining in compounds, elements can form more complex substances. Compounds form through **chemical bonds**, which are links between two or more atoms that hold the atoms together.

Although scientists have identified only some of the compounds that are found in nature, we do know that most compounds are one of two basic types: covalent compounds and ionic compounds.

3-1A The Synthesis of Oxygen

Find Out ACTIVITY

Hydrogen peroxide is a compound that can be made to quickly decompose into the element oxygen and another compound, water. In this activity, you will decompose hydrogen peroxide by adding a catalyst, which is a chemical that helps speed up the process.

Safety

- Hydrogen peroxide solution is corrosive.
- Be careful around open flames.
- Tie back long hair.

Materials

- liquid dish soap
- medium test tube in a test tube rack
- hydrogen peroxide (H_2O_2) solution
- candle and lighter
- scoopula
- potassium iodide (KI) crystals
- 2 wooden splints

What to Do

1. Put one drop of dish soap into the test tube.
2. Carefully pour hydrogen peroxide solution into the test tube until it is no more than $\frac{1}{3}$ full.
3. Light a candle.
4. Use a scoopula to obtain about 1 mL (the size of a pea) of potassium iodide (KI) crystals and drop them into the test tube. You should see bubbles appear, making a foam as oxygen collects in the soapy water.
5. Light a wooden splint and blow it out, leaving a few embers glowing.
6. Place the glowing splint in the soap bubbles, keeping it above the solution. Observe.
7. Repeat steps 5 and 6 several times.
8. Clean up and put away the equipment you have used.

What Did You Find Out?

1. What happens to a glowing splint when it is placed in pure oxygen?
2. If you have practised the burning splint test for hydrogen in a previous investigation, compare the test for oxygen with the test for hydrogen, using a lit splint for both.
   (a) How are the procedures different?
   (b) How do the observations differ?

Covalent Compounds

In **covalent compounds**, atoms combine by sharing electrons to form molecules. A **molecule** is a group of atoms in which the atoms are held together by sharing one or more pairs of electrons. The shared pairs of electrons form covalent bonds that keep the atoms together. Carbon dioxide and water are examples of covalent compounds.

The smallest possible particle of water is a single molecule. A water molecule is composed of two hydrogen atoms and one oxygen atom. The formula for water shows this two-to-one relationship using element symbols and a subscript number: H_2O. Figure 3.2 on the next page shows two common ways of modelling a water molecule. In both cases, the covalent bonds that hold the water molecule together are formed by the atoms of oxygen and hydrogen sharing pairs of electrons.

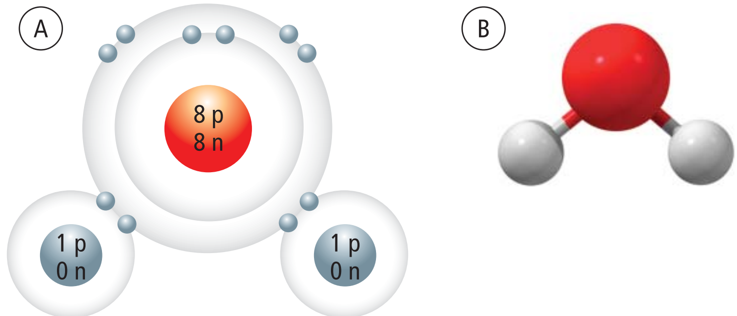


Figure 3.2 (A) A Bohr-Rutherford diagram of a water molecule. Notice how the eight electrons in the outermost energy levels of oxygen and hydrogen are being shared. (B) A ball and stick model of a water molecule. The sticks represent covalent bonds. Compare the formula H_2O with the ball and stick model in (B). The formula is composed of the symbols representing the elements on the periodic table, and subscripts are used to indicate how many atoms of each element are in the molecule. The white spheres represent the two atoms of hydrogen (H_2) in water; the red sphere represents the one atom of oxygen (O). Together these elements form water, H_2O.

When a jar is filled with water, trillions and trillions of molecules bump into each other constantly, but the atoms in one molecule are not bonded to atoms in other water molecules. Each molecule is separate from the other. Liquid water flows because the water molecules can move past each other.

Ionic Compounds

In **ionic compounds**, atoms gain or lose electrons to form ions. For example, table salt is made from the elements sodium and chlorine. When the atoms of each element first come together, both are electrically neutral. When they get close enough, an electron transfers from the sodium to the chlorine. This makes a positive sodium ion, Na^+, and a negative chloride ion, Cl^-. The process is shown in Figure 3.3. The chemical formula for table salt is NaCl.

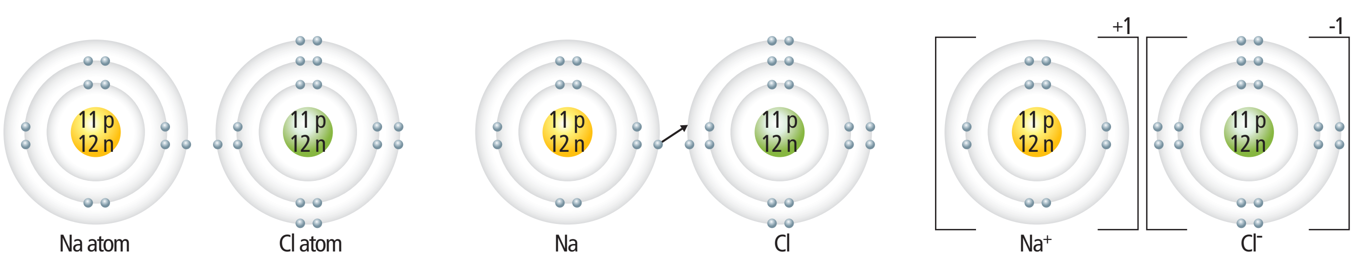


Figure 3.3 An ionic compound forms when an electron on a metal atom transfers to a non-metal atom, creating oppositely charged ions.

Figure 3.4 Striped and solid-coloured balls arranged alternately can model the arrangement of ions in an ionic compound.

Ionic compounds exist as a solid in the form of an ionic lattice. An ionic lattice is a repeating pattern of positive and negative ions. Ionic compounds can be modelled by arranging striped and solid-coloured balls. Striped balls would repel other striped balls. Solid-coloured balls would repel other solid-coloured balls. But striped balls and solid-coloured balls would strongly attract each other. What would happen to real balls if they had this property? They would assemble into a pattern that looks like Figure 3.4. This type of pattern happens when a crystal of table salt forms (Figure 3.5 on the next page). In an ionic compound, all the positive ions attract *all* the negative ions everywhere in the same crystal.

Comparing Ionic and Covalent Compounds

Water, H_2O, and carbon dioxide, CO_2, are both examples of covalent compounds that are formed when atoms share electrons. Covalent compounds are formed from non-metals only; they do not conduct electricity. Other physical and chemical properties vary greatly among covalent compounds. Covalent compounds may be solids, liquids, or gases at room temperature, and they have a wide variety of uses. Crude oil, which is a mixture of covalent compounds, is a cornerstone of Newfoundland and Labrador's economy (Figure 3.6).

Ionic compounds are formed between metals and non-metals through the transfer of electrons. All ionic compounds are solid at room temperature and have high melting and boiling points. Although they do not conduct electricity in the solid state, ionic compounds are electrically conductive when dissolved in water or melted. The term "salt" is often used to describe table salt, NaCl, but all ionic compounds can be called salts. Calcium carbonate, $CaCO_3$, is another example of a common salt (Figure 3.7).

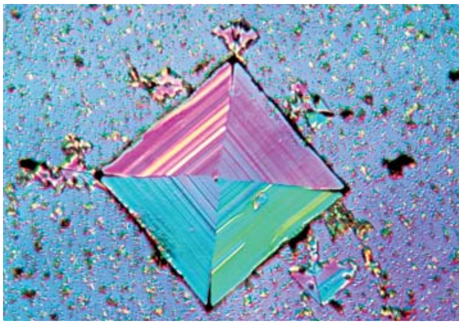


Figure 3.5 There is one sodium atom for every chlorine atom, so the chemical formula for table salt is NaCl.

Figure 3.7 Calcium carbonate, $CaCO_3$, is found in shells and can be used as both a calcium supplement and an antacid.

Figure 3.6 Crude oil is a mixture of covalent compounds. The Hibernia oil field off the coast of Newfoundland and Labrador is a source of crude oil.

Reading Check

1. Name two ways in which elements can combine into compounds.
2. How are atoms connected to each other in covalent compounds?
3. Give one example of a covalent compound.
4. Give one example of an ionic compound.
5. What needs to happen to atoms of different elements to allow them to combine to form an ionic compound?

3-1B The Synthesis and Detection of Copper

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Predicting
- Evaluating information
- Working co-operatively

Safety

- Wear protective clothing and safety goggles.
- Hydrochloric acid is corrosive.
- Be careful around open flames.

Materials

- solution of a copper compound
- two 400 mL beakers
- aluminum foil
- crucible tongs
- waste container
- dilute hydrochloric acid solution (HCl)
- wooden splint
- paper towel
- Bunsen burner

In this activity, you will transform a copper compound into pure copper metal. This is similar to how copper ore is processed into metallic copper in smelting operations.

Question

How can copper be extracted from a compound of copper, purified, and then tested to verify success?

Procedure

1. Carefully pour 100 mL of the copper compound solution into a 400 mL beaker.
2. Roll a 10 cm by 10 cm piece of aluminum foil into a small cylinder (try rolling it around a pencil). Place it in the solution. Wait and observe.
3. After the reaction has slowed down, or no longer than 5 min later, pick out the larger pieces of aluminum foil, using crucible tongs.
4. Add about 30 mL of water to the solution and let the brown solid settle for about 1 min. Pour the top part of the liquid into the other 400 mL beaker.
5. Pour the contents of the second beaker and all waste materials into the waste container provided by your teacher. Do not pour it down the sink.
6. Fill the first beaker again with water until it nearly reaches the top. Let the solids settle again for 1 to 2 min. Be patient. Then pour out the top part of the water. This process washes the copper, which is collecting at the bottom of the first beaker. Repeat until your copper product appears clean.
7. Add about 25 mL of hydrochloric acid solution (HCl) to the copper in the first beaker, and let it sit for about 1 min. Then begin rinsing again with water, as in steps 4 and 6. The hydrochloric acid helps to clean the copper.
8. Pour out as much water as you can, then pour your copper product onto a paper towel, using a wooden splint as needed to make the transfer.
9. Light a Bunsen burner. Pick up a piece of copper with crucible tongs and place it in the Bunsen burner flame. Observe the colour of the flame.
10. Wash all materials into the waste container provided.
11. Clean up and put away the equipment you have used.

Analyze

1. What colour changes showed that a chemical change took place when aluminum was placed in the copper compound solution?
2. Describe what happens when copper is placed in a Bunsen burner flame.

Conclude and Apply

1. List several properties of copper that distinguish it from another metal, such as iron.

Science Watch

Petroleum – The Solution or the Problem?

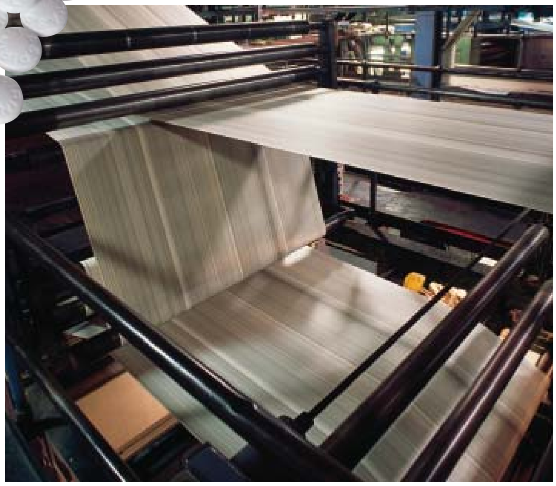
Most of the world's limited supply of petroleum is used as fuel. But did you know that petroleum is also used to make many of the products we use in our daily lives? It has replaced other natural compounds as a raw material in the manufacturing of clothing, medicine, ink, and many other products. Petroleum, however, is not a renewable resource. Scientists are now finding and developing substitutes to replace petroleum as a raw material in many products.

Replacing Natural Compounds with Petroleum Products

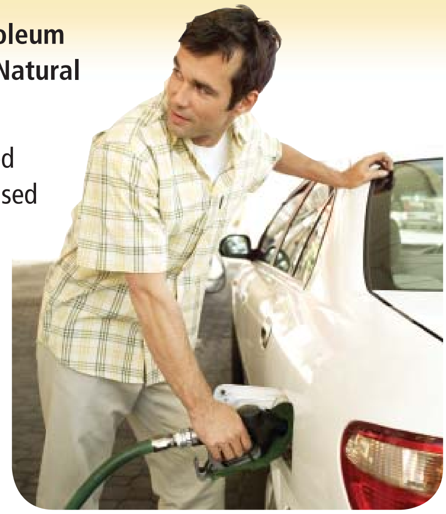
Much of our clothing is now made with synthetic fabrics instead of linen, silk, and other natural fibres. Popular synthetic fibres, such as polyester and nylon, are made from petroleum.

Aspirin was once made from a chemical found in willow tree bark. It is now made using petroleum.

The first printing inks were made from fruit or vegetable juices, and secretions or blood from animals such as squid, octopuses, and shellfish. Today, ink in our newspapers is made from carbon black, which is manufactured using petroleum.



Replacing Petroleum Products with Natural Compounds



Ethanol-based fuels are being used as a renewable alternative to petroleum. The use of ethanol, however, is controversial, partly because ethanol is produced using food crops, such as corn. Cropland that could be used to produce food is being used to produce ethanol instead. This can drive up the price of food or lead to a food shortage.

Some manufacturers are replacing plastics made from petroleum with renewable and biodegradable corn-based plastics.

Questions

1. What petroleum-derived products have been used as substitutes for natural materials?
2. What are some alternatives to petroleum-based fuels and plastics?
3. Why do you think there are so many existing products that are derived from petroleum?

Career Connect

Avalanche Technician

Tony Moore

Q. How did you become an avalanche technician?

A. I was employed as a surveyor when I had the opportunity to spend a day skiing and taking snow profiles with the local avalanche technician. I thought it was a pretty interesting line of work. I took courses from the Canadian Avalanche Association, earned a blasting certificate and a first aid certificate, and learned about weather and weather forecasting.

Q. What does an avalanche technician do?

A. We provide safety from avalanches for people. We forecast avalanche activity, implement closures, and do control work to make the slopes safe. By watching the weather and looking for weak layers of snow, we can recognize when we need to close a road and trigger an avalanche.

Q. How do you trigger an avalanche?

A. For my crew, the most common method is by dropping explosives out of a helicopter. However, helicopter work depends on good weather and daylight. On some of our roads, we have the option of launching explosives from the roadside. For shorter slopes, we detonate large charges at the side of the road that send a concussion wave through the air.

Q. Why is it important to know about chemistry?

A. We assemble the charges using ANFO (ammonium nitrate fuel oil) explosives just before we go up in the helicopter. The ANFO is detonated by a booster made of PETN (pentaerythritoltetranitrate). The booster is detonated by a safety fuse assembly that has a high-strength blasting cap. The helicopters we use are capable of carrying up to 10 charges. We use up to 30 charges per mission.

Q. How long does it take to prepare once you have determined a need for avalanche control?

A. It can take up to a couple of hours to get the entire crew in place and ready. We have the pilot, the avalanche technician, and an assistant in the helicopter. On the ground, we have a flag person at each end of the closure area stopping traffic, a person to check the closure area to make sure no one is on the road, and an equipment operator to clean avalanche debris from the road.

Questions

1. What are three things that avalanche technicians do?
2. What are the three ways avalanches are controlled?
3. Why would learning about compounds and chemical reactions be important to an avalanche technician?

Check Your Understanding

Checking Concepts

1. What is a chemical bond?
2. What are the two kinds of compounds?
3. How are two atoms held together in a covalent bond?
4. What causes ions to come together in an ionic compound?
5. Sodium chloride forms when one atom of sodium combines with one atom of chlorine. How does magnesium chloride form?
6. What is the chemical formula for table salt?
7. In a water molecule, how many atoms are connected to each
   (a) oxygen atom?
   (b) hydrogen atom?
8. Calcium bromide, $CaBr_2$, is an ionic compound.
   (a) In a crystal of calcium bromide, how many bromine atoms are there for every atom of calcium?
   (b) Do you expect that calcium bromide would be a solid, liquid, or gas at room temperature? Explain.

Understanding Key Ideas

9. A compound is formed from a metal and a non-metal. Is the compound ionic or covalent? How do you know?
10. A compound is a solid at room temperature and conducts electricity when dissolved in water. Is the compound ionic or covalent?
11. A compound is a gas at room temperature. Is the compound ionic or covalent?
12. A compound is a solid at room temperature. Describe a test that you could perform that would determine whether the compound is ionic or covalent.

Pause and Reflect

Many compounds are composed of just two elements. Below is a list of pairs of elements and the type of compounds they form. Suggest a pattern that could be used to determine whether lead and chlorine combine to form a molecular compound or an ionic compound.

First Element	Second Element	Type of Compound
sodium	oxygen	ionic
magnesium	sulphur	ionic
carbon	fluorine	covalent
sulphur	oxygen	covalent
iron	iodine	ionic
phosphorus	bromine	covalent

3.2 Names and Formulas of Simple Compounds

Each compound has a name that identifies the types of ions or atoms it contains. A compound also has a chemical formula that shows the ratio of the ions or atoms in the compound. In an ionic compound with only two elements, the first ion is always a positive metal ion and the second ion is always a negative non-metal ion. When naming ionic compounds, the suffix of the first ion is unchanged, while the suffix of the second ion is changed to "ide." In a covalent compound, the atoms are always non-metals. Prefixes are used to express the ratio of atoms in the molecule.

Key Terms

chemical formula
chemical name

Table salt, road salt, rock salt, and sea salt are all different types of salt (Figure 3.10). Table salt and road salt are pure substances. Their chemical names are sodium chloride and calcium chloride. Rock salt and sea salt are mixtures of many different compounds. Names are important to us: we name ourselves, our pets, and the places where we live. What is important in naming a chemical?

(A) Table salt (B) Road salt (C) Rock salt (D) Sea salt

Figure 3.8 Salt comes in many forms and can be made of different compounds.

3-2A What's in a Name? — Find Out ACTIVITY

A chemical name refers to only one compound and indicates the elements present. In this activity, you will work with a partner to discover what information can be collected from the names of ionic compounds.

What to Do

1. Working with your partner and the periodic table on page 50, review the ionic compounds listed below.
   lithium fluoride — zinc bromide
   calcium chloride — aluminum sulphide
   copper oxide
2. Look at where each element in the compound is located in the periodic table. What is one pattern that you can find in how these names are written?
3. Find one more pattern by examining the name of each ionic compound listed. The pattern has to apply to each chemical name.
4. Record any further patterns you or your partner observes.
5. Share your findings with the class.

What Did You Find Out?

1. What were two patterns you found in the chemical names of ionic compounds?
2. (a) What patterns and observations did you and your partner make that were similar to others in your class?
   (b) Which patterns and observations were different?
3. Explain how these patterns could be used as rules for identifying ionic compounds.

A Compound Has Both a Name and a Formula

All ionic compounds are composed of positive ions and negative ions. You can describe ionic compounds using a name or a formula. A **chemical name** indicates the elements present in the compound.

The chemical name

The International Union of Pure and Applied Chemistry (IUPAC) is a group that represents chemists around the world and is responsible for the rules for naming compounds. These rules are used in this textbook. The chemical name of an ionic compound always has two parts, one for each type of ion in it. The chemical name of table salt is sodium chloride.

- The first part of "sodium chloride" names the positive ion, sodium, which comes from the name of the sodium atom. The positive ion is *always* a metal in a compound containing two elements.
- The second part of "sodium chloride" names the negative ion, chloride. It is derived from a chlorine atom. The negative ion is *always* a non-metal in a compound containing two elements.
- The non-metal ion's name always ends with the suffix "-ide." In this example, "chlorine" changed to "chloride." The names and symbols for the non-metal ions are shown in Table 3.1.

Table 3.1 Names and Symbols of Non-metal Ions

Name	Symbol
fluoride	F^-
chloride	Cl^-
bromide	Br^-
iodide	I^-
oxide	O^{2-}
sulphide	S^{2-}
selenide	Se^{2-}
nitride	N^{3-}
phosphide	P^{3-}

Table 3.2 shows some examples of elements that can combine to form ionic compounds and the name of the resulting compound. Notice that the non-metal ion's name always ends in "-ide."

Table 3.2 Examples of Names of Ionic Compounds

Elements Forming the Ionic Compound	Name of the Ionic Compound
calcium and nitrogen	calcium nitride
potassium and oxygen	potassium oxide
lithium and chlorine	lithium chloride
magnesium and sulphur	magnesium sulphide
silver and fluorine	silver fluoride

Did You Know?

All medicines come with a list of ingredients like the one shown below. The list may include the chemical name, the generic or common name, or the trade or brand name of the medicine. Chemical names can be several lines long, so medicinal ingredients are often referred to by their common or generic name. The common or generic name allows you to compare products that have different brand names but contain the same active (medicinal) ingredient. Non-medicinal ingredients may improve the taste, act as filler to make the dose large enough to handle, or increase shelf life.

Did You Know?

Calcium carbonate, $CaCO_3$, is an example of an ionic compound. It is formed from the positive ion calcium (Ca^{2+}) and the negative ion carbonate (CO_3^{2-}). The carbonate ion contains both carbon (C) and oxygen (O). When an ion is made of more than one type of atom, it is called a polyatomic ion.

The chemical formula

The **chemical formula** of an ionic compound contains symbols to identify each ion. It also shows the relative numbers of ions in the compound. These numbers are shown by a subscript set to the right of the element symbol. Three examples are explained below:

- NaCl is formed from one sodium ion (Na^+) and one chloride ion (Cl^-)
- CaF_2 is formed from one calcium ion (Ca^{2+}) and two fluoride ions (F^-)
- Na_3P is formed from three sodium ions (Na^+) and one phosphide ion (P^{3-})

Rules for Writing the Names of Ionic Compounds

The rules for writing the name of an ionic compound from its formula are shown in Table 3.3, including two examples.

Table 3.3 Rules for Naming Ionic Compounds Containing Two Elements

Steps for Writing the Name	Examples	
	$MgBr_2$	Li_3N
1. Name the metal ion.	• The metal ion is Mg^{2+}. • The ion's name is given in the periodic table as magnesium.	• The metal ion is Li^+. • The ion's name is given in the periodic table as lithium.
2. Name the non-metal ion by ending the element name with the suffix "ide."	• The non-metal ion is Br^-. The element's name is bromine. • Changing the name to end with the suffix "-ide" gives "bromide."	• The non-metal ion is N^{3-}. The element's name is nitrogen. • Changing the name to end with the suffix "-ide" gives "nitride."
3. Write the name of the compound.	magnesium bromide	lithium nitride

Practice Problems

Write the names of the following compounds.

1. (a) AlI_3 (f) K_2S (k) CdS
(b) Na_2O (g) RbF (l) Ag_2O
(c) Mg_3P_2 (h) Ag_3N (m) Cs_2S
(d) AgI (i) KBr (n) CaI_2
(e) CaSe (j) Sr_3P_2 (o) NaF

Answers provided on page 510

Rules for Writing the Names of Covalent Compounds

The main difference between naming covalent and ionic compounds is that prefixes are used to indicate the number of each type of atom in a covalent compound. These prefixes are shown in Table 3.4. The rules for writing the name of a covalent compound from its formula are shown in Table 3.5, including two examples.

Table 3.5 Rules for Naming Covalent Compounds Containing Two Elements

Steps for Writing the Name	Examples	
	CO	$SiCl_4$
1. Name the first atom.	• The atom is C, carbon.	• The atom is Si, silicon.
2. Name the second atom by ending the element name with the suffix "ide."	• The second atom is O, oxygen. • Changing the name to end with the suffix "-ide" gives "oxide."	• The second atom is Cl, chlorine. • Changing the name to end with the suffix "-ide" gives "chloride."
3. Add prefixes to the atom names to indicate the number of each atom in the compound.	• There is one atom of carbon. • No prefix is needed if there is only one of the first atom. • There is one atom of oxygen. • The prefix for one is "mono-." • Adding the prefix "mono-" gives "monoxide."	• There is one atom of silicon. • No prefix is needed if there is only one of the first atom. • There are four atoms of chlorine. • The prefix for four is "tetra-." • Adding the prefix "tetra-" gives "tetrachloride."
4. Write the name of the compound.	• carbon monoxide	• silicon tetrachloride

Some covalent compounds are known by common names as well as by chemical names. For example, water is the common name for, H_2O. Other common names and formulas are shown in Table 3.6.

Table 3.4 Prefixes Used in Naming Covalent Compounds

Number of atoms	Prefix
1	mono (used only for the second atom)
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

Table 3.6 Common Covalent Compounds

Name	Formula
C_3H_8	propane
C_4H_{10}	butane
$C_6H_{12}O_6$	glucose
$C_{12}H_{22}O_{11}$	sucrose (sugar)

Practice Problems

Write the names of the following compounds.

1. **(a)** SO_3 **(b)** CCl_4 **(c)** N_2O_3
(d) P_2O_5 **(e)** C_4H_{10} **(f)** SiO_2

Reading Check

1. Explain how to name an ionic compound.
2. How does naming differ for ionic and covalent compounds?
3. What information is given in the chemical formula $CaCl_2$?

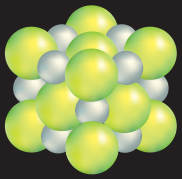
NATIONAL GEOGRAPHIC

VISUALIZING SALT

The salt you use every day comes from both the land and the sea. Some salt can be mined from the ground in much the same way as coal, or salt can be obtained by the process of evaporation in crystallizing ponds.

MINING SALT Underground salt deposits are found where there was once a sea. Salt mines can be located deep underground or near Earth's surface in salt domes. Salt domes form when pressure from Earth pushes buried salt deposits close to the surface, where they are easily mined.

EVAPORATION PROCESS Workers fill evaporation ponds with salt water, or brine. They move the brine from pond to pond as it becomes saltier through evaporation. (Red-tinted ponds have a higher salt content.) The saltiest water is then pumped from evaporation ponds into crystallizing ponds, where the remaining water is drained off. In the five years it takes to produce a crop of salt, brine may move through as many as 23 different ponds.



Unit cell of sodium chloride (NaCl)

TABLE SALT Raw sodium chloride is washed in chemicals and water to remove impurities before it appears on your dining-room table as salt. Iodine is added to table salt to ensure against iodine deficiency in the diet.

SALT MOUNDS When the crystallizing ponds are drained, the result is huge piles of salt, like these on the Caribbean island of Bonaire.

Check Your Understanding

Checking Concepts

1. (a) How many parts are there in the name of an ionic compound?
(b) What does each part describe?

2. (a) How many parts are there in the name of a covalent compound?
(b) How are prefixes used in naming covalent compounds?

3. How can you tell if a compound is ionic or covalent by looking at the chemical formula?

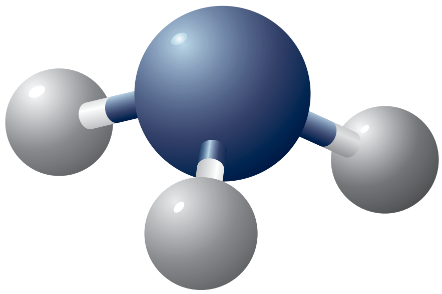
4. Complete the following table.

Name of Ion	Symbol
nitride	
	O^{2-}
fluoride	
	P^{3-}
sulphide	
chloride	
	Na^{+}
	Mg^{2+}

Understanding Key Ideas

5. Write the name or formula of the following compounds.
(a) LiBr
(b) NaI
(c) K_2S
(d) MgF_2
(e) Al_2O_3
(f) Ca_3N_2
(g) N_2S_4
(h) BF_3
(i) NO_2
(j) PBr_5
(k) SiF_4

6. The molecule shown below, NH_3, is known by the common name "ammonia". What is its chemical name, according to the IUPAC rules given in this text?



7. Identify the following compounds as ionic or covalent.
(a) sodium chloride
(b) magnesium sulphide
(c) carbon tetrafluoride
(d) silicon disulphide
(e) lithium nitride

8. Write the formula of the following covalent compounds.
(a) water
(b) sucrose (sugar)
(c) diphosphorus pentoxide
(d) carbon dioxide

Pause and Reflect

All ionic compounds have a chemical name and a chemical formula in accordance with rules of the IUPAC. It may be tempting to think that the formula is simply a shorter way of writing the chemical name. However, the two do not give exactly the same information about a compound. What information does the formula give about a compound that is not present in the name?

3.3 Physical and Chemical Changes

Chemical changes produce new substances with new properties. Physical changes, such as changes of state, do not change the identity of a substance. Both physical and chemical changes are accompanied by energy changes. Evidence that a chemical change has occurred includes colour change; production or consumption of heat, light, or sound; appearance of gas bubbles; formation of a precipitate; and/or the process is difficult to reverse.

Key Terms

chemical change
combustion
condensation
corrosion
dissolving
evaporation
freezing
melting
physical change
products
reactants

Change is a central part of our world. We change as we grow, first from childhood to adolescence, then to adulthood. Freshly baked cookies change from powders and liquids into tasty treats with fragrant aromas. Open a cellphone, and chemicals inside the battery immediately begin to move around and transform into new materials. These transformations cause electric currents to flow through the phone's computer chips. For anything to happen anywhere, there must be change.

There are different kinds of change. Some changes produce entirely different substances, such as when the wood in your campfire burns to produce smoke, ashes, and some gases (Figure 3.9). In other changes, only the appearance of the substance changes, such as when the ice cubes in your soft drink melt into liquid water or when you crush the ice cubes between your teeth to form tiny ice crystals. Is there anything that these processes have in common? As you may have already guessed, the answer is yes.

Figure 3.9 A fire is a dramatic example of rapid change that produces different substances.

All of cooking, all of electronics, and all the life processes that keep us alive happen in essentially the same way—through changes in the position and movement of atoms or groups of atoms. The world you see around you, the one in which you live, eat, sleep, play, and work, is built out of another world, equally complex, but on a scale a billion times smaller. This other world is occupied by an immense number of tiny atoms, ions, and molecules. The properties of matter and the way that matter changes result from the structures and interactions within the world of particles.

Did You Know?

Glow sticks contain chemicals separated into two compartments. When these are "cracked," the chemicals mix and begin a reaction that releases light energy. Because the reaction does not release a noticeable amount of heat, the light of a glow stick is called "cold light."

How do changes in the atomic world affect your everyday world? Consider ice cream (Figure 3.10). All ice cream flavours are determined at the atomic level. For example, ice cream flavour can change from spearmint to caraway just by moving a few carbon atoms around. The colour of a solution can turn from red to blue in an instant just by removing a hydrogen ion from a pigment molecule.

This section focusses on two kinds of change. Chemical changes produce new substances with new properties. Physical changes change the appearance of substances but do not produce new substances. Energy can be an important part of these changes. Some kinds of chemical changes absorb energy, whereas other kinds of chemical changes release it.

Figure 3.10 Changes that turn starting materials into wonderful flavours happen at the atomic level.

3-3A Magnesium in Dilute Acid

Find Out ACTIVITY

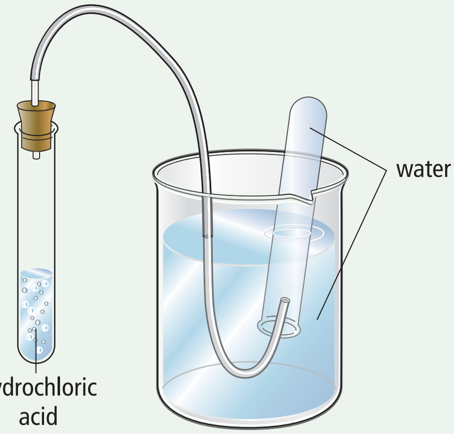
In this activity, you will observe a chemical reaction between magnesium metal and hydrochloric acid.

Safety

- Be careful around open flames.
- Tie back long hair.
- Acids are corrosive.

Materials

- one 400 mL beaker
- two medium-sized test tubes
- water
- rubber stopper fitted with glass tubing
- rubber tubing
- dilute hydrochloric acid solution
- magnesium metal
- paper towel
- test tube clamp or tongs
- candle and lighter or matches
- wooden splints



What to Do

1. Place about 300 mL of water in a 400 mL beaker. Fill a test tube with water and place it upside down in the beaker. Keep out the air as much as possible.
2. Slide the rubber tubing onto the glass tubing in the stopper and place the free end of the tubing in the mouth of the test tube that is inverted in the beaker of water.
3. Carefully fill a second test tube $\frac{1}{3}$ with hydrochloric acid.
4. Obtain a few pieces of magnesium metal from your teacher, who will place them on a paper towel.
5. Quickly place the magnesium into the test tube containing the hydrochloric acid and seal the test tube with the stopper. The gas produced is collected in the upside-down test tube.
6. After a few minutes, lift the test tube out of the water. Be careful to keep the mouth of the test tube pointed downward.
7. Hold the test tube with a test tube clamp. Using the matches and candle, light the wooden splint and bring it close to the mouth of the test tube. If the gas produced is hydrogen, the flaming splint will cause a "pop;" if it is oxygen, the flame will burn stronger.

What Did You Find Out?

1. What changes (state, colour, shape of solid, formation of gas) did you observe during the chemical reaction?
2. Classify the changes you observed as physical or chemical.
3. What is the likely identity of the gas that was produced?

Physical Changes

A chocolate candy left out in the Sun on a hot day gradually changes into a small puddle of warm, brown liquid. What kind of change has the candy undergone? In a **physical change**, the appearance of a substance may have changed, but the bonds holding the atoms together in molecules and ions have not been broken and new bonds have not been made.

Melting is an example of a physical change. It occurs when a substance changes from a solid to a liquid. This is what happened to the chocolate candy. This is also what happens when ice turns into liquid water. The water molecules begin to flow, but they do not break up into atoms. That is, the change is physical, not chemical.

All changes of state are physical changes. **Evaporation** is a change from liquid to gas; **condensation** is a change from gas to liquid; and solidification or **freezing** is a change from liquid to solid. Although all of these will change the appearance of a substance, they will not produce new substances. The same is true for other physical changes, such as ripping, cutting, grinding, and tearing.

Dissolving occurs when a solution is formed by mixing two substances together. It is usually considered to be a physical change as well. For example, when salt dissolves in water, the salt seems to disappear. However, this does not cause the individual sodium and chloride ions or the water molecules to change. The only reason we can no longer see the salt is that, once dissolved, the ions are separated from each other. This makes them too small to see.

Figure 3.11 The thundering bangs and spectacular colour changes of a fireworks display are evidence of chemical change taking place.

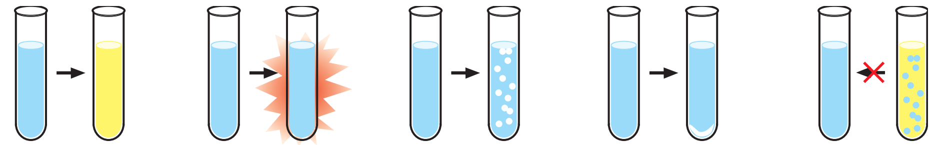
Evidence of Chemical Changes

A **chemical change** produces new substances with new properties, which might or might not be noticeable. In a chemical change, new bonds are formed while other bonds are broken.

You start with the substances that are going to react. These substances are called **reactants**. The new substances produced are called **products**. During a chemical change, the elements in the reactants will form new bonds with each other to create the products. All of the elements present in the reactants are present in the same quantities as in the products. In other words, elements are conserved during chemical change, but compounds are not.

Some chemical reactions are easy to spot. When fireworks explode, energy is released in the form of heat, light, and sound, as shown in Figure 3.11. Smoke may be produced, and you might be able to smell the reaction products. This does not guarantee that new products have been produced, but it is strong evidence for it. At other times, it can be harder to determine whether a chemical reaction has taken place.

Evidence that a chemical change has occurred includes:



Is it a chemical change when an apple ripens and eventually rots? Tests show that in fact many new chemicals are produced (Figure 3.12). This means that rotting involves many chemical reactions. As well, some of the water in the rotting apple may evaporate, which is a physical change. Chemical and physical changes often happen at the same time.

Figure 3.12 As it ripens and then rots, an apple gives off ethene gas (C_2H_4), a chemical messenger. This signals neighbouring apples to rot, too, which is why one bad apple spoils the bunch.

Reading Check

1. In a propane gas fireplace, the propane gas combines chemically with oxygen gas. The new substances made in this reaction are carbon dioxide and water. Identify the reactants and products in this reaction.
2. How could you distinguish between a chemical change and a physical one?
3. Identify each of the following processes as mainly a chemical change or a physical change: (a) boiling water, (b) tearing clothes, (c) rusting of a nail, and (d) lighting a match.

Suggested Activities

Design an Investigation 3-3B on page 91
Conduct an Investigation 3-3C on page 92

Applications of Chemical Changes

We can apply our knowledge of chemical change in many ways. Here are several examples.

Harnessing combustion

Combustion, also known as burning, is a chemical change that involves a substance combining with oxygen coupled with the release of a large amount of energy. The heat energy released by combustion can be used directly to provide heat and light, as with a candle or a campfire, or it can be used to produce other types of energy, including electrical energy or mechanical energy. The energy produced by burning gasoline in a car's engine is converted to mechanical energy to make the car move. Other types of fuel can be used to produce even greater amounts of mechanical energy, such as the blast that propels a space shuttle off of the launch pad (Figure 3.13).

Figure 3.13 Combustion occurs when liquid hydrogen fuel reacts chemically with liquid oxygen within the shuttle's rockets. Light, heat, and sound are produced, along with a stream of hot gases that expand and propel the shuttle upwards.

Explore More

Many deep-sea creatures living off our coast attract prey using a chemical reaction that produces a glow. Find out more about bioluminescence at **www.discoveringscience9.ca**.

Solving the corrosion problem

Corrosion is a process by which metals combine with oxygen. Steel ferries, such as the many that operate in Newfoundland and Labrador, undergo a rusting process. Rust is the product of a chemical reaction between iron and water containing dissolved oxygen gas. One way to protect the ships is to apply several coats of paint. Another method is to clamp blocks of zinc metal to the ferry's hull—the zinc tends to corrode instead of the iron.

While corrosion is often a problem, it is not always destructive. Aluminum corrodes easily, but this can be a benefit. The product of corrosion, aluminum oxide, forms a smooth, transparent surface that prevents further corrosion. It is as if the aluminum paints itself!

Some kinds of corrosion can even improve the appearance of a metal. The attractive blue-green "patina" that forms on copper contains several corrosion products, including copper sulphate. The Parliament Buildings in Ottawa are landmark buildings with blue-green copper roofs (Figure 3.14).

Figure 3.14 Corrosion has turned the roof of the Parliament Buildings in Ottawa from a red-brown to a blue-green colour.

Using chemical change for traditional products

Figure 3.15 Drying cod

First Nations, Metis, and Inuit people in Newfoundland and Labrador use many traditional chemical technologies for managing their natural resources. These include curing or tanning hides, making dyes and medicines from plants, and preserving food.

For the people of the East Coast, including the Innu Nation, Inuit, Mi'kmac, and Metis, the ocean is a major source of food. Fish is dried in smokehouses or salted and hung on racks in the sun (Figure 3.15). Drying and salting are physical changes that remove water from the cells of the fish and from any bacteria present. This prevents the bacteria from attacking the flesh. Smoke causes chemical changes in the meat that kill bacteria.

The chemical properties of blubber, the thick layer of fat found underneath the skin of whales and seals, have long been used by aboriginal peoples and commercial industries to perform a variety of chemical reactions. Not only is blubber a concentrated source of energy when consumed or used to produce lamp oil, but it can also be used in chemical reactions to produce soap.

3-3B Detecting Vitamin C in Fruit Drinks

Design an INVESTIGATION

SkillCheck

- Observing
- Measuring
- Controlling variables
- Communicating

Safety

- Iodine and starch solutions will cause stains.

Materials

- 1 vitamin C tablet, 100 mg or less
- mortar and pestle
- 100 mL beaker
- water
- stirring rod
- 10 mL graduated cylinder
- 2 medicine droppers
- iodine-starch solution
- up to 8 medium test tubes
- samples of fruit juices or other beverages

Inquiry Focus

We can use chemical change to help us analyze foods for the presence of certain chemicals such as vitamin C (chemical formula $C_6H_8O_6$). In this activity, you will test for the presence of vitamin C in different drinks.

Question

How can chemical changes be used to detect vitamin C in fruit drinks?

Procedure

Part 1 Preparing a Vitamin C Test Solution

1. Grind up the vitamin C tablet using a mortar and pestle.
2. Transfer the grindings to a 100 mL beaker. Use about 100 mL of water to wash the grindings out of the mortar and into the beaker. Stir the liquid in the beaker using a stirring rod. Some of the grindings will not dissolve but this is not a problem, because all of the vitamin C will be dissolved.
3. With the graduated cylinder, measure 5 mL of the iodine-starch solution into a test tube.
4. Use a clean medicine dropper to add some of your vitamin C solution to the iodine-starch solution. Keep adding until you see a definite change in colour. Note the colour change. This colour change indicates that the vitamin C solution has destroyed the iodine in the iodine-starch solution.
5. Do a similar test with water. Measure 5 mL of the iodine-starch solution into a clean test tube. Using a second, clean medicine dropper, add water to the iodine/starch solution. Note what happens. Remember that water does not contain vitamin C.

Part 2 Testing Fruit Juices for Vitamin C

6. Select several fruit drinks for testing. Choose some that advertise that they contain vitamin C and some that have an unknown vitamin C content.
7. With your group, plan a procedure to measure vitamin C in the fruit drinks. Make sure to plan a fair test. For example, it is important that the same amount of fruit drink is in each test tube so you can compare results.
8. Test the fruit drinks to see which have more vitamin C. You can do this by counting the number of drops needed to cause a colour change.
9. Clean up and put away the equipment you have used.

Conclude and Apply

1. Explain how a chemical change involving the chemical reaction of vitamin C with an iodine solution can produce a test for the presence of vitamin C.
2. List the fruit drinks in decreasing order of amount of vitamin C. Support your conclusions by presenting your experimental data along with your results.

3-3C Observing Changes in Matter

SkillCheck

- Observing
- Evaluating information
- Predicting
- Explaining systems

Safety

- Be careful around open flames.
- Handle chemicals safely. One chemical is mildly toxic.
- Tie back long hair.
- Wash your hands thoroughly after you finish the activity.

Materials

- calcium chloride solution ($CaCl_2$)
- two 100 mL beakers
- 100 mL graduated cylinder
- 3 small test tubes, labelled "Ca^{2+} ion," "Li^+ ion," and "unknown ion"
- 3 wooden splints
- lithium carbonate solution (Li_2CO_3)
- ring stand and ring
- funnel
- filter paper
- Bunsen burner
- crucible tongs
- felt pen
- test tube rack

Science Skills

Go to Science Skill 10 for information about how to fold a filter paper.

When the two colourless solutions in this activity are mixed, the chemicals react, producing a white solid and a second, invisible substance that stays dissolved. In this activity, you will separate the two new substances and identify them.

Question

What substances are produced in a chemical reaction?

Procedure

Part 1 Observing a Chemical Change and Separating Products

1. Measure 25 mL of calcium chloride solution into a 100 mL beaker using a graduated cylinder. Pour a small amount of this solution into a test tube labelled "Ca^{2+} ion." Put a wooden splint into the test tube and set the test tube aside.
2. Rinse the graduated cylinder with water. Measure 25 mL of lithium carbonate solution into the second beaker. Pour a small amount of this solution into a test tube labelled "Li^+ ion." Put a wooden splint into the test tube and set the test tube aside.
3. Pour the contents of the beaker containing lithium carbonate into the beaker containing calcium chloride. You should see a cloudy white solid form.
4. Set up a ring stand and funnel. Fold a piece of filter paper as directed by your teacher and place it in the funnel. Rinse the empty beaker with water and place it under the funnel to catch the liquid that passes through.

Step 4 (A) The fluted filter paper will sit high in the funnel. (B) Adding a drop of liquid will hold the paper in place.

5. Pour the contents of the beaker into the filter paper so that the liquid portion can drain through the filter. Not all of the product will drain into the funnel from the beaker.
6. One of your products will be a white solid trapped in the filter. The other product is still in solution and will slowly pass through the filter with the water. If time permits, you may wish to add a small amount of water to the funnel to wash the white product.
7. Once enough solution has passed through the filter to fill a small test tube, pour it into the remaining test tube, labelled "unknown ion."

Part 2 Flame Test to Identify Products

This test will work best in a darkened room.

8. Set up a Bunsen burner and adjust it so that it has a blue flame with very little yellow in it.
9. Place the wooden splint that has been soaking in the test tube labelled "Ca^{2+} ion" into the Bunsen burner flame. Note the colour. This is the colour of Ca^{2+}.
10. Place the wooden splint that has been soaking in the test tube labelled "Li^{+} ion" into the Bunsen burner flame. Note the colour. This is the colour of Li^{+}.
11. Using metal tongs, pick up some of the white product in the filter and heat it in the Bunsen burner flame. As you observe the colour, decide whether the white powder contains the Ca^{2+} ion or the Li^{+} ion. If your products are not completely separated, you may get a mixture of colours. Try to decide which colour is the main one.
12. Place the wooden splint that has been soaking in the test tube labelled "unknown ion" into the Bunsen burner flame. As you observe the colour, decide whether the unknown ion solution contains the Ca^{2+} ion or the Li^{+} ion.
13. Clean up and put away the equipment you have used.

Analyze

1. List the changes that you observed during the two parts of this investigation. Identify them as chemical or physical changes.
2. Explain your answer to question #1.

Conclude and Apply

1. Use your results to identify the white powder and the chemical present in the liquid that passed through the filter.

Wild, Weird, Wonderful

www Science

Simulating Core Chemicals

Studies of Earth reveal that it is formed in layers. At the centre is a ball of solid iron, and this is surrounded by a sea of molten iron several hundred kilometres thick. Measurements of earthquake energy tell us that 2900 km below our feet the molten iron gives way to rock, which floats on the hot, liquid iron. This rock is called the mantle. Because it is so hot, the rock is capable of flowing slowly, like molasses. Chemists would like to study the compounds at the boundary between the molten iron and the mantle. Since no one can get a sample of this material, the next best thing is to simulate it in the lab. All that is needed is a temperature of 5000°C and 1 million times the pressure at sea level. Does this sound impossible? It is not, if you have access to a laser, a couple of diamonds, and a creative mind.

You start with a diamond anvil small enough to hold in one hand. Diamond is the hardest substance known and can be cut to a tiny point. The points of two diamonds are pressed together against a tiny piece of iron and rock of the type known to exist deep inside Earth. (Material has come to the surface through volcanoes.)

When two diamonds are pressed together this way, a hand-turned screw, like a nutcracker, can reach high pressures. Pressure is force over area. Because the tips of the diamonds are so small, it does not take much force to generate a lot of pressure. Researchers squeeze the device, and a powerful laser blasts the point at which the diamonds touch. With a twist of the thumbscrew, the hottest, most pressurized bit of matter outside Earth's core is produced. The sample is then analyzed to see what is in it.

Researchers now believe that the types of chemicals produced in reactions at the boundary of Earth's core affect features we see at the surface. These include mountain ranges and even the slow movement of continents.

Two diamonds are used to press together samples of rock and iron at a pressure of 1 million atmospheres. A laser then heats the sample to 5000°C. Only the test samples heat up.

Checking Concepts

1. (a) Name two kinds of changes that can affect matter.
   (b) Which kind of change involves the formation or breaking of bonds between atoms?
   (c) Which kind of change involves only changes to the appearance of a substance?
2. (a) Give one specific example of a change that produces new substances with new properties.
   (b) Give one specific example of a change that affects a substance without producing a new substance.
3. When magnesium metal burns in oxygen gas it gives off a brilliant white light and a white solid forms.
   (a) Identify the reactants and the product.
   (b) What kind of chemical change is taking place?
4. A lot of chemistry happens in the kitchen, including, sometimes, the making of chili. A simple chili involves frying onions, garlic, and ground beef together and then adding chili spices, tomatoes, and kidney beans. Keeping this in mind, decide whether each step below is primarily a chemical change, a physical change, or a mixture of both.
   (a) thawing the ground beef
   (b) slicing onions, crushing garlic
   (c) your eyes watering when the onion is chopped (causes stinging)
   (d) frying onion slices, garlic, and ground beef in vegetable oil
   (e) stirring chili spices, tomatoes, and kidney beans into the fried portions
   (f) burning your tongue when tasting the chili
5. Each of the following involves both chemical and physical changes. Identify both in each of the examples.
   (a) flattening a flower in a book and leaving it there for a few weeks
   (b) leaving a banana to become overripe and then decompose
   (c) baking bread
6. Explain why liquid water changing into steam is a physical and not a chemical change.

Understanding Key Ideas

7. A white crystal is ground up into a fine powder and then placed into a beaker full of water. The mixture is stirred until the white powder disappears. After two weeks, the water is gone and a number of white crystals are crusted onto the inside of the beaker. Make a brief list of the physical changes that occurred.
8. Two clear and colourless solutions are mixed together and stirred. Almost immediately, the mixture becomes cloudy white. After a while, a white solid settles out on the bottom of the beaker. Explain whether the process of forming the white solid was likely to be a physical change or a chemical change.

Pause and Reflect

When mould grows on a tomato, many chemical and physical changes take place. Describe the process from ripe to mouldy, listing as many physical and chemical changes as you can.

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated compounds and chemical change. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with graphic organizers.) Use the following headings to organize your notes:

1. Distinguishing Between Ionic and Covalent Compounds
2. Names of Ionic Compounds
3. Names of Covalent Compounds
4. Comparing Chemical and Physical Change
5. Applications of Chemical Change

Checking Concepts

1. How is a chemical compound different from an element?
2. (a) State the names of the two basic kinds of compounds.
   (b) For each kind of compound, describe how the atoms of the elements join together.
3. (a) Draw a diagram of a water molecule.
   (b) Highlight the location of the covalent bonds.
   (c) How many hydrogen atoms and oxygen atoms are in one molecule of water?
4. List three properties of ionic compounds. Identify the properties as chemical or physical.
5. Name one property of covalent compounds. Identify the property as chemical or physical.
6. Are the ions in one part of an ionic lattice attracted to oppositely charged ions in another part of the same ionic lattice? Explain.
7. Provide the chemical formula for each of the following compounds:
   (a) calcium carbonate
   (b) table salt
   (c) propane
   (d) sucrose (sugar)
   (e) carbon dioxide
8. Decide whether a compound formed from each of the following combinations of elements will be an ionic compound or a covalent compound:
   (a) potassium and sulphur
   (b) lithium and chlorine
   (c) oxygen and fluorine
   (d) sulphur and bromine
   (e) copper and iodine
9. Why is it important that a chemical name refer to only one specific compound?
10. (a) Give the full name of the scientific organization IUPAC.
    (b) What important responsibility does it have?
11. Define the terms:
    (a) reactant
    (b) product
12. List five pieces of evidence of chemical change.

Understanding Key Ideas

13. Name the ionic compound that forms when each of the following pairs of elements are combined chemically:
(a) sodium and iodine
(b) magnesium and nitrogen
(c) zinc and oxygen
(d) aluminum and fluorine

14. Write the name of each of the following compounds:
(a) K_3N
(b) CaS
(c) Ag_2S
(d) AlP
(e) Sr_3N_2
(f) Cs_2O

15. Name each covalent compound:
(a) SO_2
(b) NF_3
(c) NO
(d) N_2O
(e) PCl_5
(f) NH_3
(g) N_2H_4
(h) PH_3

16. Identify each of the following as a chemical or physical change:
(a) melting
(b) combustion
(c) evaporation
(d) freezing
(e) corrosion
(f) dissolving
(g) fruit ripening

17. Describe what happens to elements and compounds during a chemical change.

Pause and Reflect

Chemical and physical changes often happen at the same time. What chemical and physical changes might be taking place as explosives are detonated to blast away rock during highway construction?

Unit Summary

1 Atomic theory explains the composition and behaviour of matter.

- Safe practice in the science laboratory includes knowledge of hazards, awareness of safe procedures during lab work, and the ability to take action to correct a problem. (1.1)
- Warning labels and WHMIS labels identify materials that are risky. (1.1)
- A physical property is anything you can observe about matter, such as density, state, colour, melting point, and boiling point. (1.2)
- A chemical property describes how a substance reacts with other substances.
- John Dalton proposed that matter is made of atoms, which can be part of an element (one kind of atom) or a compound (more than one kind of atom joined together). (1.3)
- Ernest Rutherford discovered the nucleus, a tiny dense region at the centre of an atom. (1.3)
- The nucleus was found to contain two types of particles: protons, which are positively charged, and neutrons, which have no electric charge; negatively charged electrons surround the nucleus. (1.3)
- Most of the volume of an atom is occupied by electrons, which exist in specific electron shells first discovered by Niels Bohr. (1.3)

2 Elements are the building blocks of matter.

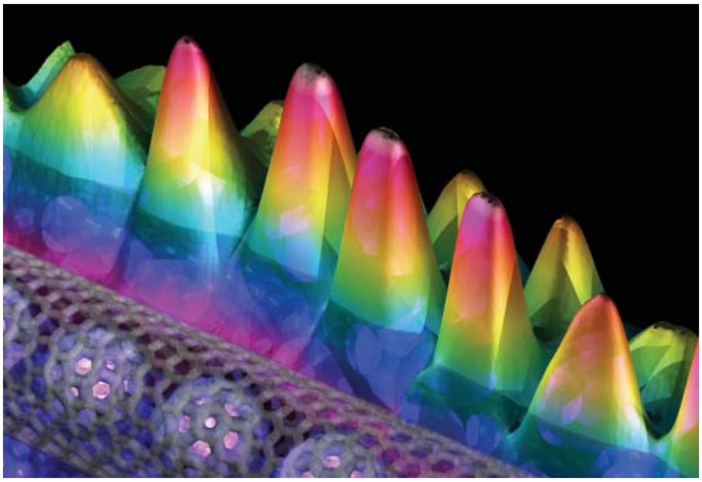
- Each element contains only one kind of atom, and all other forms of matter are made from combinations of these atoms and elements. (2.1)
- The periodic table lists the elements in order of increasing atomic number, arranged into families according to their properties. (2.2)
- In the periodic table, metals are on the left side, non-metals are on the right, transition metals are in columns 3-12 in the middle, and metalloids form a diagonal line near the right side. (2.2)
- Electrons can be pictured as arranged in shells in a specific pattern around the nucleus. (2.3)
- Elements in the same chemical family have the same number of electrons in their outermost occupied electron shell. (2.3)
- A Bohr-Rutherford diagram shows the arrangement of electrons in a specific pattern around the nucleus. (2.3)

3 Elements combine to form compounds.

- A compound is a pure substance made up of two or more different elements in which the atoms are connected. (3.1)
- In covalent compounds, atoms join together by sharing electrons, whereas in ionic compounds, oppositely charged ions attract each other. (3.1)
- In an ionic compound with only two elements, the first ion is always a positive metal ion, and the second ion is always a negative non-metal ion. (3.2)
- A chemical formula indicates the proportion of elements present in a compound. (3.2)
- When naming ionic compounds, the suffix of the first element's name is unchanged, while the suffix of the second element's name is changed to "ide". (3.2)
- When naming covalent compounds, prefixes are used to express the ratio of atoms in the molecule. (3.2)
- Chemical changes produce new substances with new properties, whereas physical changes do not change the identity of a substance. (3.3)

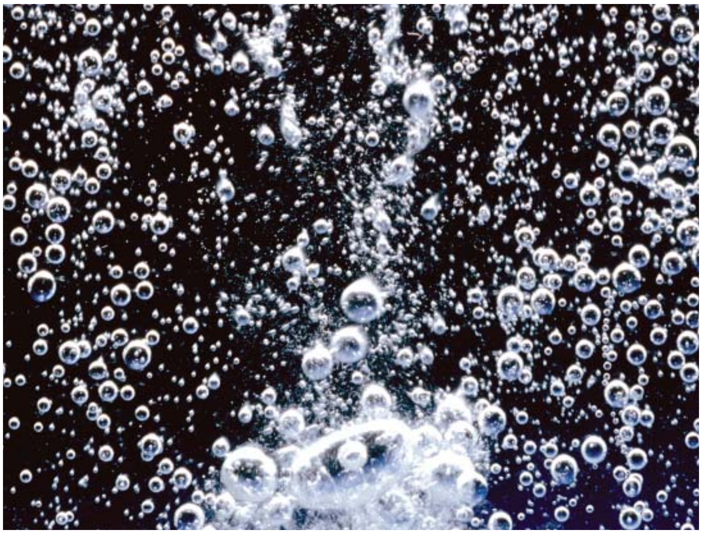
Key Terms

- atom
- atomic theory
- boiling point
- chemical properties
- combustibility
- conductivity
- density
- electron
- element
- hazard symbol
- mass
- matter
- melting point
- neutron
- nucleus
- physical properties
- proton
- reactivity
- state
- subatomic particle
- volume
- WHMIS



Key Terms

- alkali metals
- alkaline earth metals
- atomic mass
- atomic number
- Bohr-Rutherford diagram
- chemical family
- chemical symbol
- electron shells
- energy levels
- halogens
- metal
- metalloid
- noble gases
- non-metal
- period
- periodic table
- transition metals



Key Terms

- chemical bonds
- chemical change
- chemical formula
- chemical name
- combustion
- condensation
- corrosion
- covalent compound
- dissolving
- evaporation
- freezing
- ionic compound
- melting
- molecule
- physical change
- products
- reactants

Corroding Nails

Corrosion is an example of a chemical change. Commonly called rusting, this chemical change can cause damage to a variety of iron structures. The amount of corrosion depends on a variety of factors including the amount of moisture, amount of oxygen, and whether the iron has a protective coating. In this activity, you will investigate what conditions cause the most corrosion of an iron nail.

Problem

What conditions are required to cause the most corrosion of an iron nail?

Safety

- Do not mix any chemicals without your teacher's knowledge or approval.

Materials

- 6 test tubes
- 6 iron nails
- cotton ball
- water
- calcium chloride
- vegetable oil
- 2 stoppers
- test tube holder

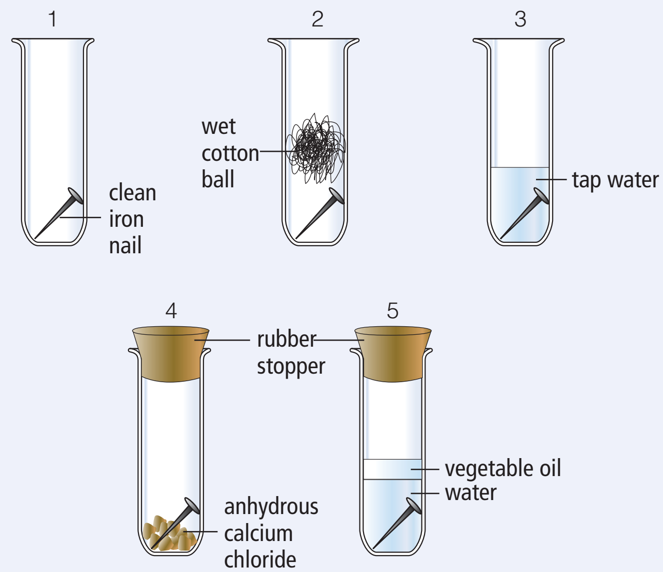
Criteria

- Develop a procedure to test the rate of corrosion in iron nails.
- Have your teacher approve your procedure.
- Safely carry out your experiment.
- Collect experimental data describing the conditions in each of the test tubes.
- Correctly identify and describe the appropriate conditions for corroding nails.

Procedure

1. With your group create a procedure to test six different conditions for testing how fast an iron nail will corrode. The illustration below shows the materials to be placed in each of the first five test tubes. Use the sixth tube to create your own set of conditions.

> **Science Skills**
>
> Go to Science Skill 2 for more information on designing and carrying out an experiment.



2. Have your teacher approve your procedure.
3. Perform your experiment.
4. Gather and record your data and observations.
5. Clean up and put away the equipment you have used. Follow your teacher's instructions for the disposal of chemicals.

Report Out

Create a report describing your experiment. The titles for each section in your report are:

1. Question Investigated
2. Outline of Procedure Used in the Experiment
3. Data Collected
4. Conclusion

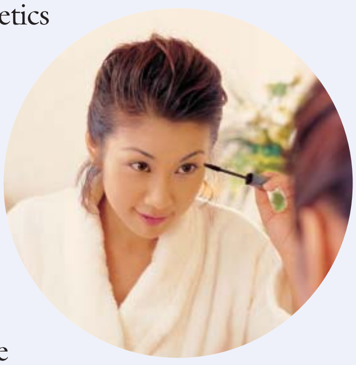
Chemical Contents

Chemicals are used in almost every aspect of our society. Many of the most important ones may be unfamiliar to you because you do not use them directly. Instead, you use the materials made from them, or they are included in complex mixtures such as a natural product, cosmetics, or paint. Using your research skills, find out more about one particular chemical. Some ideas to get you started are provided.

Natural products

Products described as "natural" contain chemicals from natural sources, such as from plants or the sea. For example, bearberry plants produce useful berries and leaves. The berries are a good source of protein and may be eaten raw. The leaves are used to make medicinal teas.

Cosmetics and hygiene products



Read the label of a cosmetics or hygiene product and you may be interested to discover the very long names of chemicals that have been used to create the product. How do the chemicals contribute to the effectiveness of the product? Why are they added?

Paints

What chemicals produce the rainbow variety of colours in paints? What chemicals help the paint to remain liquid in the container, go onto a brush or roller without dripping, spread evenly, add colour, dry quickly, and clean up easily?

Medicines

Acetaminophen is used in many flu and cold medications, as well as by itself, to reduce pain. Other chemicals used to reduce mild pain are ibuprofen and acetylsalicylic acid (aspirin).

Industrial chemicals

Benzene is a chemical that is too dangerous to handle without professional training. Yet it is used in the manufacture of gasoline, acetate overhead plastic sheets, and decaffeinated coffee.

Find Out More

Choose one particular chemical or product and research how it is made and what it is used for. Use the Internet (start at **www.discoveringscience9.ca**), encyclopedias, or interviews with experts to gather facts on your topic. Carefully record the information you discover. Be sure to note and credit the sources of your information.

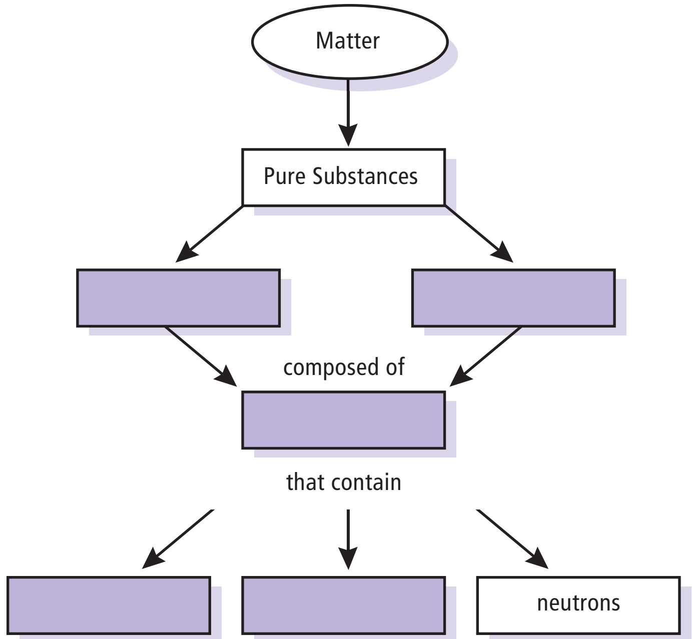
Report Out

1. Make a pamphlet including illustrations, photographs, and a description of the chemical you researched. Be sure to include a description of how the chemical is produced and what it is used for.
2. Create an Internet page that has links to sources for more information on the chemical you have researched. One link might be to a Material Data Safety Sheet (MSDS) that will explain safety hazards related to your chemical.

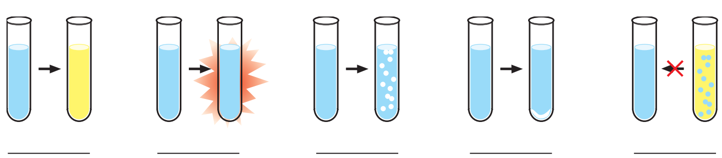
Unit Review

Visualizing Key Ideas

1. Copy and complete the following chart about matter.



2. Evidence for ____________ change:



Using Key Terms

3. State whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) Matter is anything that has volume and colour.
   (b) Physical changes involve changes in appearance without the formation of any new substances.
   (c) The three types of subatomic particles in an atom are the proton, the electron, and the nucleus.
   (d) Elements can be divided into metals, metalloids, and gases.
   (e) A group of elements that have similar chemical properties is called a period.
   (f) The atomic number counts the number of neutrons in the nucleus of an atom.
   (g) In a covalent bond, a pair of electrons is shared by two atoms.
   (h) A group of atoms joined by covalent bonds is called a molecule.
   (i) Corrosion is a chemical change that releases a large amount of heat energy.

Checking Concepts

1

4. Define a physical property.
5. What is the difference between a physical property and a chemical property?
6. What is the difference between a theory and a law? Provide an example of each.
7. (a) What are the subatomic particles that make up an atom?
   (b) Where is each kind of particle located in an atom?
8. (a) Where is most of the mass of an atom located?
   (b) What part of an atom makes up most of the volume?

2

9. (a) What is an element?
   (b) Approximately how many different elements have been identified?
10. List six properties typical of a metallic element.
11. List four properties typical of a non-metallic element.
12. Describe what elements in the same column of the periodic table have in common.
13. In the periodic table, what is another name for
    (a) a row?
    (b) a group?
14. List four pieces of information usually recorded in the periodic table for each element.
15. (a) What are the names of two families of metals in the periodic table?
    (b) What are the names of two families of non-metals in the periodic table?
16. How many electrons are in each of the occupied electron shells in an atom of magnesium (atomic number 12)?
17. How many electrons are in the outermost shell for:
    (a) elements belonging to the alkali metal family?
    (b) elements belonging to the halogen family?
18. Describe the arrangement of electrons that noble gases have that makes them very stable.

3

19. What is a compound?
20. (a) Name the kind of compound that involves the attraction of oppositely charged ions.
    (b) Name the kind of compound that involves atoms sharing a pair of electrons.
21. How are ionic compounds named?
22. What are the two kinds of ions in an ionic compound made from only two elements?
23. Explain the difference between a chemical change and a physical change.
24. What happens in a combustion reaction?

Understanding Key Ideas

25. (a) List five physical properties of water. For example, water has a low viscosity (because it flows easily). (**Hint:** You can use Table 1.1, on page 18, to help you.)
    (b) Identify each as either quantitative or qualitative.
26. Identify the following properties as qualitative or quantitative:
    (a) conductivity
    (b) reactivity
    (c) melting point
    (d) texture
    (e) solubility
    (f) colour
27. Why can sodium not be used to make a container in which to boil water? Provide at least two reasons.

28. Write a brief description of how the periodic table is organized.
29. In the periodic table, where are each of the following groups of elements located?
    (a) metals
    (b) non-metals
    (c) metalloids
30. Identify the following elements as a metal, nonmetal, or metalloid.
    (a) magnesium
    (b) chlorine
    (c) copper
    (d) silicon
    (e) a solid at room temperature, conducts electricity, a poor conductor of heat
    (f) a gas at room temperature
    (g) a solid at room temperature, is malleable
    (h) a liquid at room temperature, conducts heat and electricity
31. Using atomic theory, explain hydrogen's unique position on the periodic table and its unique chemical properties.
32. Determine the number of neutrons in an atom of carbon if its mass number is 12.
33. Determine the mass number of an atom of sodium if it has 11 neutrons.
34. How many protons and electrons are found in an atom with atomic number 25?
35. Which chemical family is composed of elements that have full electron shells?
36. Identify which of the following compounds are ionic and which are covalent.
    (a) calcium fluoride
    (b) carbon tetrafluoride
    (c) magnesium sulfide
    (d) diphosphorus pentoxide
    (e) silicon dioxide
37. Write the names of the following ionic compounds:
    (a) $NaCl$
    (b) K_2O
    (c) Cs_3P
    (d) CaF_2
    (e) $AlBr_3$
    (f) Mg_3N_2
38. Name the following covalent compounds.
    (a) CS_2
    (b) PF_3
    (c) N_2S_5
    (d) SiO
    (e) PCl_3
    (f) C_3H_8

Thinking Critically

39. (a) Draw a simple diagram of the Rutherford gold foil experiment. Using arrows, show how the alpha particles were deflected in different ways as they struck the gold.
    (b) What did this deflection indicate about the gold atoms?
40. Explain how mercury can be used to make an electrical switch that does not produce a spark.
41. Mendeleev predicted the properties of the element germanium before it was actually discovered. How was he able to do this?
42. (a) What is the atomic number of an element?
    (b) How do atomic numbers change as you move through the periodic table?
43. (a) Name the families in columns 1, 2, 17, and 18.
    (b) Provide two properties typical of elements in each family.
44. Refer to the outermost electrons to explain why the halogens (F, Cl, Br, I, and At) are all in the same chemical family.
45. Explain the difference between a covalent compound and an ionic compound.

Developing Skills

46. Draw a diagram of an atom containing seven protons, eight neutrons, and as many electrons as are needed to make the atom neutral. Show the correct number of electrons in each energy level.

47. Explain why sodium and chlorine atoms are extremely reactive but sodium ions and chloride ions are not. (**Hint:** Refer to the number of electrons in the outermost shell in your explanation.)

48. Use a periodic table to find the atomic number, atomic mass, and number of electrons for these elements.
(a) iron
(b) gold
(c) Cu
(d) U

49. Use a periodic table to identify these elements:
(a) the metal in period 4, column 2
(b) the non-metal in period 3, column 17
(c) the element that has an atomic number of 13
(d) the element that has an atomic mass of 19.0 amu

50. Draw a Bohr-Rutherford diagram of each of the following atoms: (a) O (b) F (c) Ne (d) Na (e) Mg

Pause and Reflect

Even though it is difficult to observe atoms without special equipment, the atomic theory describes our current understanding of atoms. How has the use of models helped explain the structure of atoms?