How Atoms Combine

7.3

Atoms combine to become more stable. The most stable elements in the periodic table are the noble gases (Group 18). They are considered to be the most stable because they have the maximum number of electrons in their outermost orbits: 2 for helium, 8 for the others. Elements that do not have the maximum number of electrons in their outermost orbits combine with other elements to obtain this maximum number of electrons. Atoms become more stable by gaining, losing, or sharing electrons, depending on whether the atoms are metals or non-metals.

Metals and Metals

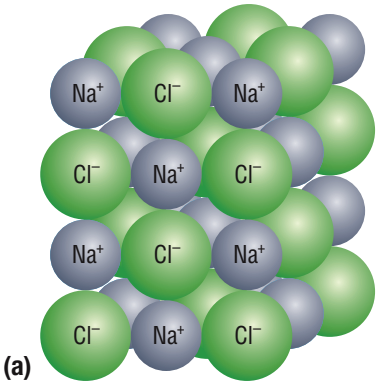
Metals form mixtures with other metals. These mixtures are called alloys (see Section 5.1). Alloys are created by melting two or more metals and then mixing these hot liquids. After mixing, the alloy is allowed to solidify. Alloys are different from compounds because in compounds, atoms join chemically in specific ratios to form pure substances. Alloys are solutions of metals. The metals do not combine chemically. For example, sterling silver is a solution of 92.5 % silver and 7.5 % copper (Figure 1).

Figure 1 Mixing copper with silver makes the silver harder but also causes it to tarnish.

To learn about becoming a metallurgical engineer,
GO TO NELSON SCIENCE

Metals and Non-Metals

In Section 7.1, you learned about ionic compounds. When metallic atoms such as sodium combine with non-metallic atoms such as chlorine, they usually form compounds made up of charged particles called ions. Metals lose electrons and become cations, whereas non-metals gain electrons and become anions. Cations and anions attract each other because they have opposite charges. When there are millions and billions and trillions of ions, the size of the new compound grows indefinitely. That is how you can grow large crystals of compounds such as sodium chloride (Figure 2).



(a)

(b)

Figure 2 (a) Ions of opposite charges attract each other to form layer after layer of closely packed ions. Eventually, a crystal emerges that has sharp edges, a unique shape, and a beautiful colour. (b) This rock salt, or halite, crystal is made up of sodium chloride.

Like many substances, ionic compounds have both chemical names and common names. To name an ionic compound such as sodium chloride, write the name of the metal first: sodium. Then write the name of the non-metal and change its ending to *–ide*: chloride. This is just one rule for naming ionic compounds. Other ionic compounds have different rules for naming. Table 1 lists a few ionic compounds, which consist of metals and non-metals. You will learn more about the rules for naming ionic compounds in Grade 10.

WRITING TIP

State the Hypothesis

A hypothesis answers a testable question and gives reasons for the answer. For example, if the question being investigated is "What substance is produced when magnesium reacts with oxygen?" your hypothesis should clearly state what substance would be produced, along with an explanation for why this substance is produced.

Table 1 Ionic Compounds

Chemical formula	Chemical name	Common name	Common use
NaCl	sodium chloride	table salt/road salt	food seasoning, melting road ice
KCl	potassium chloride	potash	fertilizer
CaO	calcium oxide	quicklime	masonry
NaOH	sodium hydroxide	lye	drain cleaner
$CaCO_3$	calcium carbonate	limestone, chalk	building materials
$NaHCO_3$	sodium hydrogen carbonate	baking soda	rising agent in baking
$Mg(OH)_2$	magnesium hydroxide	milk of magnesia	antacid
$CuSO_4$	copper(II) sulfate	bluestone	algicide and fungicide

TRY THIS WHEN MAGNESIUM MEETS OXYGEN

SKILLS: Predicting, Performing, Observing, Analyzing, Communicating

SKILLS HANDBOOK 3.B.3.

You have seen how iron, a metal, and oxygen, a non-metal, combine to form a single compound—rust. In this activity, you will combine another metal and non-metal pair: magnesium and oxygen. This reaction will occur quickly, producing a new substance while giving off a great deal of energy in the form of heat and light.

Equipment and Materials: **eye protection; lab apron; beaker; tongs; Bunsen burner; magnesium ribbon**

Do not look directly at the flame while the magnesium is burning. Wear eye protection and a lab apron. Tie back long hair and loose clothing.

1. Put on your eye protection and lab apron.
2. Obtain approximately 2–3 cm of magnesium ribbon. Record its appearance. Predict what will happen when magnesium is heated in the presence of oxygen.
3. Obtain a clean, dry beaker.
4. Light the Bunsen burner.
5. Hold the magnesium ribbon securely with the tongs and ignite it using the flame of the Bunsen burner. **Do not look directly at the bright flame.**
6. Hold the burning magnesium over the beaker so that any product formed falls into the beaker. Again, be careful not to look directly at the flame.
7. Observe and record the properties of the new substance formed.

A. Describe the physical properties of the magnesium ribbon that indicate it is a metal. K/U

B. Describe the physical properties of oxygen that indicate it is a non-metal. K/U

C. Describe the physical properties of the new substance formed.

D. Do the properties indicate that this new substance is a metal, a non-metal, or a compound? Give reasons for your answer. T/I

E. What is the element that usually takes part in all reactions in which burning occurs? K/U

F. Describe some applications of this reaction, which produces extremely bright light. A

Non-Metals and Non-Metals

When non-metallic elements combine with other non-metallic elements, they do not become ions by losing or gaining electrons the way metals and non-metals do. Instead, the nucleus of one atom forms a strong attraction to an electron in the outermost orbit of another atom and vice versa. A "tug of war" for electrons occurs, but neither atom wins. The two atoms share each other's electrons, resulting in a bond that holds the atoms together. A chemical bond that results from atoms sharing electrons is called a **covalent bond**. These bonded atoms form a molecule. Figure 3 shows the covalent bond between hydrogen atoms in a hydrogen molecule. Since the molecule contains two hydrogen atoms, its chemical formula is H_2.

covalent bond a bond formed when two non-metal atoms share electrons

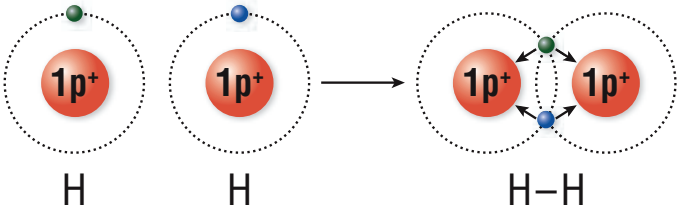


Figure 3 A covalent bond results from the sharing of electrons. In the hydrogen molecule (H_2), the two hydrogen nuclei simultaneously attract both electrons. The notation H–H can also be used to represent a hydrogen molecule. The dash between the bonding elements represents the covalent bond.

Two hydrogen atoms can also form covalent bonds with one oxygen atom to form a molecule of water. The chemical formula of this compound is H_2O. Table 2 shows some common molecules. As you can see, many of these molecules have both chemical names and common names. In the next section, you will build models of some of these molecules.

Table 2 Common Molecules

Chemical formula	Chemical name	Common name	Common use/Source
N_2	nitrogen	nitrogen	• approximately 80 % of air
O_2	oxygen	oxygen	• approximately 20 % of air
O_3	trioxygen	ozone	• in stratosphere • absorbs ultraviolet light
H_2O	dihydrogen oxide	water	• needed in all cells • home for aquatic organisms
CO_2	carbon dioxide	dry ice (solid)	• carbonated beverages • refrigeration
HCl	hydrogen chloride	muriatic acid (solution)	• stomach acid • important industrial chemical
CH_4	methane	natural gas	• fuel
NH_3	nitrogen trihydride	ammonia	• used in fertilizers and household cleaners
C_3H_8	propane	propane	• fuel
$C_2H_4O_2$	acetic acid	vinegar	• used in cooking • preservative
$C_9H_8O_4$	acetylsalicylic acid (ASA)	Aspirin	• blood thinner • for pain

IN SUMMARY

- Metals do not form compounds with other metals. They form solutions called alloys.
- Metals and non-metals combine by forming charged particles called ions. Oppositely charged ions attract and form ionic compounds.
- Table salt, or sodium chloride (NaCl), is an ionic compound.
- Non-metals share electrons with other non-metals to make molecules.
- The atoms in a molecule are held together by covalent bonds.
- An example of a molecule is water (H_2O). Each water molecule consists of two hydrogen atoms and one oxygen atom covalently bonded to each other.
- Many chemicals have both chemical names and names that are used in common language.

CHECK YOUR LEARNING

1. A piece of jewellery that is made of 14 kt gold contains 14 parts gold and 10 parts copper.
   (a) What percentage of the jewellery is gold? K/U
   (b) Do gold and copper form compounds in the jewellery? Explain. T/I
   (c) Explain how the 14 kt gold used to make jewellery is different from the element gold. T/I
2. Metal alloys are sometimes described as solid solutions. Explain how an alloy is similar to a solution such as salt water. K/U
3. Write the common name for each of the following compounds. T/I
   (a) sodium hydroxide
   (b) O_3
   (c) sodium chloride
   (d) CO_2
   (e) sodium hydrogen carbonate
   (f) calcium carbonate
4. Write the chemical name for each of the following compounds. T/I
   (a) muriatic acid
   (b) vinegar
   (c) potash
   (d) quicklime
   (e) milk of magnesia
   (f) natural gas
5. The formula for propane gas, often used as barbecue fuel, is C_3H_8. The formula for butane, the liquid fuel in cigarette lighters, is C_4H_{10}. The wax in a candle is a mixture of molecules, one of which is $C_{30}H_{62}$. K/U T/I
   (a) What is similar and what is different about the chemical compositions of these three substances?
   (b) Consider the physical states of these three substances at room temperature and discuss any relationship you see between the formula and physical state.
   (c) Are these three substances considered molecules? Give reasons for your answer.
6. Draw a Bohr–Rutherford diagram for each of the following molecules. T/I
   (a) fluorine (F_2)
   (b) hydrogen fluoride
7. Explain the difference between a molecule and an ionic compound. K/U
8. Describe how ions are able to form large crystals. A
9. In your own words, write a definition for "covalent bond." K/U
10. Explain what types of atoms tend to form covalent bonds. K/U