Section 2
Chemical Formulas and Equations

Key Concept Chemical formulas and chemical equations are used to show how atoms are rearranged to form new substances in a chemical reaction.

What You Will Learn
- Chemical formulas are a simple way to describe which elements are in a chemical substance.
- Chemical equations are a concise way to write how atoms are rearranged in a chemical reaction.
- A balanced chemical equation shows the law of conservation of mass.

Why It Matters
Chemical equations provide a great deal of information about chemical reactions.

Letters are used to form words. In the same way, chemical symbols are put together to make chemical formulas that describe substances. Chemical formulas are added together to describe a chemical reaction just as words make a sentence.

Chemical Formulas
All substances are formed from about 100 elements. Each element has its own chemical symbol, which is found in the periodic table. A **chemical formula** is a shorthand way to use chemical symbols and numbers to represent a substance. A chemical formula shows how many atoms of each kind of element are present in a molecule.

The chemical formula for water, shown in **Figure 1,** is H_2O. This formula tells you that one water molecule is made of two hydrogen atoms and one oxygen atom. The small 2 in the formula is a subscript. A *subscript* is a number written below and to the right of a chemical symbol in a formula. Sometimes, a symbol—such as O for oxygen in the formula for water—has no subscript. If there is no subscript, only one atom of that element is present. **Figure 1** has more examples of chemical formulas.

Figure 1 Chemical Formulas of Different Substances

Water	Oxygen	Glucose
H_2O	O_2	$C_6H_{12}O_6$
Water molecules are made up of 2 atoms of hydrogen bonded to 1 atom of oxygen.	**Oxygen** is a diatomic molecule. Each molecule has 2 atoms of oxygen bonded together.	**Glucose** molecules have 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen.
		

Writing Formulas for Covalent Compounds

If you know the name of a covalent compound, you can often write the chemical formula for that compound. Simple covalent compounds are usually composed of two nonmetals. The names of many covalent compounds use prefixes. Each prefix represents a number, as shown in **Table 1.** The prefixes tell you how many atoms of each element are in a formula. **Figure 2** shows you how to write a chemical formula from the name of a covalent compound.

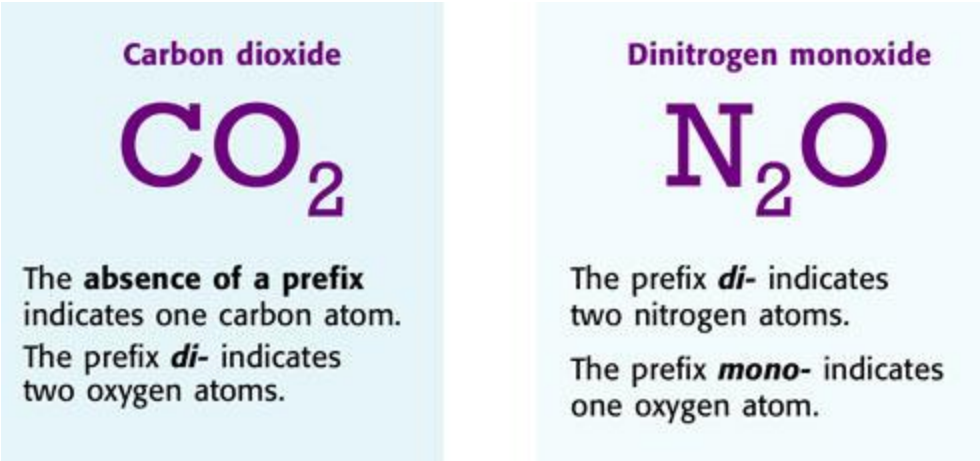

Figure 2 The formulas of these covalent compounds can be written by using the prefixes in the names of the compounds.

Table 1 Prefixes Used in Chemical Names	
mono- 1	hexa- 6
di- 2	hepta- 7
tri- 3	octa- 8
tetra- 4	nona- 9
penta- 5	deca- 10

Writing Formulas for Ionic Compounds

If the name of a compound contains the name of a metal and the name of a nonmetal, the compound is ionic. To write the formula for an ionic compound, make sure that the compound's charge is 0. In other words, the formula must have subscripts that cause the charges of the ions to cancel out. **Figure 3** shows you how to write a chemical formula from the name of an ionic compound.

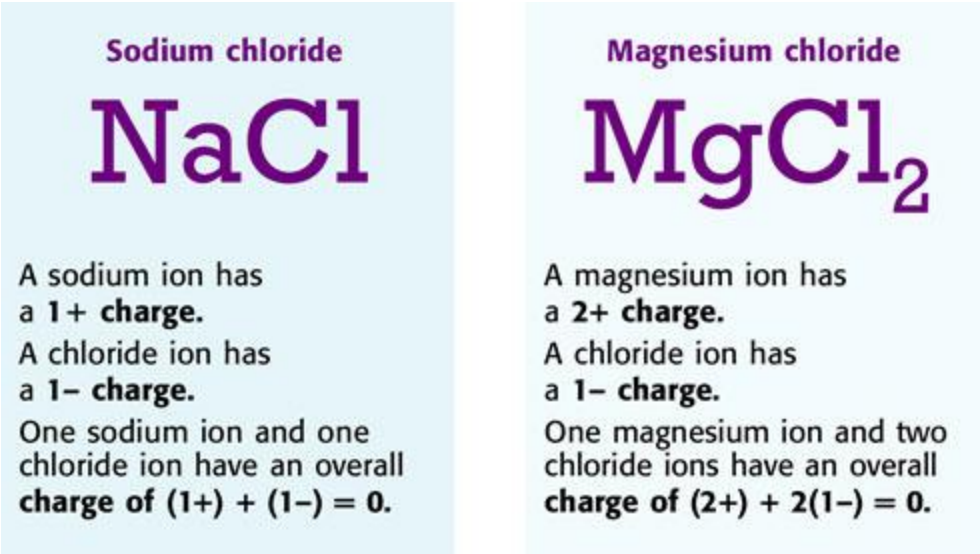

Figure 3 The formula of an ionic compound is written by using enough of each ion so that the overall charge is 0. **What is the group number from the periodic table for each of these elements?**

Standards Check Use the periodic table in the Appendix to write the formula for the covalent compound silicon tetrachloride.

Chemical Equations

Think about a piece of music, such as the one in **Figure 4.** The person writing the music must tell the musician what notes to play, how long to play each note, and how each note should be played. Words aren't used to describe the musical piece. Instead, musical symbols are used. The symbols can be understood by anyone who can read music.

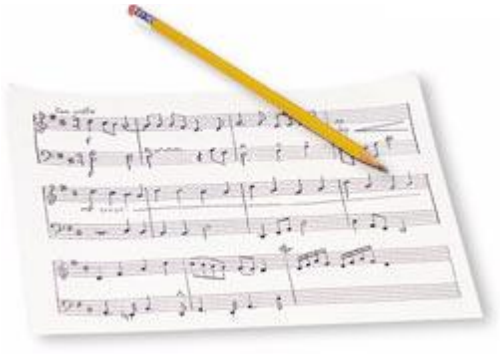

Figure 4 Like chemical symbols, the symbols on this musical score are understood around the world!

Describing Reactions by Using Equations

In the same way that composers use musical symbols, chemists around the world use chemical symbols and chemical formulas. Chemists use chemical equations to describe reactions. A **chemical equation** uses chemical symbols and formulas as a short way to describe a chemical reaction. Anyone around the world who understands chemical formulas can understand chemical equations.

From Reactants to Products

When carbon burns, it reacts with oxygen to form carbon dioxide. **Figure 5** shows how to write an equation to describe this reaction. The starting materials in a chemical reaction are **reactants.** The substances formed from a reaction are **products.** In this example, carbon and oxygen are reactants. Carbon dioxide is the product. The plus sign is used to show that the reactants are added together. The arrow points to the products.

Figure 5 The Parts of a Chemical Equation

Charcoal is used to cook food on a barbecue grill. When carbon in charcoal reacts with oxygen in the air, the primary product is carbon dioxide, as the chemical equation shows.

The formulas of the reactants are written before the arrow.

$$C + O_2 \rightarrow$$

A **plus sign** separates the formulas of two or more reactants or the formulas of two or more products.

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The Importance of Accuracy

The symbol or formula for each substance in an equation must be written correctly. For an element, use the proper chemical symbol. For a compound, use the correct chemical formula. An equation that has a wrong chemical symbol or formula will not describe the reaction correctly. Even a simple mistake can make a huge difference, as **Figure 6** shows.

Figure 6 Examples of Similar Symbols and Formulas

Co

Cobalt The chemical symbol for the element cobalt is Co. Cobalt is a hard, bluish gray metal.

CO

Carbon Monoxide The chemical formula for the compound carbon monoxide is CO. Carbon monoxide is a colorless, odorless, and poisonous gas.

C

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pound c
Carbon
odorless

Why Equations Must Be Balanced

Atoms are never lost or gained in a chemical reaction. They are just rearranged. Every atom in the reactants becomes part of the products. When writing a chemical equation, make sure that the total number of atoms of each element in the reactants equals the total number of atoms of that element in the products. This process is called *balancing* the equation.

Balancing equations comes from the work of a French chemist, Antoine Lavoisier (lah vwah ZYAY). In the 1700s, Lavoisier found that the total mass of the reactants was always the same as the total mass of the products. Lavoisier's work led to the **law of conservation of mass.** This law states that mass is neither created nor destroyed in chemical and physical changes. This law means that the total mass of the reactants is the same as the total mass of the products. So, a chemical equation must show the same numbers and kinds of atoms on both sides of the arrow even though the atoms are rearranged.

Standards Check Why must the number of atoms of each element remain the same in a chemical equation?

How to Balance an Equation

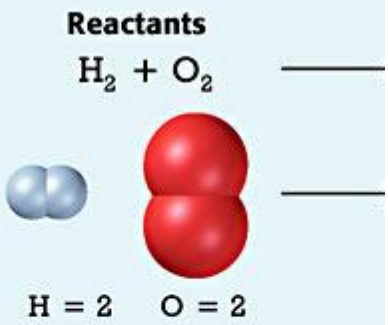
You must use coefficients (KOH uh FISH uhnts) to balance an equation. A *coefficient* is a number that is placed in front of a chemical symbol or formula. For example, 2CO represents two carbon monoxide molecules. The number 2 is the coefficient.

For an equation to be balanced, all atoms must be counted. So, you must multiply the subscript of each element in a formula by the formula's coefficient. For example, $2H_2O$ contains a total of four hydrogen atoms and two oxygen atoms. Only coefficients—not subscripts—are changed when balancing equations. Changing the subscripts in the formula of a compound would change the compound. **Figure 7** shows you how to use coefficients to balance an equation.

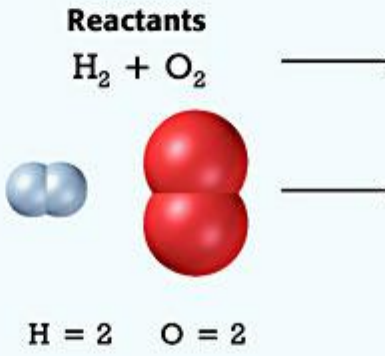
Figure 7 Balancing a Chemical Equation

Follow these steps to write a balanced equation for $H_2 + O_2 \longrightarrow H_2O$.

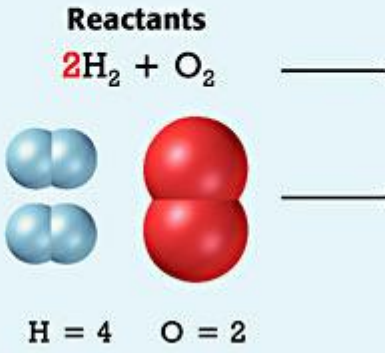
1 **Count the atoms** of each element in the reactants and in the products. You can see that there are fewer oxygen atoms in the product than in the reactants.



2 **To balance the oxygen atoms,** place the coefficient 2 in front of H_2O. Doing so gives you two oxygen atoms both in the reactants and in the products. But now there are too few hydrogen atoms in the reactants.



3 **To balance the hydrogen atoms,** place the coefficient 2 in front of H_2. But to be sure that your answer is correct, always double-check your work!



Standards Check If you see $4O_2$ in an equation, what is the coefficient?

Section Summary

- A chemical formula uses symbols and subscripts to describe the makeup of a compound.
- Chemical formulas can often be written from the names of covalent and ionic compounds.
- A chemical equation uses chemical formulas, chemical symbols, and coefficients to describe a reaction.
- A balanced equation has the same numbers and kinds of atoms on each side of the equation.
- A balanced equation shows the law of conservation of mass: mass is neither created nor destroyed during ordinary physical and chemical changes.

Chapter Summary

The Big Idea

Substances undergo chemical reactions, which form new substances whose properties differ from the properties of the original substances.

Section 1

Forming New Substances

Key Concept During chemical reactions, atoms rearrange to form new substances that have different properties than the original substances had.

- Four signs that indicate that a chemical reaction may be taking place are a change in color, the formation of a gas, the formation of a precipitate, and a change in energy.
- Chemical reactions produce new substances whose chemical and physical properties differ from the properties of the original substances.
- In a chemical reaction, chemical bonds break and atoms rearrange.
- Chemical reactions absorb or release energy.

The properties of the substances made by a chemical reaction differ from the properties of the starting substances.

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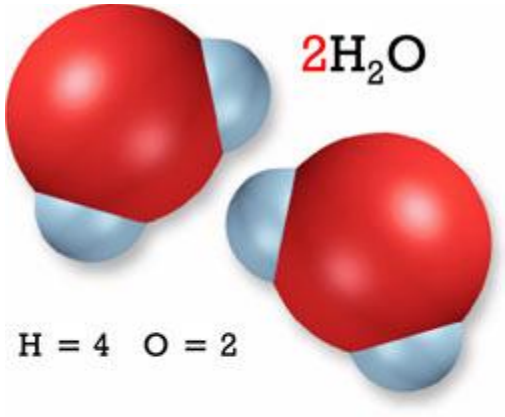

The subscripts in a chemical formula tell you how many atoms of each element are in the substance. A coefficient is used before a formula to balance a chemical equation.

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