Name _____ Class _____ Date _____

CHAPTER 2 Chemical Reactions

SECTION 2

Chemical Formulas and Equations

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are chemical formulas?
- What are chemical equations?
- How do you balance a chemical equation?

National Science Education Standards

PS 1b

What Is a Chemical Formula?

We use letters to form words. We put words together to form sentences. In the same way, scientists use symbols to form chemical formulas that describe different substances. They put chemical formulas together to show how chemical reactions happen.

Remember that substances are formed from different elements. Each element has its own chemical symbol. You can find the symbol for an element in the periodic table. Scientists combine the symbols for different elements when they write chemical formulas. A **chemical formula** shows which elements are found in a substance. It also shows how many atoms of each element are found in a molecule of the substance. ☑

In order to learn how chemical formulas work, let's look at an example. The chemical formula for water is H_2O. This formula means that a molecule of water is made of two hydrogen (H) atoms and one oxygen (O) atom.

The small 2 in the formula is a subscript. A *subscript* is a number that tells you how many atoms of an element are in a molecule. Subscripts are always written below and to the right of the symbol for an element. No subscript with an element's chemical symbol means the substance has only one atom of the element.

STUDY TIP

Ask Questions As you read this section, make a list of questions that you have. Talk about your questions with a small group. When you figure out the answers to your questions, write them in your notebook.

READING CHECK

1. Identify What are two things that are shown by a chemical formula?

_____

_____

_____

_____

Water

H_2O

Water A molecule of water contains 2 hydrogen (H) atoms and 1 oxygen (O) atom.

Oxygen

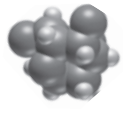
O_2

Oxygen A molecule of oxygen is made of 2 oxygen (O) atoms.

Glucose

$C_6H_{12}O_6$

Glucose A molecule of glucose cotains 6 carbon (C) atoms, 12 hydrogen (H) atoms and 6 oxygen (O) atoms.



Math Focus

2. Calculate How many oxygen atoms are in three molecules of water?

_____

FORMULAS FOR COVALENT COMPOUNDS

In many cases, the name of a covalent compound tells you how to write its chemical formula. This is because the names of many covalent compounds use prefixes. Prefixes represent numbers. For example, the prefix di- means "two." The prefixes tell you how many atoms of an element are found in a substance. The table below shows the meanings of different prefixes.

Critical Thinking

3. Apply Concepts Write the formula for the covalent compound whose name is phosphorus trichloride.

_____

Prefix	Number
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5

Prefix	Number
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

Carbon dioxide

CO_2

The ***absence of a prefix*** indicates one carbon atom.

The prefix ***di-*** indicates two oxygen atoms.

Dinitrogen monoxide

N_2O

The prefix ***di-*** indicates two nitrogen atoms.

The prefix ***mono-*** indicates one oxygen atom.

FORMULAS FOR IONIC COMPOUNDS

If the name of a compound contains the name of a metal and a nonmetal, the compound is ionic. To write the name of an ionic compound, make sure the compound's charge is 0. Therefore, the formula must have subscripts that cause the charges of the ions to cancel. The figure below shows some examples of how to name ionic compounds.

Math Focus

4. Identify What is the charge on the Fe ion in the ionic compound $FeCl_3$? Hint: find the charge of a chloride ion.

_____

Sodium chloride

$NaCl$

A sodium ion has a **1+ charge.**

A chloride ion has a **1– charge.**

One sodium ion and one chloride ion have an **overall charge of (1+) + (1–) = 0.**

Magnesium chloride

$MgCl_2$

A magnesium ion has a **2+ charge.**

A chloride ion has a **1– charge.**

One magnesium ion and two chloride ions have an **overall charge of (2+) + 2(1–) = 0.**

How Are Chemical Formulas Used to Write Chemical Equations?

Scientists use chemical equations to describe reactions. A **chemical equation** uses chemical symbols and formulas as a short way to show what happens in a chemical reaction. A chemical equation shows that atoms are only rearranged in a chemical reaction. No atoms are gained or lost in a chemical reaction. ☑

The starting materials in a chemical reaction are the **reactants**. The substances that form during the reaction are the **products**. In a chemical equation, the reactants and products are written using chemical formulas. Scientists use a plus sign to separate the formulas of two or more reactants or products. An arrow points from the formulas of the reactants to the formulas of the products.

READING CHECK

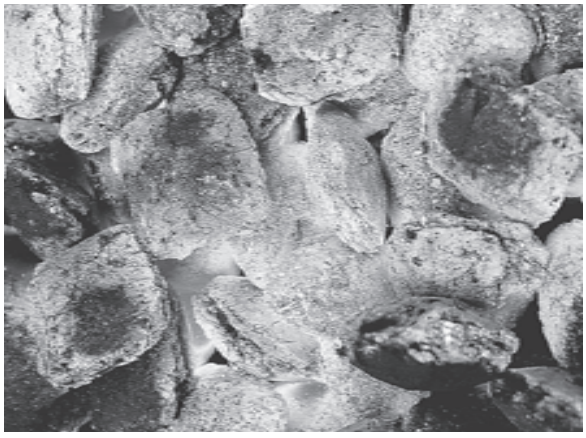
5. Define What is a chemical equation?

_____

_____

_____

_____



Carbon is the main element in charcoal. When charcoal burns, it reacts with oxygen in the air. The reaction produces heat, light, and carbon dioxide.

The formulas of the reactants are written before the arrow.

The formulas of the products are written after the arrow.

$$C + O_2 \longrightarrow CO_2$$

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

The **arrow,** also called the *yields sign,* separates the formulas of the reactants from the formulas of the products.

TAKE A LOOK

6. Identify List the reactants and the products of the reaction in the figure. Use chemical symbols and chemical formulas in your answer.

reactants: _____

products: _____

CHECKING SYMBOLS

When you write a chemical formula, it is important that you check to make sure that it is correct. If you use the wrong formula or symbol in an equation, the equation will not describe the correct reaction. Even a small mistake can make a big difference. ☑

As an example, consider the three formulas Co, CO, and CO_2. These formulas look very similar. However, the substances they represent are very different. Co is the symbol for the element cobalt, a hard, bluish-grey metal. CO is the formula for carbon monoxide, a colorless, poisonous gas. CO_2 is the formula for carbon dioxide, a colorless gas that living things give off when they breathe.

READING CHECK

7. Explain Why is it important to check to make sure that your chemical formulas are correct?

_____

_____

_____

_____

_____

Examples of Similar Symbols and Formulas

CO_2	CO	Co
The chemical formula for the compound **carbon dioxide** is CO_2. Carbon dioxide is a colorless, odorless gas that you exhale.	The chemical formula for the compound **carbon monoxide** is CO. Carbon monoxide is a colorless, odorless, and poisonous gas.	The chemical symbol for the element **cobalt** is Co. Cobalt is a hard, bluish gray metal.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with the properties or actions of substances

8. Explain How does a balanced chemical equation show the law of conservation of mass?

_____

_____

_____

_____

_____

CONSERVING MASS

The **law of conservation of mass** states that mass cannot be lost or gained during a chemical reaction. The total mass of the reactants in a chemical reaction is the same as the total mass of the products. You can use this law to help you figure out how to write a chemical equation.

During a chemical reaction, atoms are not lost or gained. Every atom in the reactants becomes part of the products. Therefore, in a chemical equation, the numbers and kinds of atoms in the reactants and products must be equal. In other words, the chemical equation must be balanced.

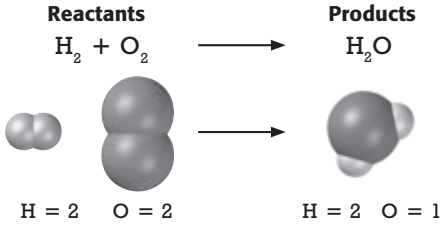
HOW TO BALANCE A CHEMICAL EQUATION

To balance an equation, you must use coefficients. A *coefficient* is a number that is placed in front of a chemical formula. For example, 2CO represents two carbon monoxide molecules. The number 2 is the coefficient. ☑

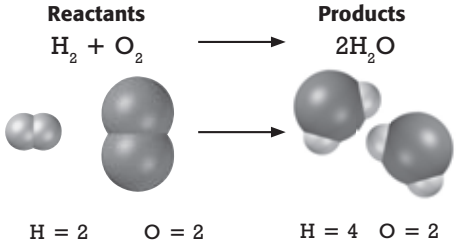
For an equation to be balanced, all atoms must be counted. So you must multiply the subscript for each element in a formula by the formula's coefficient. For example, $2H_2O$ contains a total of four hydrogen atoms and two oxygen atoms. Only coefficients, not subscripts, may be changed when balancing equations. The figure below shows you how to use coefficients to balance an equation. ☑

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

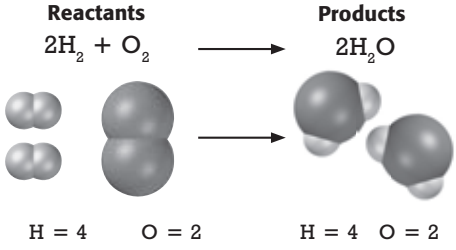
❶ **Count the atoms** of each element in the reactants and the products. Here, you can see that there are more oxygen atoms in the reactants than in the products. Therefore, the chemical equation is not balanced.



❷ **Add coefficients to balance the atoms** of oxygen. There are two atoms of oxygen in the reactants. Place the coefficient 2 in front of the products to give two atoms of oxygen in the products. Then, count the atoms again. Now, the hydrogen atoms are not balanced.



❸ **Add coefficients to balance the atoms** of hydrogen. Add the coefficient 2 to the H_2 reactant to give four atoms of hydrogen in the reactants. Then, count the atoms again to double-check your work.



READING CHECK

9. Describe What is a coefficient?

_____

_____

_____

READING CHECK

10. Identify What can't be changed when balancing a chemical equation?

_____

Math Focus

11. Applying Concepts Balance the equation:

___Na + ___Cl_2 ⟶ ___NaCl

by putting coefficients where needed.

Name _____ Class _____ Date _____

Section 2 Review

NSES PS 1b

SECTION VOCABULARY

chemical equation a representation of a chemical reaction that uses symbols to show the relationship between the reactants and the products

chemical formula a combination of chemical symbols and numbers to represent a substance

law of conservation of mass the law that states the mass cannot be created or destroyed in ordinary chemical and physical changes

product a substance that forms in a chemical reaction

reactant a substance or molecule that participates in a chemical reaction

1. Compare How is a chemical equation different from a chemical formula?

_____

_____

2. Identify Fill in the blank spaces in the table.

Chemical equation	Number of atoms in the reactants	Number of atoms in the products	Is the equation balanced?
$Na + Cl_2 \rightarrow NaCl$	Na = Cl =	Na = Cl =	
$HCl + NaOH \rightarrow NaCl + H_2O$	H = Cl = Na = O =	H = Cl = Na = O =	
$2Sb + 3I_2 \rightarrow 2SbI_3$	Sb = I =	Sb = I =	

3. Describe Give the names of the covalent compounds listed below.

SiO_2 _____

SbF_3 _____

4. Explain Why can't you change the subscripts in a formula in order to balance a chemical equation?

_____

_____

5. Applying Concepts Balance the equation:

____Mg + ____N_2 → ____Mg_3N_2 by putting coefficients where needed.

4. The properties of oxygen change; water does not have the same properties as oxygen.
5. Metals can conduct electricity, can be stretched into wires, and can be hammered into thin sheets.

Chapter 2 Chemical Reactions

SECTION 1 FORMING NEW SUBSTANCES

1. One or more substances break apart or combine to form one or more new substances.
2. A solid forms in a solution.
3. No, some physical changes, like boiling, may produce a gas.
4. The chemical properties of the new substances are different from those of the original substances.
5. Some bonds are broken and new bonds form.
6. The bonds in the hydrogen and chlorine molecules are broken. The bonds in the hydrogen chloride molecule form.

Review

1. New substances are formed during a chemical reaction. Formation of a precipitate is one sign that a new substance has been formed.
2.

Observed during a chemical reaction	Sign of a chemical reaction
precipitate in a solution	solid formation
heat given off	energy change
green gas	gas formation
colorless solution turned blue	color change

3. chemical bond
4. When water boils, a new substance is not formed. The water vapor that forms during boiling can condense into liquid water.
5. The chemical properties of the material in the beaker are different from those of the original substances. This shows that a chemical reaction must have occurred.

SECTION 2 CHEMICAL FORMULAS AND EQUATIONS

1. the elements found in a substance and how many atoms of each element are in a molecule
2. three
3. PCl_3
4. 3+
5. a short way to show what happens in a chemical reaction using symbols and formulas
6. Reactants: C, O_2

   Products: CO_2
7. If you use the wrong chemical formula, a chemical equation will not describe the reaction you are trying to describe.
8. A chemical equation shows that no atoms are lost or gained during a chemical reaction.
9. a number that is placed in front of a chemical formula
10. subscripts
11. $2Na + Cl_2 \longrightarrow 2NaCl$

Review

1. A chemical formula represents a substance. A chemical equation represents a chemical reaction.
2.

Chemical equation	Number of atoms in the reactants	Number of atoms in the products	Is the equation balanced?
$Na + Cl_2 \longrightarrow NaCl$	Na = 1 Cl = 2	Na = 1 Cl = 1	no
$HCl + NaOH \longrightarrow NaCl + H_2O$	H = 2 Cl = 1 Na = 1 O = 1	H = 2 Cl = 1 Na = 1 O = 1	yes
$2Sb + 3I_2 \longrightarrow 2SbI_3$	Sb = 2 I = 6	Sb = 2 I = 6	yes

3. SiO_2: silicon dioxide

   SbF_3: antimony trifluoride
4. Changing the subscripts changes the substance in the chemical reaction. Therefore, if you change subscripts, you change the chemical reaction that you are describing.
5. $3Mg + N_2 \longrightarrow Mg_3N_2$