Chemical Equations

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Printed: January 7, 2014

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CONCEPT 1

Chemical Equations

Lesson Objectives

- Describe how to write chemical equations.
- Demonstrate how to balance chemical equations.
- Relate the law of conservation of mass to balancing chemical equations.

Lesson Vocabulary

- chemical equation

Introduction

Chemists use a standard method to represent chemical reactions. It includes chemical symbols and formulas to stand for reactants and products. The symbols and formulas are used to write chemical equations.

Writing Chemical Equations

A **chemical equation** is a symbolic representation of a chemical reaction. It is a shorthand way of showing how atoms are rearranged in the reaction. The general form of a chemical equation was introduced in this chapter's lesson "Introduction to Chemical Reactions." It is:

$$\text{Reactants} \rightarrow \text{Products}$$

Consider the simple example in **Figure** 1.1. When carbon (C) reacts with oxygen (O_2), it produces carbon dioxide (CO_2). The chemical equation for this reaction is:

$$C + O_2 \rightarrow CO_2$$

The reactants are one atom of carbon and one molecule of oxygen. When there is more than one reactant, they are separated by plus signs (+). The product is one molecule of carbon dioxide. If more than one product were produced, plus signs would be used between them as well.

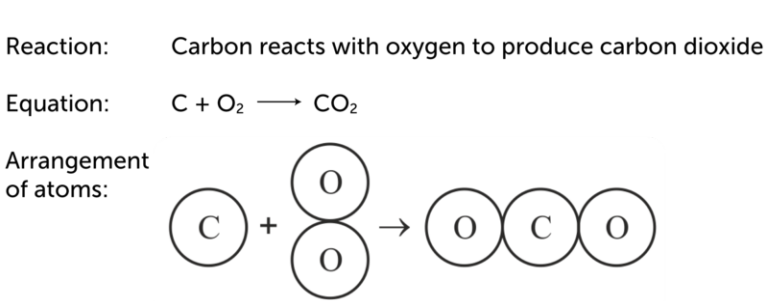


FIGURE 1.1

This figure shows a common chemical reaction. The drawing below the equation shows how the atoms are rearranged in the reaction. What chemical bonds are broken and what new chemical bonds are formed in this reaction?

Balancing Chemical Equations

Some chemical equations are more challenging to write. Consider the reaction in which hydrogen (H_2) and oxygen (O_2) combine to form water (H_2O). Hydrogen and oxygen are the reactants, and water is the product. To write a chemical equation for this reaction, you would start by writing symbols for the reactants and products:

Equation 1: $H_2 + O_2 \rightarrow H_2O$

Like equations in math, equations in chemistry must balance. There must be the same number of each type of atom in the products as there is in the reactants. In equation 1, count the number of hydrogen and oxygen atoms on each side of the arrow. There are two hydrogen atoms in both reactants and products. There are two oxygen atoms in the reactants but only one in the product. Therefore, equation 1 is not balanced.

Using Coefficients

Coefficients are used to balance chemical equations. A coefficient is a number placed in front of a chemical symbol or formula. It shows how many atoms or molecules of the substance are involved in the reaction. For example, two molecules of hydrogen would be written as $2H_2$. A coefficient of 1 usually isn't written.

Coefficients can be used to balance equation 1 (above) as follows:

Equation 2: $2H_2 + O_2 \rightarrow 2H_2O$

Equation 2 shows that two molecules of hydrogen react with one molecule of oxygen to produce two molecules of water. The two molecules of hydrogen each contain two hydrogen atoms. There are now four hydrogen atoms in both reactants and products. Is equation 2 balanced? Count the oxygen atoms to find out.

Steps in Balancing a Chemical Equation

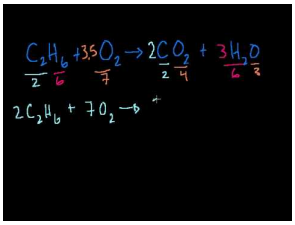
Balancing a chemical equation involves a certain amount of trial and error. In general, however, you should follow these steps:

1. Count the number of each type of atom in reactants and products. Does the same number of each atom appear on both sides of the arrow? If not, the equation is not balanced, and you need to go to step 2.
2. Add coefficients to increase the number of atoms or molecules of reactants or products. Use the smallest coefficients possible.
3. Repeat steps 1 and 2 until the equation is balanced.

Helpful Hint

When you balance chemical equations, never change the subscripts in chemical formulas. Changing subscripts changes the substances involved in the reaction. Change only the coefficients.

Work through the **Problem Solving** examples below. Then do the **You Try It!** problems to check your understanding. If you need more help, go to this URL: http://www.youtube.com/watch?v=RnGu3xO2h74 (14:28).



MEDIA

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Problem Solving

Problem: Balance this chemical equation: $N_2 + H_2 \rightarrow NH_3$

Hints for balancing

1. Two N are needed in the products to match the two N (N_2) in the reactants. Add the coefficient 2 in front of NH_3. Now N is balanced.
2. Six H are now needed in the reactants to match the six H in the products. Add the coefficient 3 in front of H_2. Now H is balanced.

Solution: $N_2 + 3H_2 \rightarrow 2NH_3$

Problem: Balance this chemical equation: $CH_4 + O_2 \rightarrow CO_2 + H_2O$

Solution: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

You Try It!

Problem: Balance these chemical equations:

$Zn + HCl \rightarrow ZnCl_2 + H_2$

$Cu + O_2 \rightarrow CuO$

Conserving Mass

Why must chemical equations be balanced? It's the law! Matter cannot be created or destroyed in chemical reactions. This is the law of conservation of mass. In every chemical reaction, the same mass of matter must end up in the products as started in the reactants. Balanced chemical equations show that mass is conserved in chemical reactions.

How do scientists know that mass is always conserved in chemical reactions? Careful experiments in the 1700s by a French chemist named Antoine Lavoisier led to this conclusion. For this and other contributions, Lavoisier has been called the father of modern chemistry.

Lavoisier carefully measured the mass of reactants and products in many different chemical reactions. He carried out the reactions inside a sealed jar, like the one in **Figure** 1.2. As a result, any gases involved in the reactions were captured and could be measured. In every case, the total mass of the jar and its contents was the same after the reaction as it was before the reaction took place. This showed that matter was neither created nor destroyed in the reactions. Another outcome of Lavoisier's research was his discovery of oxygen. You can learn more about Lavoisier and his important research at: http://www.youtube.com/watch?v=x9iZq3ZxbO8

FIGURE 1.2

Lavoisier carried out several experiments inside a sealed glass jar. Why was sealing the jar important for his results?

Lesson Summary

- A chemical equation is a symbolic representation of a chemical reaction. It shows how atoms are rearranged in the reaction.
- Equations in chemistry must balance. There must be the same number of each type of atom in the products as there is in the reactants. Coefficients are used to balance chemical equations. They show how many atoms or molecules of a substance are involved in a reaction.
- Chemical equations must be balanced because matter cannot be created or destroyed. This is the law of conservation of mass. Experiments by Antoine Lavoisier led to this law.

Lesson Review Questions

Recall

1. What is a chemical equation? Give an example.
2. What is a coefficient? How are coefficients used in chemistry?
3. Describe how Antoine Lavoisier showed matter is conserved in chemical reactions.

Apply Concepts

4. Draw a sketch that shows how atoms are rearranged in the chemical reaction represented by equation 2.
5. Balance this chemical equation: $Hg + O_2 \rightarrow HgO$

Think Critically

6. Explain why it is necessary to balance chemical equations.

Points to Consider

In this lesson, you saw examples of chemical reactions in which two reactants combine to yield a single product. This is called a synthesis reaction. It is just one type of chemical reaction.

- What might be other types of chemical reactions?
- How might one reactant produce more than one product?

References

1. Christopher Auyeung. CK-12 Foundation. CC BY-NC 3.0
2. . http://commons.wikimedia.org/wiki/File:David_-_Portrait_of_Monsieur_Lavoisier_and_His_Wife.jpg. Public Domain