Chemical Reactions

The process by which the atoms of one or more substances are rearranged to form different substances is called a **chemical reaction**.

Although some chemical reactions are hard to detect, many reactions provide evidence that they have occurred. Listed below are several examples of evidence that may indicate a chemical reaction has taken place.

- a temperature change occurs (some reactions produce heat, others absorb heat)
- a color change
- production of an odor
- production of gas bubbles
- the appearance of a new substance (for example, the appearance of a solid when two liquids are mixed)

Representing Chemical Reactions

Chemists use statements called equations to represent chemical reactions. The equation shows a reaction's **reactants**, which are the starting substances, and **products**, which are the substances formed during the reaction.

The equations used by chemists show the direction in which the reaction progresses. Thus, an arrow is used (rather than an equal sign) to separate the reactants from the products. The arrow is read as "react to produce." The reactants in a reaction are written to the arrow's left, and the products are written to the right.

The elements of a typical equation are shown below.

$$reactant\ 1 + reactant\ 2 \rightarrow product\ 1 + product\ 2$$

In equations, symbols are used to show the physical states of the reactants and products. Reactants and products can exist as solids (*s*), liquids (*l*), and gases (*g*). When they are dissolved in water, they are said to be aqueous (*aq*).

Word Equations

You can use statements called word equations to indicate the reactants and products of a chemical reaction. The word equation below describes the reaction between iron (a solid) and chlorine (a gas).

$$iron(s) + chlorine(g) \rightarrow iron(III)\ chloride(s)$$

This word equation is read, "Iron and chlorine react to produce iron(III) chloride."

Skeleton Equations

A skeleton equation uses chemical formulas rather than words to identify the reactants and the products. For example, the skeleton equation for the reaction between iron and chlorine would be

$$Fe(s)+Cl_2(g)\rightarrow FeCl_3(s)$$

Example 1
Write the skeleton equation for the reaction between carbon and sulfur. Note: Carbon and sulfur are both solids.

Chemical Equations

The **law of conservation of mass** states that in a chemical change, matter is neither created nor destroyed. Chemical equations must show that matter is conserved during a reaction. Both word equations and skeleton equations lack this information.

Consider the reaction between iron and chlorine that we discussed earlier.

$$\underbrace{Fe(s)+Cl_2(g)}_{\substack{\text{one iron atom}\\ \text{two chlorine atoms}}}\rightarrow \underbrace{FeCl_3(s)}_{\substack{\text{one iron atom}\\ \text{three chlorine atoms}}}$$

Was a chlorine atom created in the reaction? Atoms are not created in chemical reactions, and to accurately show what happened, more information is needed.

To accurately represent a chemical reaction by an equation, the equation must show how the law of conservation of mass is obeyed. In other words, the equation must show that the number of atoms of each reactant and each product is equal on both sides of the arrow. Such an equation is called a **balanced chemical equation**.

Balancing Chemical Equations

The balanced equation for the reaction between iron and chlorine is shown below.

$$\underbrace{2Fe(s) + 3Cl_2(g)}_{\substack{\textit{two iron atoms} \\ \textit{six chlorine atoms}}} \rightarrow \underbrace{2FeCl_3(s)}_{\substack{\textit{two iron atom} \\ \textit{six chlorine atoms}}}$$

To balance an equation, you must find the correct coefficients for the chemical formulas in the skeleton equation. A **coefficient** in a chemical equation is the number written in front of a reactant or product. Coefficients are whole numbers, and are usually not written if the value is 1.

A coefficient tells you the smallest number of particles of the substance involved in the reaction. That is, the coefficients in a balanced equation describe the lowest whole-number ratio of the amounts of all of the reactants and products.

Most chemical equations can be balanced by following the steps given below.

1. Write the skeleton equation for the reaction.
    - show the physical states of all reactants and products

2. Count the atoms of the elements in the reactants.
    - if a reaction involves identical polyatomic ions in the reactants and products, count the ions as if they were elements

3. Count the atoms of the elements in the products.

4. Change the coefficients to make the number of atoms of each element equal on both sides of the equation.
    - never change a subscript of a formula, since doing so changes the identity of the substance

5. Write the coefficients in their lowest possible ratio.
    - think of this like reducing a fraction

6. Check your work.
    - make sure the chemical formulas are written correctly
    - check that the number of atoms of each element is equal on both sides of the equation

Example 2
Write the balanced chemical equation for the reaction in which hydrogen gas and chlorine gas react to produce hydrogen chloride.

Example 3
Write the balanced chemical equation for the reaction in which sodium hydroxide and calcium bromide react to produce solid calcium hydroxide and sodium bromide. The reaction occurs in water.

Example 4

Write the balanced chemical equation for the reaction in which methane gas reacts with oxygen gas to produce carbon dioxide gas and water vapor.

Example 5

Write the balanced chemical equation for the reaction in which solid magnesium reacts with nitric acid (HNO_3) to produce hydrogen gas and magnesium nitrate. The reaction occurs in water.

Worksheet

1. What is the purpose of writing a word equation?

2. Examine the following word equation:

$$\text{propane} + \text{oxygen gas} \rightarrow \text{carbon dioxide} + \text{water}$$

   a) List all the reactants in this reaction.

   b) List all the products in this reaction.

   c) What is the purpose of the arrow in the word equation?

3. Write word equations for the following reactions:

   a) $CaCl_2$ and Na_2SO_4 react to form $CaSO_4$ and $NaCl$.

   b) $BaCO_3$ reacts when heated to produce BaO and CO_2.

   c) $AgNO_3$ reacts with KCl to produce $AgCl$ and KNO_3.

4. Write word equations to represent the following chemical reactions:

   a) Carbon dioxide and water are produced in human cell respiration. The reactants are sugar and an important gas that humans need to survive.

   b) Stalactites form in caves when calcium bicarbonate reacts to form calcium carbonate, water, and carbon dioxide gas.

5. Write your own word equation for the production of a peanut butter sandwich.

6.
   a) Why is the following equation not balanced?

$$N_2 + H_2 \rightarrow NH_3$$

   b) The following is an attempt to balance the above equation. What is wrong with the way that the equation is balanced?

$$N_2 + H_3 \rightarrow N_2H_3$$

7. Copy the following skeleton equation into your notebook. Then balance the equations.

   a) $Na + Cl_2 \rightarrow NaCl$
   b) $K + O_2 \rightarrow K_2O$
   c) $H_2 + O_2 \rightarrow H_2O$
   d) $H_2 + Cl_2 \rightarrow HCl$
   e) $N_2 + H_2 \rightarrow NH_3$
   f) $CO + O_2 \rightarrow CO_2$
   g) $Al + Br_2 \rightarrow AlBr_3$
   h) $N_2H_4 + O_2 \rightarrow H_2O + N_2$
   i) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

8. For each of the following, write the correct skeleton equation, and then balance it to form a chemical equation.

   a) copper(II) oxide + hydrogen → copper + water
   b) lead(II) nitrate + potassium iodide → lead(II) iodide + potassium nitrate
   c) calcium + water → calcium hydroxide + hydrogen gas
   d) lead(II) sulfide + oxygen → lead + sulfur dioxide
   e) hydrogen sulfide → hydrogen + sulfur

9. Imagine that you are an engineer trying to determine how much air had to be supplied to burn gasoline in a car engine. Assuming that gasoline is heptane (C_7H_{16}), the word equation is:

   heptane + oxygen → carbon dioxide + water vapor

   a) Write the skeleton equation for the reaction.
   b) Balance the equation by adding coefficients as necessary.
   c) How many molecules of oxygen are required for every molecule of heptane that burns?