8.5E: Chemical Reactions

Reflect

Have you ever seen fireworks explode in the sky? If so, you may have observed a variety of different colors and shapes in the sky and watched with amazement as the colors changed overhead. These displays are not just a form of entertainment. When each firework is ignited, one or more chemical reactions take place. The color of the display in the sky is determined by each chemical reaction. Each burst of color depends on the elements and compounds that are present in the firework.

Fireworks are chemical reactions. The color of the firework depends on the reactants that are used.

What types of things do you observe during a fireworks display? Perhaps you hear loud sounds, see bright lights, and feel the warmth of the explosion. Do any of these indicate that a chemical reaction has taken place?

Chemical reactions produce new molecules.

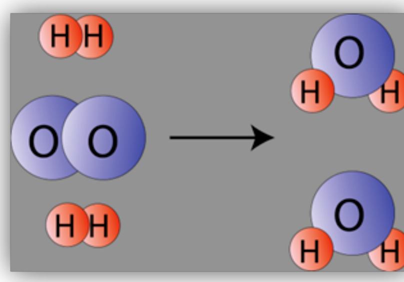
In a *chemical reaction*, molecules can change into different molecules through the rearrangement of their atoms. More specifically, atoms of the reactants rearrange to form new molecules. A chemical equation can be written to show what happens to the atoms in a chemical reaction. A chemical equation is written like this:

$$(\text{reactants}) \rightarrow (\text{products})$$

The arrow in a chemical reaction means “produce” or “are converted to.”

If you have ever seen water, you have seen the result of a chemical reaction. In this reaction, oxygen gas (O_2) and hydrogen gas (H_2) rearrange to form water (H_2O). The balanced chemical equation for this reaction is written like this:

$$O_2 + 2H_2O \rightarrow 2H_2O$$



The hydrogen and oxygen molecules involved in the reaction have different properties from water vapor.

In this reaction, the reactants have different properties than the product. Oxygen gas and hydrogen gas have different properties than water. In the gas form, water vapor may look similar to both hydrogen gas and oxygen gas. They are all colorless gases. Yet, they have different chemical properties. Oxygen is very reactive compared to both hydrogen gas and water vapor.

Hydrogen gas is much lighter than both oxygen gas and water vapor. The molecular structure of water is different from the structure of both oxygen and hydrogen gas. These properties can distinguish the reactants from the products. These differences allow scientists to identify when a chemical reaction occurs.

What Do You Think?

Take a look at the following photographs. The picture on the left shows rusty nails. The picture in the middle shows a rotting pumpkin. The picture on the right shows a lit matchstick. These images are all examples of chemical reactions taking place. In each image, how do you know a chemical reaction is occurring?

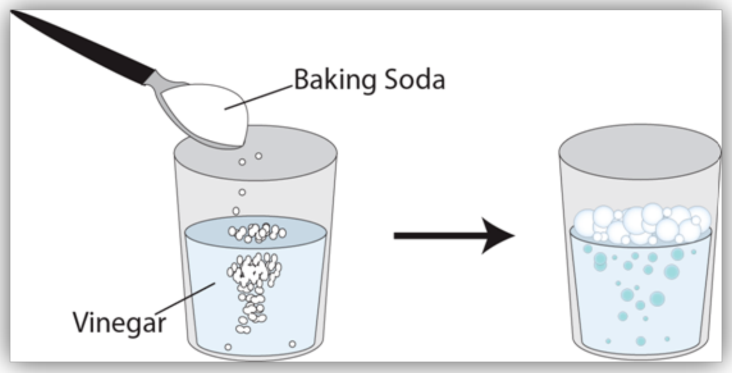


We can observe evidence of chemical reactions.

Scientists confirm that a chemical reaction occurs by determining if a new substance, with new properties, is formed. Scientists may perform additional chemical reactions and use instrumentation to confirm these new substances. Yet, there are signs or indicators that can suggest that a chemical reaction has occurred. The only way to know for sure that a chemical reaction has occurred is to identify the new substance. If you observe one or more of these signs, this provides evidence that a chemical reaction may have taken place. Remember that not all chemical reactions will produce one of these signs.

Let's look at the signs that provide evidence of a chemical reaction.

- **Production of a gas:** One very common reaction that involves the production of a gas is mixing sodium bicarbonate, also known as baking soda ($NaHCO_3$), with an acid such as vinegar (CH_3COOH). The products of this reaction are water (H_2O), carbon dioxide (CO_2), and a substance called sodium acetate (CH_3COONa). During this reaction, you can see



bubbles in the solution, as shown in the picture on the next page. These bubbles are caused by the carbon dioxide gas escaping into the air as the reaction takes place. The chemical equation for this reaction is:

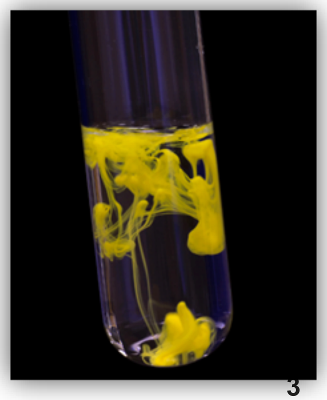
$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

(vinegar) + (baking soda) → (sodium acetate) + (water) + (carbon dioxide)

- **Production of light:** The burning of logs in a fireplace is the reaction of the wood and oxygen along with a heat initiation source. Wood is made of cellulose, a combination of different substances that contain carbon, hydrogen, and oxygen. When this reaction occurs, a large amount of energy is produced. This energy is in the form of both heat and light. This type of reaction is a combustion reaction. It is similar to the reaction that produces the bright light and heat in fireworks.

- **Change in temperature:** Chemical reactions can either give off heat or use heat. Perhaps you have had an injury and applied a chemical heat pack to the area. A chemical heat pack is an example of a reaction that produces heat. A common substance in a heat pack is magnesium sulfate ($MgSO_4$). When the heat pack is activated, the magnesium sulfate reacts with water. The result is the production of heat, which you use to soothe your injury. Chemical cold packs work in an opposite way to use heat when they mix with water. They may feel very cool to the touch. These temperature changes are evidence of a chemical reaction.

- **Formation of a precipitate:** A *precipitate* is a solid substance that forms and separates from a solution. A precipitate often settles to the bottom of a liquid reaction. One common chemical reaction that forms a precipitate is the reaction of solutions of lead nitrate ($Pb(NO_3)_2$) and potassium iodide (KI). Each of these substances in solution is clear and colorless. But, if you mix a solution of each substance, lead iodide (PbI_2) and potassium nitrate



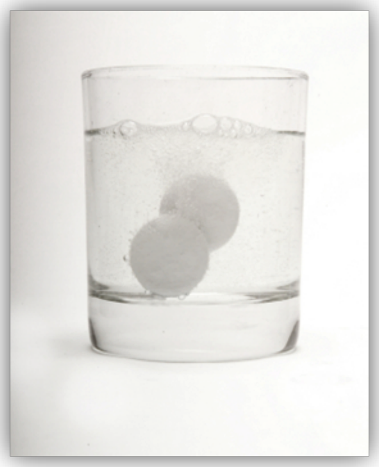
($2KNO_3$) form as products. Lead iodide is insoluble, so it separates from the solution as a yellow precipitate (shown in the image to the left). The potassium nitrate remains in solution. The chemical equation for this reaction is:

$$Pb(NO_3)_2 + PbKI \rightarrow PbI_2 + 2KNO_3$$

- **Change in color:** You may have seen rust form on a steel object, such as a chain or an automobile. In this chemical reaction, iron (Fe) in the steel reacts with oxygen (O_2) in the air, as well as water (H_2O), to produce rust (($Fe(OH)_3$). The properties of steel are different than the properties of rust. Steel is a shiny, silver metal made from iron and other elements. Rust is a flaky, reddish-colored substance. The change in color from silver to red provides evidence that a chemical reaction has happened. Rusting is a complex reaction that happens in stages; the overall reaction may be written as follows:

$$4Fe + 6H_2O + 3O_2 \rightarrow 4Fe(OH)_3$$

Look Out!



Do not confuse some physical changes with chemical reactions. Suppose you have a glass of water and a spoonful of sugar. If you dissolve the sugar in the water, the resulting product seems different than the reactants, but it is just a mixture of sugar and water. No new substance has formed. However, if you place antacid tablets in water, the tablets dissolve through a chemical reaction. This is readily observed by the bubbling of gas in the glass. The antacid tablets contain the substances sodium bicarbonate ($NaHCO_3$) and citric acid ($C_6H_8O_7$). When these substances are placed in water, the atoms rearrange and carbon dioxide gas is produced. The picture to the right shows the gas bubbles that you observe in the glass.

Everyday Life: Rising dough is a chemical reaction.

Chemical reactions occur all around us: in rotting fruit, in rusting nails, and in baking bread. Bread dough is a mixture of ingredients, including flour, salt, sugar, warm water, and yeast. When these ingredients are combined, the ball of dough begins to expand, or *rise*. The rising happens because a chemical reaction is taking place inside the dough.

This reaction is caused by yeast, a living organism that becomes active in warm water. Once activated, the yeast converts the sugar ($C_6H_{12}O_6$) in the dough into alcohol (CH_3CH_2OH) and carbon dioxide (CO_2) through a chemical reaction. This process is called *fermentation*. The balanced chemical equation for this reaction is:

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

(glucose) → (alcohol) + (carbon dioxide)

The process of fermentation—the conversion of sugar to alcohol and carbon dioxide—is a chemical reaction that causes bread to rise.

The release of carbon dioxide, which is a gas, causes the bread to rise. The carbon dioxide also gives the bread its light, airy texture. The alcohol produced by the reaction gives the bread its final taste. During baking, this alcohol evaporates and the yeast cells cease to be active.

What Do You Know?

Certain evidence indicates that a chemical reaction may have occurred. This evidence includes the production of a gas, the production of light, a change in temperature, a color change, and the formation of a precipitate. Look at the types of reactions given below. For each reaction, decide which of the five types of evidence would be observed, and write your answer in the space below that evidence in the column on the next page. More than one type of evidence may be possible for each example.

Type of Reaction	
• The exploding of fireworks • Baking a cake • Burning paper • Mixing an antacid tablet and water • Making chalk from two liquids • Blue litmus paper turning red in acid	• A salt solution becoming cold as the salt dissolves • A copper penny tarnishing • Oxygen gas and hydrogen gas producing water and heat • Testing for carbon dioxide by bubbling a gas in limewater to produce a milky-white solution

Production of Gas	Production of Light	Change in Temperature	Color Change	Formation of Precipitate

Connecting With Your Child: Investigating Chemical Reactions

To help your child learn more about chemical reactions, work together to determine how to identify the evidence that may be observed when a chemical reaction occurs. To do so, gather the following materials:

- 3 glasses of water
- 2 effervescent tablets
- a tablespoon of sugar
- a tablespoon of Epsom salt
- a thermometer

While performing the chemical reactions, encourage your child to record all observations. Let the first glass contain the control sample in which no chemical reaction occurs. Add a tablespoon of sugar to the water in the glass and stir until the sugar dissolves completely. Record all observations until the sugar dissolves. Remember that this control sample does not involve a chemical reaction because sugar dissolving in water is only a physical change. Then, have your child add both of the effervescent tablets to the second glass of water. Record any observations for at least two minutes while the tablets dissolve. Finally, place the thermometer in the third glass and record the initial water temperature. If a thermometer is not available, feel the outside of the glass and record if it feels hot, warm, or cold. Then add a tablespoon of Epsom salt and gently stir the liquid using the thermometer. Make sure to watch the temperature closely and determine how the temperature changes when the salt is added.

After performing the reactions, discuss the following questions with your child:

- In which of the glasses did a chemical reaction take place? How do you know?
- Why can you assume that a chemical reaction did not take place in all three glasses? How could you confirm that a chemical reaction took place in the glasses?
- Can you write a chemical equation to describe each chemical reaction that occurred?