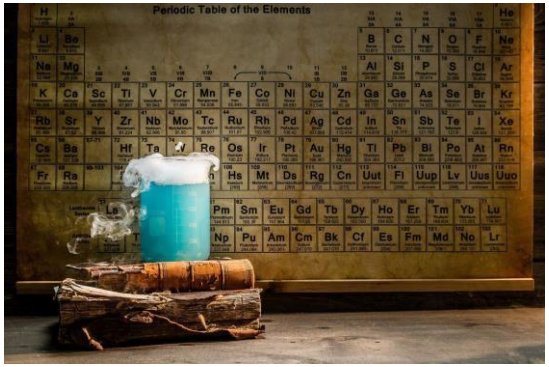
Mission Log

Name: _____ Date: _____

Mission Briefing



Anchoring Phenomena
How can chemical reactions be used to describe the law of conservation of mass?

Mission Briefing
You are to create your own chemical reaction using fictional substances. Your substance should include a chemical equation and a description of the atomic structure of the substances used, the properties of the reactants and products, and how matter is conserved during the reaction.

- What is all matter made of?
- What is the difference between physical and chemical properties?
- What happens to atoms in chemical reactions?
- What are synthetic materials?
- Describe the law of conservation of mass.

Mission Log

Class Mission Log

Information Gained

Physical and Chemical Properties

Describe the difference between physical and chemical properties.

Physical	Chemical

Connection to Mission

Physical and Chemical Properties

How can an unknown substance be identified using physical and chemical properties?

Mission Log

Class Mission Log

Information Gained

Characteristics of Chemical Reactions

What happens to atoms during a chemical reaction?

What are some signs of a chemical reaction?

Connection to Mission

Characteristics of Chemical Reactions

Identify the reactants and products in the following chemical equation.

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

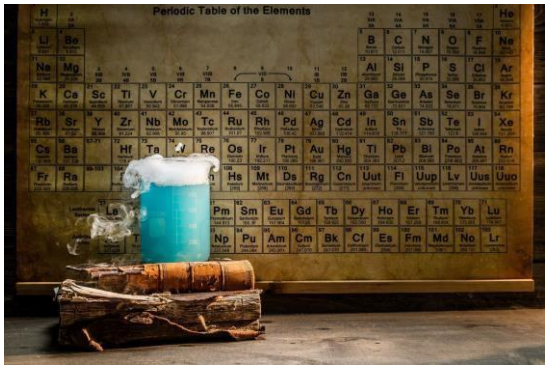
Make a list of chemical reactions that you have seen and the sign of a chemical change.

Reaction	Evidence

Action Plan

Name:_____ Date: _____

Create your own chemical reaction using fictional substances. Write a balanced chemical equation and then create a model of the atomic structure of the substances used. Finally, write a description of the properties of the reactants and products and how matter is conserved during the reaction.



Here's what we know:

- All matter is made up of atoms.
- Physical properties can be observed without changing the substance, but chemical properties can only be observed during chemical reactions.
- During a chemical reaction, atoms rearrange to form new substances.
- Synthetic materials are natural resources that undergo chemical changes.
- The law of conservation of mass states that matter cannot be created nor destroyed.

Reflect

Our world is full of various substances we call **matter**. Matter is anything that takes up space (volume) and has mass. Take a look at the picture on the right. What kinds of matter do you see? The cars are made of solid matter such as metal frames and glass windows. Cars also need liquid matter to function, such as gasoline for fuel and oil for lubrication. The exhaust coming from the tailpipes is matter in the form of a gas.

matter – anything that has volume and mass; occurs as elements, compounds, and mixtures

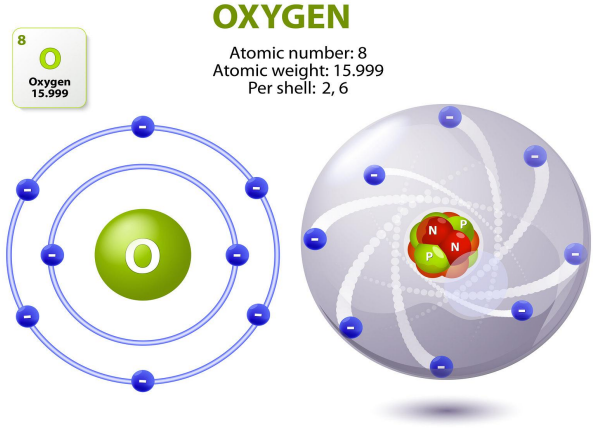
The metal, glass, gasoline, and exhaust are composed of many different types of matter. For example, metal car frames are typically hard steel made from the elements iron and carbon, while the glass is a compound made of silicon and oxygen. The exhaust is a mixture of gases such as carbon dioxide. There are more than 100 different elements, each with its own type of atom. These **atoms** are the tiny particles that serve as building blocks of all matter.

A bar of the element gold contains quadrillions of individual gold atoms. An atom is the smallest particle of an element that cannot be broken down without changing the properties of the element. One atom of gold is very small, too small to be visible. However, a single atom of gold has the same properties as every other gold atom.

atom – the smallest particle of an element, made of electrons, protons, and neutrons

What are atoms made of? Do all atoms have the same structure? All atoms have the same general arrangement of subatomic particles, with protons and neutrons in the nucleus, or center, of the atom surrounded by a cloud of electrons. Scientists refer to this structure as the *electron cloud model* of an atom.

Look Out!

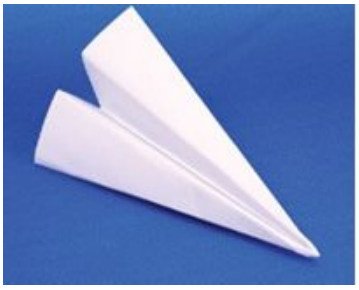


The electron cloud model of an atom is more accurate in its depiction of the electrons than the older atomic model developed by Niels Bohr in 1913. Bohr's model described electrons as orbiting the nucleus in a flat plane, like planets in our solar system. In the electron cloud model, the nucleus is surrounded by a negatively charged electron cloud where electrons travel in high-probability areas called orbitals. Both models describe a dense central nucleus composed of positive protons and neutral neutrons.

Physical and Chemical Properties

Reflect

How can you describe a piece of paper? You can talk about its color and size. What other **properties** of paper can you identify? Imagine that you took a full sheet of paper and folded it into a paper airplane. Would you still have paper? Yes. Being flexible or foldable is a property of paper. Will paper burn if it is near a flame? Yes. Being flammable is another property of paper. You could measure other properties of the paper, such as its mass, volume, and density. Properties help distinguish one substance from another.



properties – physical and chemical characteristics of matter used to describe or identify a substance

Not all properties can be seen when you first observe or measure a substance. Physical properties can be seen without chemically changing the matter, while chemical properties are observed during a chemical reaction:

- *Physical properties* are characteristics that can be observed or measured without changing the substance, such as state of matter (solid, liquid, gas), color, melting point, boiling point, odor, density, and conductivity.
- *Chemical properties* are characteristics that can only be observed or measured when atoms of matter rearrange during a chemical change, such as flammability (burning); corrosion and rusting, or oxidation (reactivity with the oxygen in air); and reactivity with water (some metals explode in contact with water!).

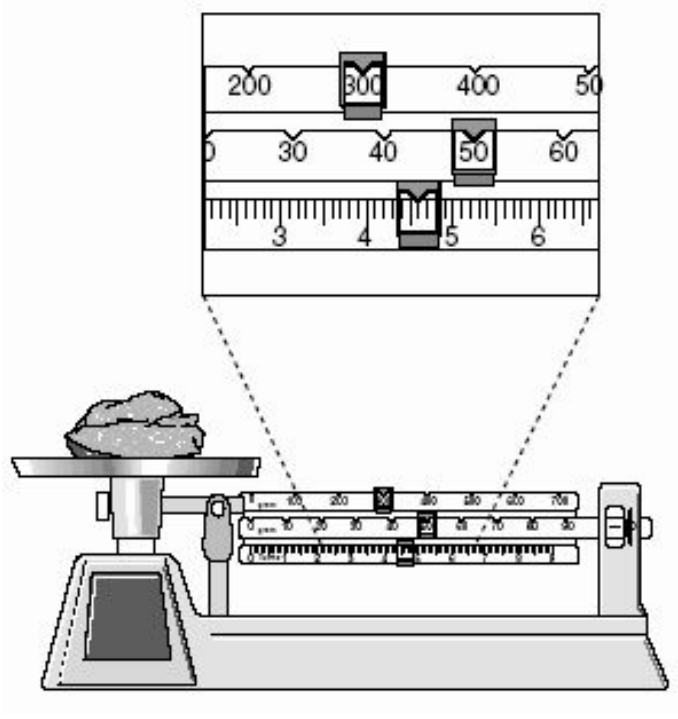
Look Out!

Some physical properties depend on the size of the substance. An *intensive property* is a bulk property and does *not* depend on the amount of matter. Intensive properties include shape, state of matter, color, temperature, density (sink or float, or g/cm^3), hardness (resistance to breaking), luster (shine), texture, malleability (ability to flatten), ductility (ability to be drawn into a wire), flexibility (ability to bend), attraction or repulsion to magnets, melting point, boiling point, odor, heat conductivity, electrical conductivity, solubility (ability to dissolve in water), and viscosity (resistance to flow). For example, when a diamond is cut, the pieces maintain their intrinsic property of hardness. A piece of paper remains white even when folded. Water will freeze at 0°C, regardless of the amount of water present. Intensive properties can be observed and measured to determine the identity of a substance.

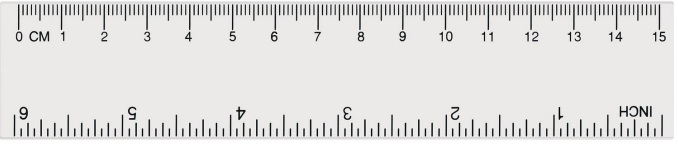
In contrast, an *extensive property* is proportional to the amount of material. Examples of extensive properties include mass, length, and volume. A ream of paper has more mass and volume than a sheet of paper. A foot-long hot dog has more length than a regular hot dog.

What Do You Think?

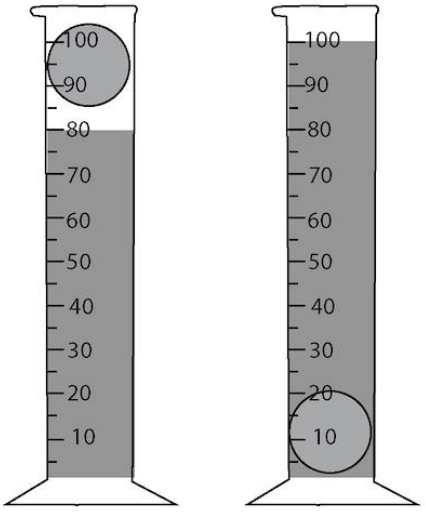
How can you measure physical properties accurately?
Use the proper equipment to measure extensive physical properties of mass, length, or volume.



Finding mass: Use a balance scale to measure the amount of matter in an object in grams. Be sure to set the mass sliders to zero, if using a triple arm balance. Look at the scale numbers at eye level. Move the 100 g slider to the right until the balance arrow is centered. Then move the 10 g slider to the right until the arrow is centered. Lastly, use the 1 g slider until the balance arrow centers. Only the 1 g slider can be placed between two numbers. Add the three measurements for the total mass in grams (300 g + 50 g + 4.6 g = 354.6 g). *Note: When finding the mass of a liquid, there is one extra step. You must mass the empty container and subtract it to get the mass of the liquid alone.*



Finding length: Use a metric ruler or meterstick to accurately measure the length of the object. Remember, a meterstick is usually 100 cm long. Each centimeter is divided into 10 mm. *Note: Do not confuse the inch side with the centimeter side of the ruler.*



Finding volume (V): For solids with flat sides, use a metric ruler to measure the length, width, and height in cm. Then use the same formula you would in math class. To find the volume of a rectangular prism, for example, use V = l x w x h. Your answer will be in cm^3 or mL. Conveniently, 1 cm^3 has the exact same volume as 1 mL, so these units are interchangeable.

To find the volume of an irregular solid, place enough water to submerge the object in a graduated cylinder. Write down the volume of the water. Carefully lower the object into the water. Record the volume of the water and object. Then simply subtract to find the volume of the object in mL or cm^3. This is called the water displacement method for finding volume (100 mL – 80 mL = 20 mL).

Try Now

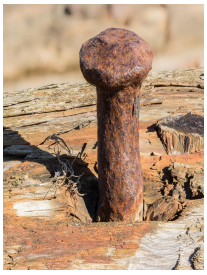
Physical Properties

Consider the following physical properties and fill in the missing information.

Property	Tool	Unit
Mass		
Length		
Volume of a regular solid		
Volume of a liquid or an irregular solid		
Melting and boiling points		

Chemical Properties

Consider the following objects and describe some of their chemical properties after observing a chemical reaction.

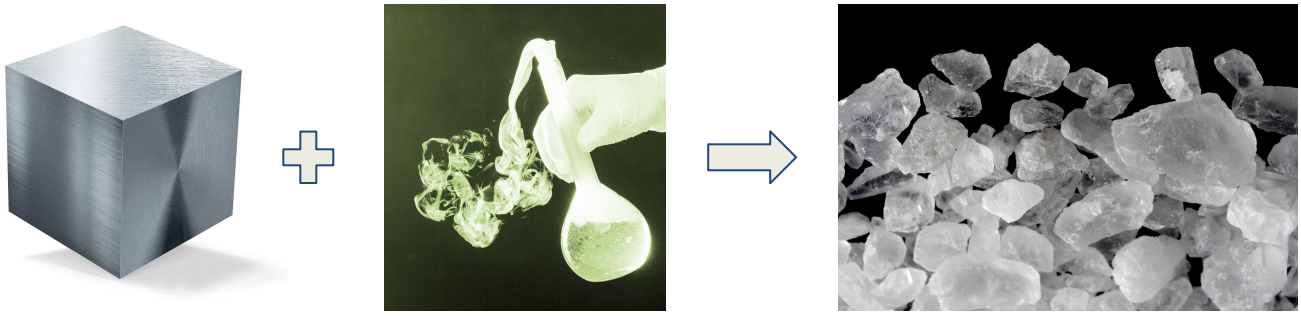


Substance	Chemical Property	Description
Wood		Wood catches on fire, displaying the production of light and heat.
Iron nail		Brittle orange rust, a new substance, forms on the surface of the object.
Potassium		When placed in water, potassium explodes rapidly, giving off heat and light.
Fruit		Organic tissues break down and begin to give off a foul odor when left in the heat over time.

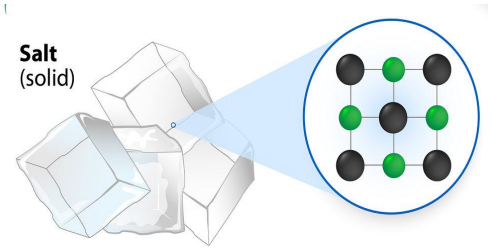
Reflect

Properties and Reactions

The production of a new substance is the only undeniable evidence that a chemical reaction has occurred. By examining the physical properties of the substances before and after the suspected chemical change, we can determine if a new substance was produced.



For example, sodium is a shiny silver solid, and chlorine is a toxic green gas. When sodium and chlorine react, they form sodium chloride (table salt). Sodium chloride is a white, granular solid. We know a chemical reaction has occurred because the properties of salt are so different from the properties of sodium and chlorine that it is easy to observe that a new substance was formed.



Look Out!

It is not always easy to determine if a new substance was formed. Sometimes the products of a chemical reaction can share some properties in common with the reactants that formed them. In these cases, very careful observation and measurement of many different properties should be made to determine if a new substance has formed. For example, when hydrogen peroxide (H_2O_2) is left out in an open dish, it will go through a decomposition reaction, breaking down into water (H_2O) and oxygen gas. This reaction of peroxide in the dilute solutions we can buy at the pharmacy will be very slow and impossible to observe by simply watching the liquid. However, if the properties of the clear liquids are carefully observed before and after the reaction, it is possible to prove a chemical change occurred. The table below shows one physical property and two chemical properties that could be used to prove a new substance was produced.

Substance	Odor	pH	Reactivity of Small Sample with Yeast
Hydrogen peroxide H_2O_2	Displeasing odor	Acidic	Fast reaction producing foamy bubbles and heat
Water H_2O	No odor	Neutral	Unreactive

Characteristics of Chemical Reactions

Reflect

When you combine two or more substances called *reactants*, the atoms interact, rearrange, and produce new substances called *products.* A **chemical reaction** takes place. Some chemical reactions take place quickly, such as a burning match. Others require more time, such as chains left outside for a month exposed to weather, which causes the iron to react with the oxygen in the air, producing a new compound called iron oxide, or rust. This overall reaction can be described in writing with the following chemical reaction equation:

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

reactants products

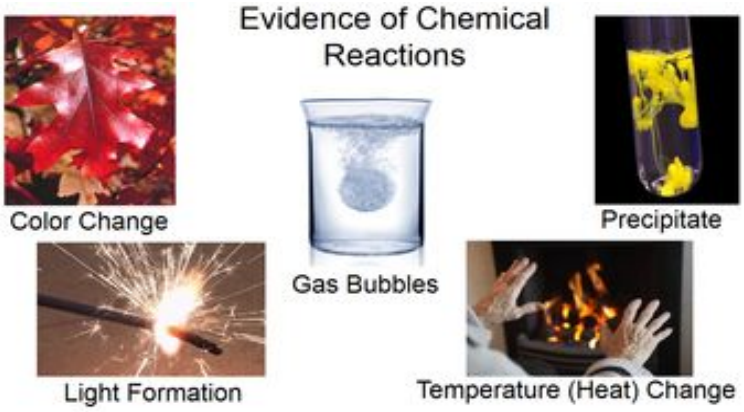
chemical reaction – a process by which two or more chemical substances interact and are chemically changed, producing different chemical substances

What Do You Think?

Take a look at the pictures below of a smelly, rotting pumpkin; a burning campfire; and some tarnished silverware. These images are examples of chemical reactions taking place. In each image, how do you know a chemical reaction is taking place?

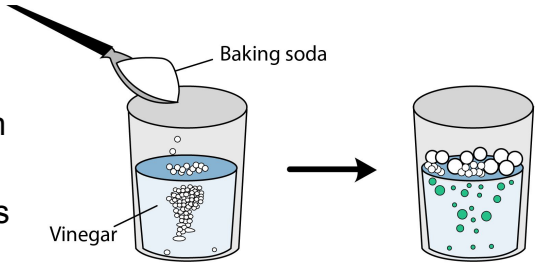
We can observe evidence of chemical reactions.

Scientists confirm that a chemical reaction has occurred by determining if a new substance with new properties was formed, sometimes using instrumentation. In most chemical reactions, there are signs that indicate a chemical reaction has occurred. If you observe one or more of the signs, this provides evidence that a chemical reaction may have taken place. Five possible signs of a chemical reaction are production of a gas, production of light, unexpected temperature change, unexpected color change, and the formation of a precipitate. These signs can be helpful as long as we remember that the only way to be certain that a chemical reaction has occurred is to identify a new substance that was produced in the reaction. Remember, not all chemical reactions will produce one of the five signs.



Reflect

Production of a gas: Mix sodium bicarbonate or baking soda ($NaHCO_3$) with an acid such as vinegar (CH_3COOH). What do you see? 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 to the right. 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 as follows:



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

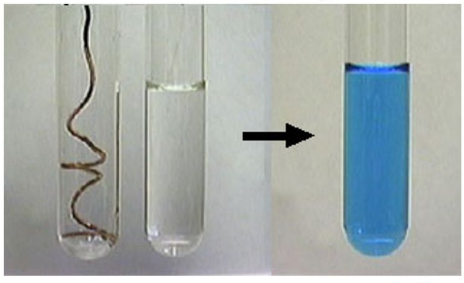
(vinegar) + (baking soda) → (sodium acetate) + (water) + (carbon dioxide)

Production of light: The burning of logs in a fireplace is the reaction of compounds in the wood rapidly combining with oxygen. Combustion reactions such as this one require a heat-initiation source to get started. 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 in the form of heat and light. This reaction 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 have applied a chemical heat pack to the area that creates a reaction that produces heat. When the heat pack is activated, the magnesium sulfate ($MgSO_4$) reacts with water and produces heat, which you use to soothe your injury. Chemical cold packs work in the opposite way when a chemical like ammonium nitrate is mixed with water. That combination absorbs heat, creating an endothermic reaction and feels 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 and often settles to the bottom of a liquid reaction. One common chemical reaction that forms a precipitate is the reaction in a solution of lead nitrate ($Pb(NO_3)_2$) and potassium iodide (KI). Each of these substances in a solution is clear and colorless. But if you mix a solution of each substance, lead iodide (PbI_2) and potassium nitrate (KNO_3) form as products. Lead iodide is insoluble, so it separates from the solution as a yellow precipitate (shown in the image on the right). The potassium nitrate remains in the solution. The chemical equation for this reaction is as follows: $KI + Pb(NO_3)_2 \rightarrow KNO_3 + PbI_2$.

Evidence of color change: The color of a substance may change when its chemical composition changes. An example of a color change as evidence of a chemical reaction is seen when copper wire is placed in a clear solution of silver nitrate. The product of the reaction is a blue solution. A color change represents more than just a physical change, such as diluting a substance or adding food color to a substance. The physical changes from food coloring are not evidence of chemical reactions.



What Do You Think?

Have you ever seen a fireworks display? These colorful little explosives are not just entertainment. When each firework is ignited, one or more chemical reactions take place. The color of the display in the sky is determined by the elements or compounds involved in each chemical reaction. What can you observe during a fireworks display? Perhaps you hear loud sounds, see bright lights, and feel the warmth from the explosion. Which are evidence of a chemical reaction?

Chemical reactions produce new substances.

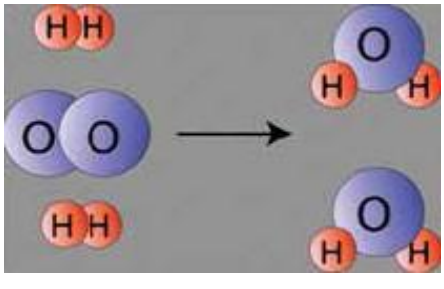
In a chemical reaction, molecules can change through the rearrangement of their atoms. More specifically, atoms of the reactants can rearrange to form new molecules. A chemical equation can be written to show what happens to the atoms in a chemical reaction. A chemical equation is written like this:

(reactants) → (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:

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

In chemical reactions, the reactants have properties different from the product's properties. For example, oxygen gas and hydrogen gas have different properties from 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.



Not all reactions combine elements to make compounds. Some reactions break down compounds into elements. When electricity is passed through water, the molecules react by breaking down into hydrogen and oxygen gas. The reaction equation is $2H_2O \rightarrow O_2 + 2H_2$.

Look Out!

Everyday Life: Rising dough is a chemical reaction.
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*. 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:

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

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$
(glucose) → (alcohol) + (carbon dioxide)

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.

Try Now

What do you know?
Certain evidence suggests that a chemical reaction 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 examples of reactions given below. Classify each reaction by which of the five types of evidence would be observed. Write your answers in the appropriate column on the next page. More than one type of evidence may be possible for each example.

Examples of Chemical Reactions	
• Exploding fireworks • Baking a cake • Burning paper • Mixing an antacid tablet and water • Making chalk from two liquids • Blue litmus paper turning red in acid	• Folding a heat pack to activate it causing an increase in temperature • 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

Characteristics of Chemical Reactions

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

Look Out!

Do not confuse some physical changes with chemical reactions. Suppose you dissolve sugar in a glass of water. The resulting product seems different from the reactants, but it is just a mixture of sugar and water. No new substance has formed, only a physical change. However, if you place antacid tablets in water, the tablets break down 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 on the right shows the gas bubbles in the glass.