Chemical Reactions

section o Chemical Formulas and Equations

Before You Read

What happens to wood when it burns? Describe the changes on the lines below.

Read to Learn

Physical or Chemical Change?

Have you ever seen smoke from a campfire? Smoke is a clue that a chemical reaction is taking place. There are always clues when a chemical reaction is happening.

Matter can change in two ways. It can have a physical change or a chemical change. Physical changes only affect physical properties. For example, the newspaper in the first figure is folded. It is a different shape, but it is still a newspaper. This is a physical change.

Chemical changes produce new substances. The newspaper in the second figure is burning. Burning is a chemical change because new substances are produced. The properties of the new substances are different from the properties of the original substances. A chemical reaction is a process that produces chemical change.

Physical Change



Chemical Change



What You'll Learn

- identify a chemical reaction
- how to read a balanced chemical equation
- how reactions release or absorb energy
- the law of conservation of mass

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Mark the Text

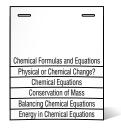
Highlight Chemical Equations Highlight each chemical equation in the section. Read the chemical equation two or three times to make sure you understand what is happening in

the chemical reaction.

FOLDABLES

A Organize Information

Make the following Foldable to help you organize information in this section. Write information about each topic in the Foldable.



Think it Over

1. Summarize What senses can you use to find clues that a chemical reaction is happening?

<u>Picture This</u>

2. **Describe** what you can see in the chemical reaction between vinegar and baking soda.

What are clues that a chemical reaction is happening?

You can use your senses to help you know if a chemical reaction is happening. When you watch a firefly glow, you are watching a chemical reaction. Two chemicals combine in the firefly's body and give off light. Your senses of touch and smell help detect chemical reactions in a fire. You smell the smoke and feel the heat. Have you ever tasted sour milk? If so, you have tasted the results of a chemical reaction. You can also hear a chemical reaction happening. The hissing sound of burning firewood is from a chemical reaction.

Chemical Equations

How can you describe a chemical reaction? First, you need to know which substances are reacting. You also need to know which substances are formed in the reaction. The substances that react are called reactants (ree AK tunts). **Reactants** are the substances that exist before the reaction starts. **Products** are the substances that are formed in the reaction.

Look at the figure below. A chemical reaction happens when you mix baking soda and vinegar. It bubbles and foams. The bubbles tell you that a chemical reaction happened.

Baking soda and vinegar are the common names for the reactants in this reaction. They also have chemical names. Baking soda is sodium hydrogen carbonate (often called sodium bicarbonate). Vinegar is a solution of acetic (uh SEE tihk) acid in water. What are the products of the reaction? You can see that bubbles form. What else is happening?

Chemical reaction with baking soda and vinegar



What is a chemical equation?

The bubbles from the baking soda and vinegar tell you a gas was produced. But, they do not tell you what kind of gas. Are bubbles of gas the only product? More happens in a chemical reaction than you can see with your eyes. Chemists try to find out what reactants are used and what products are formed in a chemical reaction. Then, they write a chemical equation. A <u>chemical equation</u> tells chemists the reactants, products, and amounts of each substance in the reaction. Some equation's tell the physical state of a substance.

How do words describe a chemical reaction?

Words can be used in an equation to name the reactants and products in a chemical reaction. The reactants in the equation are listed on the left side of an arrow. The reactants have plus signs between them. The products are on the right side of the arrow and also have plus signs between them. The arrow stands for the changes that happen during the chemical reaction. The arrow means produces.

You can begin to think of changes as chemical reactions even if you do not know the names of all the substances in the reaction. The table below shows word equations for chemical reactions you might see around your home.

Reactions Around the Home			
Reactants	Products		
Baking soda + Vinegar	\rightarrow	Gas + White solid	
Charcoal + Oxygen	\rightarrow	Ash + Gas + Heat	
Iron + Oxygen + Water	\rightarrow	Rust	
Silver + Hydrogen sulfide	\rightarrow	Black tarnish + Gas	
Gas (kitchen range) + Oxygen	\rightarrow	Gas + Heat	
Sliced apple + Oxygen	\rightarrow	Apple turns brown	

When are chemical names used?

Chemical names are usually used in word equations instead of common names like baking soda and vinegar. In the baking soda and vinegar reaction, you already know that the chemical names are sodium hydrogen carbonate and acetic acid. The chemical names of the products are sodium acetate, water, and carbon dioxide. The word equation for the reaction is:

Acetic acid + Sodium hydrogen carbonate → Sodium acetate + Water + Carbon dioxide

V	Reading Check
3.	Explain What do chemists learn from chemical equations?

Picture This

4.	Apply Use words to write
	a chemical equation for
	what happens when you
	peel a banana but do not
	eat it right away.
	- •

Why do chemists use chemical formulas?

The word equation for the reaction of baking soda and vinegar is long. So, chemists replace the chemical names with chemical formulas in the equation. The chemical equation for the reaction between baking soda and vinegar is:

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

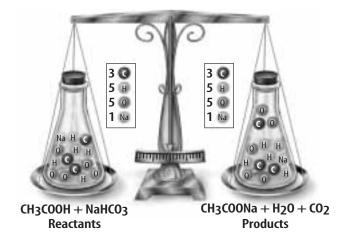
Acetic Sodium Sodium Water Carbon
acid hydrogen acetate dioxide
(vinegar) carbonate
(baking soda)

What are subscripts?

Look at the small numbers in the formula above. These numbers are called subscripts. They tell you the number of atoms of each element in that compound. For example, the subscript 2 in CO₂ means each molecule of carbon dioxide has two oxygen atoms. If an atom has no subscript, then there is only one atom of that element in the compound. There is only one atom of carbon in carbon dioxide.

Conservation of Mass

What happens to the atoms in the reactants when they are changed into products? The law of conservation of mass says that the mass of the products has to be the same as the mass of the reactants. French chemist Antoine Lavoisier proved that nothing is lost or created in chemical reactions. Chemical equations are like math equations. In math equations, the right and left sides of the equation are equal. In chemical equations, the number and kind of atoms are equal on both sides. The figure shows that every atom that is on the reactant side of the equation is also on the product side.



Think it Over

5. Identify How many hydrogen atoms are there in sodium acetate? How many sodium atoms (Na) are there?

Picture This

6. Identify How many hydrogen atoms are in the reactants in the figure? How many hydrogen atoms are in the products?

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Balancing Chemical Equations

You need to follow the law of conservation of mass when you write a chemical equation. Look back at the figure on the previous page. Count the number of each type of atom on each side of the scale. There are equal numbers of each kind of atom on each side. This means the equation is balanced. So, the law of conservation of mass is followed.

Not all chemical equations are balanced so easily. The following unbalanced equation shows what happens when silver tarnishes by reacting with sulfur compounds in air.

$$Ag + H_2S \rightarrow Ag_2S + H_2$$

Silver Hydrogen Silver Hydrogen
sulfide sulfide

How do you balance an equation?

Count the number of each type of atom in the reactants and products above. The reactants and products have the same numbers of hydrogen and sulfur atoms. But, there is one silver atom on the reactant side and two silver atoms are on the product side. This cannot be true. A chemical reaction cannot create a silver atom. This equation does not represent the reaction correctly. Place a 2 in front of the reactant Ag. Now see if the equation is balanced. Count the number of atoms of each type again.

$$2Ag + H_2S \rightarrow Ag_2S + H_2$$

The equation is now balanced. There are equal numbers of silver atoms in the reactants and the products. To balance chemical equations, numbers are placed before the formulas. These numbers, called coefficients, show how many molecules of a compound there are. Never change the subscripts in a formula. This changes the identity of the compound.

Practice balancing equations with the following:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

Count the number of carbon, hydrogen and oxygen atoms on each side. There are 2 more hydrogen atoms in the reactants. Multiply H₂O by 2 to give 4 hydrogen atoms.

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

Now there are 2 oxygen atoms in the reactants and 4 in the products. Multiply O₂ by 2 to give 4 oxygen atoms. The balanced equation is:

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

Reading Check

7.	Explain	What law is
	followed w	hen an equation
	is balanced	1 ?

App	lying	Math
	, ,	

8. Apply Balance this equation: $HCI + Cu \longrightarrow CuCl_2 + H_2$

Think it Over

9. Describe a reaction where energy is released as thermal energy.

Think it Over

10. **Identify** Which is more stable in this reaction water or hydrogen?

Picture This

11. **Determine** Where does the electrical energy come from to break water into hydrogen and oxygen atoms?

Energy in Chemical Reactions

Often, energy is released or absorbed in a chemical reaction. A welding torch burns hydrogen and oxygen to produce high temperatures. The energy for the torch is released when oxygen and hydrogen combine to form water.

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

Where does released energy come from?

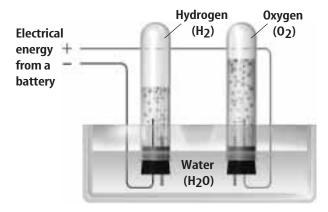
Think about the chemical bonds that break and form when atoms gain, lose, or share electrons. When a chemical reaction happens, bonds break in the reactants. New bonds form in the products. In reactions that release energy, the products are more stable. Their bonds have less energy than the bonds of the reactants. The extra energy is released. It can be released in forms like light, sound, and heat.

How is energy absorbed in a reaction?

In reactions where energy is absorbed, the reactants are more stable. Their bonds have less energy than the bonds in the products.

$$2H_2O$$
 + energy \rightarrow $2H_2$ + O_2 water Hydrogen Oxygen

In this reaction, electricity supplies the extra energy needed to break water into hydrogen and oxygen, as shown in the figure.



Reactions can release or absorb many forms of energy, including electricity, light, thermal energy, and sound. Special terms are used when thermal energy is gained or lost in reactions. Endothermic (en doh THUR mihk) reactions absorb it. Exothermic (ek soh THUR mihk) reactions release it. Therm means heat, as in thermometers.

What is an example of an exothermic reaction?

You probably already know of reactions that release thermal energy. Burning is an exothermic reaction. A substance combines with oxygen to produce thermal energy. Light, carbon dioxide, and water are also produced.

Sometimes thermal energy is released quickly. For example, charcoal lighter fluid combines with oxygen and produces enough of it to start a charcoal fire within a few minutes. Other materials also combine with oxygen, but they release thermal energy so slowly that you cannot see or feel it happen. This is what happens when iron combines with oxygen in the air to form rust.

What is an example of an endothermic reaction?

Sometimes heat energy must be added for a reaction to take place. The way a cold pack works is an example of an endothermic process. A cold pack is made of a thick plastic outer pouch filled with water. The pouch with water surrounds a thin plastic inner pouch filled with ammonium nitrate. When you squeeze the cold pack, the inner pouch breaks. The ammonium nitrate mixes with the water and dissolves. As the ammonium nitrate dissolves, it absorbs thermal energy from its surroundings. So, the cold pack absorbs thermal energy from your skin and your skin feels cold.

How is energy written in an equation?

The word *energy* in equations can be either a reactant or a product. When it is written as a reactant, it is something needed for the reaction to happen. For example, electricity is needed to break water into hydrogen and oxygen. It is important to know that energy must be added for this to happen.

In the equation for an exothermic reaction, energy often is written with the products. This tells you that energy is released. You include energy when you write the reaction that occurs between oxygen and methane in natural gas when you cook on a gas range. This thermal energy is what cooks your food.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + energy$$

Methane Oxygen Carbon Water dioxide

You don't have to write the word energy in an equation. But, if you do, it helps you remember that energy is an important part of the equation.



12. **Identify** What is released during an exothermic reaction?

Think it Over

13. Describe In what type of equation is energy written with the reactants?

After You Read

Mini Glossary

chemical equation: a written form that tells the reactants, products, physical state, and amounts of each substance in the reaction

chemical reaction: a process that produces chemical change endothermic (en doh THUR mihk) reaction: a reaction that absorbs heat energy

exothermic (ek soh THUR mihk) reaction: a reaction

that releases heat energy

product: a substance that is formed in the reaction

reactant (ree AK tunt): a substance that is there before the

reaction starts

1.	1. Read the key terms and definitions in the Mini Glossary al	ibove. I	n your	own	words,
	describe how a reactant and a product are related.				

2. Balance each equation in the table.

Equation	Balanced Equation
$H_2 + O_2 \rightarrow H_2O$	
$H_2 + Cl_2 \rightarrow HCl$	
AI + CuCl ₂ → AICl ₃ + Cu	

3.	How did highlighting the chemical equations in the section help you to understand
	chemical equations?





Section @ Rates of Chemical Reactions

Before You Read

Chemical reactions can happen quickly or slowly. Describe a chemical reaction that happens quickly.

What You'll Learn

■ how to measure the speed of a chemical reaction

■ how chemical reactions can be speeded up or slowed down

Read to Learn

How Fast?

Fireworks explode one after another quickly. Old copper pennies slowly darken. How long you fry an egg makes a difference in what the yolk is like. These are common chemical reactions in your life. Time has something to do with each example. Not all chemical reactions happen at the same speed.

Some reactions, like fireworks, need help to get going. Other chemical reactions seem to start by themselves. In this section, you also will learn what makes reactions speed up or slow down once they are going.

Activation Energy—Starting a Reaction

Before a reaction can start, molecules of the reactants have to bump into each other, or collide. The reactants must smash into each other with a certain amount of energy. If they do not have enough energy, the reaction will not happen. Why is this true?

Old bonds must break in the reactants so new bonds can form. This takes energy. To start any chemical reaction, at least some energy is needed. Activation energy is the energy needed to start a reaction. Even reactions that release energy need activation energy to start.

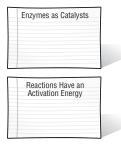
Study Coach

Make Flash Cards For each paragraph, think of a question that might be on a quiz. Write the question on one side of a flash card. Write the answer on the other side. Quiz yourself until you know all the answers.

FOLDABLES

(B) Organize Information Use two half sheets of paper to organize information about

activation energy and enzymes as catalysts.



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Gasoline One example of a reaction that needs energy to start is the burning of gasoline. Because gasoline needs energy to start burning, there are signs at filling stations warning you not to smoke. Other signs tell you to turn off your car, not to use mobile phones, and not to get in your car until you are finished fueling.

Reaction Rate

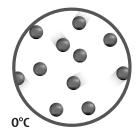
Many physical processes can be measured by rate. A rate tells you how much something changes over a given period of time. For example, you ride your bike at a rate, or speed. Rate is the distance you ride divided by the time it takes you to ride that distance. You may ride at a rate of 20 km/h.

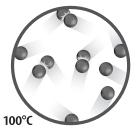
Chemical reactions have rates too. The <u>rate of reaction</u> tells how fast a reaction happens after it has started. You can measure the rate of reaction two ways. You can measure how fast one of the reactants is used up. You also can measure how fast one of the products is made. Both measurements tell how the amount of a substance changes per unit of time.

Reaction rate is important to companies that make products. The faster the product can be made, the less it usually costs. But sometimes fast rates of reaction are not good. A fast reaction rate can cause food to spoil quickly. A slower reaction rate will help food stay fresh longer.

How does temperature affect rate?

Increasing Temperature Most chemical reactions speed up when temperature increases. The high temperature inside an oven speeds up the chemical reactions that turn liquid batter into a cake. Atoms and molecules move faster at higher temperatures, as shown in the figure below. Faster molecules crash into each other more often than slower molecules. They also crash with more energy. These crashes often have enough energy to break the old bonds.





Think it Over

1. Apply Why do you think that the faster a product can be made, the less it usually costs?

Picture This

2. Analyze At which temperature are the molecules moving slower?

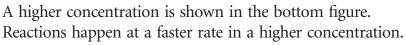
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Decreasing Temperature Lowering the temperature slows down most reactions. Food spoiling is a chemical reaction. Putting food in a refrigerator or freezer lowers its temperature. This slows the rate of reaction.

How does concentration affect rate?

When reactant atoms and molecules are closer together, there is a greater chance they will collide and react faster. Think about a crowd of people leaving a baseball game. When you try to walk through the crowd, you will probably bump into people. If it were not so crowded, you would be less likely to bump into people.

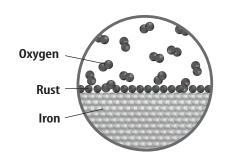
Concentration is the amount of substance in a certain volume. The figure on top shows molecules at a low concentration. If you increase the concentration, you increase the number of particles of a substance per unit of volume.

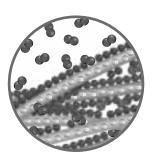


How does surface area affect rate?

Surface area also affects how fast a reaction happens. You can quickly start a campfire with small twigs, but starting a fire with only large logs would probably not work.

The figure on the left below shows the iron atoms in a steel beam. Most of the iron atoms are stuck inside the beam. They cannot react. Only the atoms in the outer layer of the reactant material can react. If more molecules are out in the open, the reaction speeds up. This happens with the iron atoms in steel wool, a mass of woven steel fibers, in the figure on the right below. Because more of its iron atoms are open to oxygen in the air, it will form rust faster.







3. Explain Why does lowering temperature slow down a chemical reaction?

Picture This

4. Describe In which circle are molecules more likely to bump into each other—the top circle or the bottom circle?

Picture This

5.	Compare How is the steel wool different from the steel beam?

FOLDABLES

Compare and **Contrast** Make the following Foldable to help you organize information in this section. Write information about each topic.





6. Analyze Why would you want to speed up the reactions that change harmful substances to less harmful ones in car exhaust?

Slowing Down Reactions

An **inhibitor** is a substance that slows down a chemical reaction. When an inhibitor is added to a reaction, it can take longer to form a certain amount of product. Some inhibitors completely stop reactions. Many cereals and cereal boxes contain butylated hydroxytoluene, or BHT. The BHT slows the spoiling of the cereal and the packaging material. This increases its shelf life. The shelf life is how long a product lasts without spoiling.

Speeding Up Reactions

You can speed up a chemical reaction by adding a catalyst (KAT uh lihst). A <u>catalyst</u> is a substance that speeds up a chemical reaction without changing permanently or being used up. Catalysts are not shown in chemical equations because they are not changed or used up in the reaction. Does a catalyst change how much product is made by a reaction? No, the same amount of product is made as would be made without the catalyst. But, with the catalyst, it will make the same amount of product faster.

How does a catalyst work?

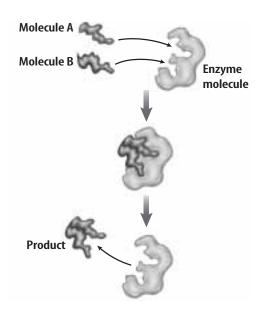
Many catalysts provide a surface on which the reaction occurs. Sometimes the catalyst holds the reacting molecules in a specific position that makes it better for the reaction to occur. Other catalysts reduce the activation energy needed to start a reaction.

How do catalytic converters work?

Catalysts are used in the exhaust systems of cars and trucks. They help fuel combustion, or burning. The exhaust goes through the catalyst. Beads coated with metals like platinum or rhodium are often the catalysts. Catalysts speed up the reactions that change the harmful substances in exhaust to less harmful substances. For example, they change carbon monoxide, a dangerous gas, into carbon dioxide, a gas normally found in air. Catalytic converters also change hydrocarbons into carbon dioxide and water. These reactions help keep the air cleaner. Without them, more harmful substances would go into the air.

What are enzymes?

Some of the best catalysts are at work in the reactions that take place in your body. These catalysts are called enzymes. Enzymes are large protein molecules that speed up reactions needed for your cells to work correctly. They help your body change food to fuel. They also help your body build bone and muscle tissue and change extra energy to fat. They even make other enzymes.



Without enzymes, reactions would happen too slowly to be useful or they would not happen at all. Enzymes work like other catalysts. They make a chemical reaction go faster by bringing certain molecules together. The figure shows how molecules that have the right shape can fit on the surface of an enzyme. Now the molecules can react and form a new product. Enzymes are chemical specialists. They exist to carry out each type of reaction in your body.

What are other uses for enzymes?

Enzymes work in other substances, too. One group of enzymes, called proteases (PROH tee ay ses), specializes in protein reactions. They work within cells to break down proteins. Proteins are large, complicated molecules. The meat tenderizer used on meat has proteases. The proteases break down the proteins in meat, making it more tender. Contact lens cleaning solutions also contain proteases. They break down proteins from your eyes that can collect on your contact lenses and cloud your view.

Reading Check

7. Identify What is one
example of how enzymes
help your body?

Picture This

8.	Describe what enzymes
	do to molecules.

After You Read

Mini Glossary

activation energy: the energy needed to start a reaction catalyst (KAT uh lihst): a substance that speeds up a chemical reaction without changing permanently or being used up

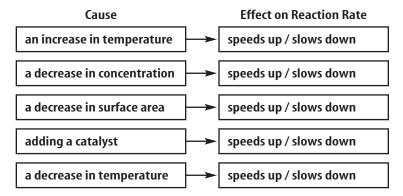
concentration: the amount of substance in a certain volume

enzyme: a large protein molecule that speeds up a reaction needed for cells to work correctly

inhibitor: a substance that slows down a chemical reaction rate of reaction: tells how fast a reaction happens after it has started

1.	Review the terms and their	definitions in	the Mini Glossary.	Write one	or two	sentences
	comparing and contrasting a	a catalyst and	an inhibitor.			

2. In the cause and effect chart below, decide whether the cause makes a chemical reaction speed up or slow down. Circle the correct answer.



3.	You were asked to write questions and answers on flash cards. How did making the flash
	cards help you learn about rates of chemical reactions?



Science Nine Visit ips.msscience.com to access your textbook, interactive games, and projects to help you learn more about rates of chemical reactions.