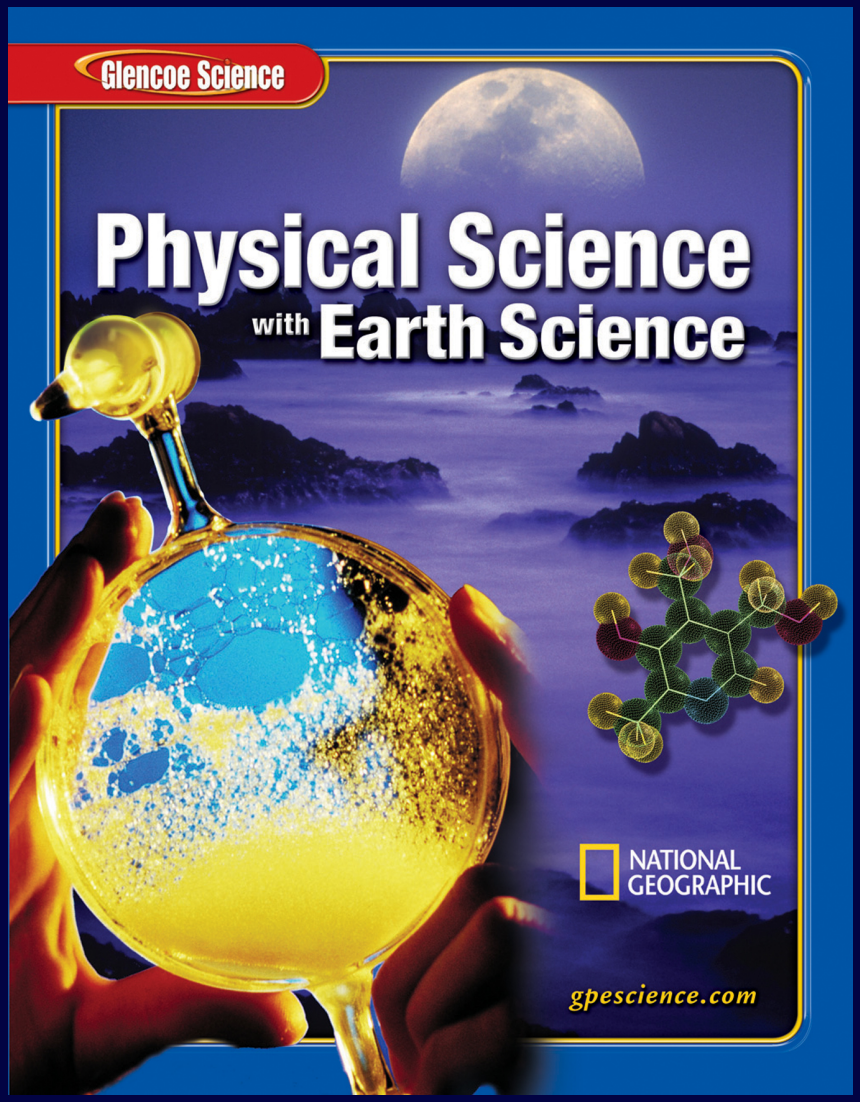
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Chapter: Chemical Reactions

1

Describing Chemical Reactions

- Chemical reactions are taking place all around you and even within you.
- A **chemical reaction** is a change in which one or more substances are converted into new substances.

A chemical reaction occurs when you bake a cake.

1

Describing Chemical Reactions

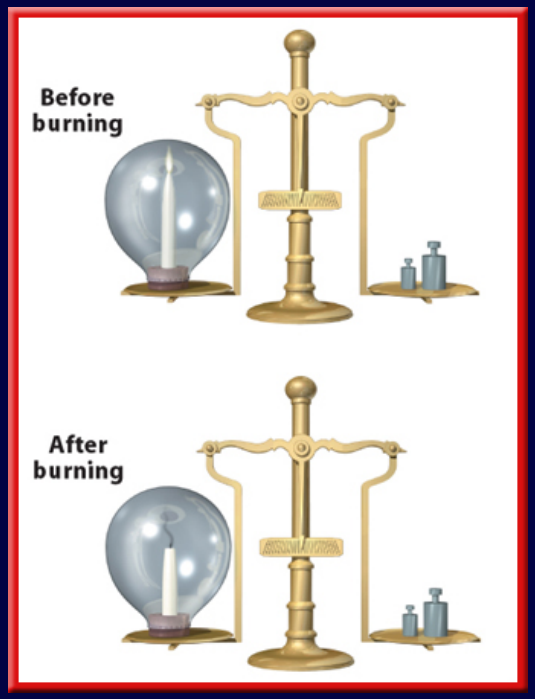
- The substances that react are called **reactants**.
- The new substances produced are called **products**.
- This relationship can be written as follows:

$$\text{reactants} \xrightarrow{\text{produce}} \text{products}$$

1

Conservation of Mass

- The French chemist Antoine Lavoisier established that the total mass of the products always equals the total mass of the reactants.
- For example, the mass of the candles and oxygen before burning is exactly equal to the mass of the remaining candle and gaseous products.



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Lavoisier's Contribution

- One of the questions that motivated Lavoisier was the mystery of exactly what happened when substances changed form.
- He began to answer this question by experimenting with mercury.

1

Lavoisier's Contribution

- Lavoisier placed a carefully measured mass of solid mercury (II) oxide, which he knew as mercury calx, into a sealed container.
- When he heated this container, he noted a dramatic change.
- The red powder had been transformed into a silvery liquid that he recognized as mercury metal, and a gas was produced.

1

Lavoisier's Contribution

- When he determined the mass of the liquid mercury and gas, their combined masses were exactly the same as the mass of the red powder he had started with.
- Lavoisier also established that the gas produced by heating mercury(II) oxide, which we call oxygen, was a component of air.

1

The Father of Modern Chemistry

- Lavoisier is known today as the father of modern chemistry for his more accurate explanation of the conservation of mass and for describing a common type of chemical reaction called combustion.

1

Nomenclature

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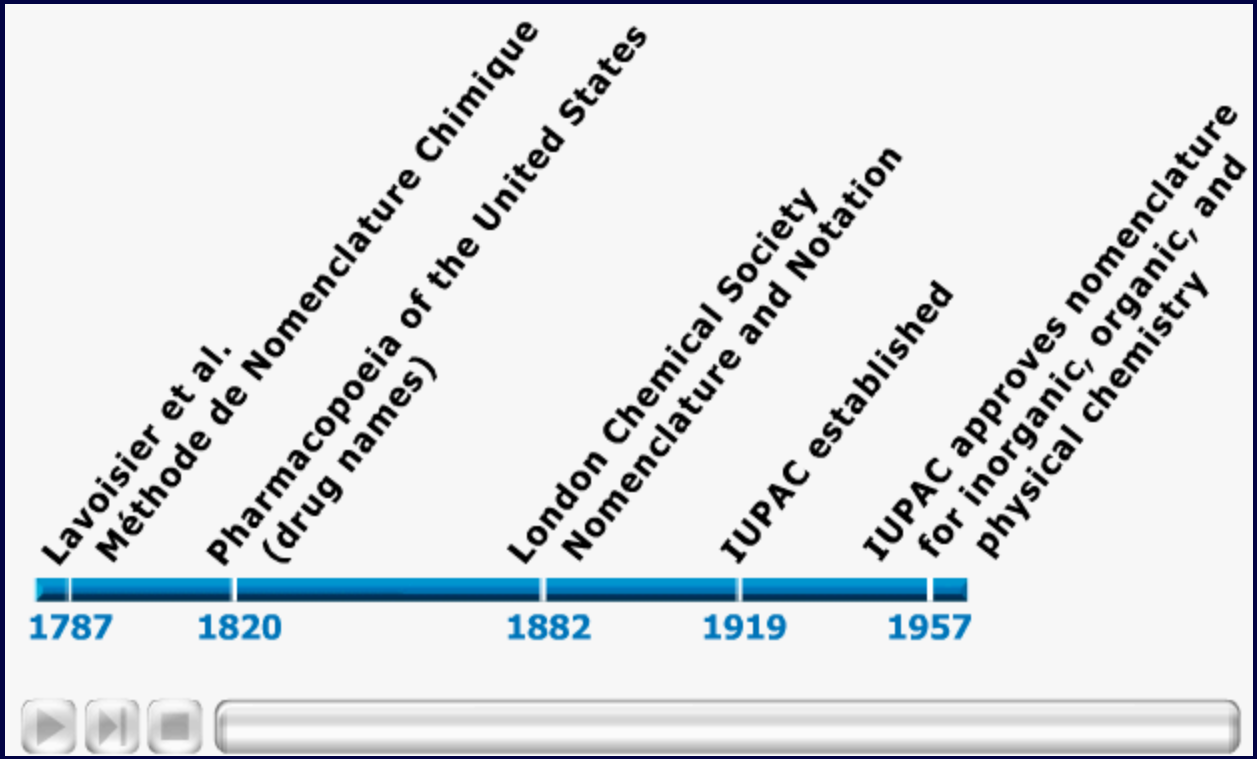
- Lavoisier developed the system of naming substances based on their composition that we still use today.



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Writing Equations

- Scientists have developed a shorthand method to describe chemical reactions.

- A **chemical equation** is a way to describe a chemical reaction using chemical formulas and other symbols.

1

Writing Equations

- Some of the symbols used in chemical equations are listed in the table.

Symbols Used in Chemical Equations

Symbol	Meaning
→	produces or forms
+	plus
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous, a substance is dissolved in water
heat →	the reactants are heated
light →	the reactants are exposed to light
elec. →	an electric current is applied to the reactants

1

Metals and the Atmosphere

- When iron is exposed to air and moisture, it corrodes or rusts, forming hydrated iron (III) oxide.
- Rust can seriously damage iron structures because it crumbles and exposes more iron to the air.

1

Metals and the Atmosphere

- Aluminum also reacts with oxygen in the air to form aluminum oxide.
- Unlike rust, aluminum oxide adheres to the aluminum surface, forming an extremely thin layer that protects the aluminum from further attack.

1

Metals and the Atmosphere

- Copper is another metal that corrodes when it is exposed to air, forming a blue-green coating called a patina.
- You can see this type of corrosion on many public monuments.

1

Question 1

What is a chemical reaction?

Answer

A process is a chemical reaction if one or more substances change into new substances.

1

Question 2

The principle that the total starting mass of all reactants equals the total final mass of all products is known as _____.

Answer

This is the law of conservation of mass; during a chemical change, matter can neither be created nor destroyed.

1

Question 3

Describe the products in the following reaction:

$$NiCl_2(aq) + 2NaOH(aq) \rightarrow Ni(OH)_2(s) + 2NaCl(aq)$$

A. aqueous
B. liquid
C. solid and liquid
D. solid and aqueous

1

Answer

The answer is D. The products are solid nickel(II) hydroxide and aqueous sodium chloride.

2

Balanced Equations

- Lavoisier's mercury(II) oxide reaction can be written as:

$$HgO(s) \xrightarrow{\text{heat}} Hg(l) + O_2(g)$$

- Notice that the number of mercury atoms is the same on both sides of the equation but that the number of oxygen atoms is not the same.

2

Balanced Equations

- One oxygen atom appears on the reactant side of the equation and two appear on the product side.
- According to the law of conservation of mass, one oxygen atom cannot just become two. Nor can you simply add the subscript 2 and write HgO_2 instead of HgO.

2

Balanced Equations

- The formulas in a chemical equation must accurately represent the compounds that react.
- Fixing this equation requires a process called balancing.
- The balancing process involves changing coefficients in a reaction to achieve a **balanced chemical equation**, which has the same number of atoms of each element on both sides of the equation.

2

Choosing Coefficients

- Finding out which coefficients to use to balance an equation is often a trial-and-error process.
- In the equation for Lavoisier's experiment, the number of mercury atoms is balanced, but one oxygen atom is on the left and two are on the right.

2

Choosing Coefficients

- If you put a coefficient of 2 before the HgO on the left, the oxygen atoms will be balanced, but the mercury atoms become unbalanced.
- To balance the equation, also put a 2 in front of mercury on the right. The equation is now balanced.

Atoms	$2HgO \rightarrow$	$2Hg + O_2$
Hg	2	2
O	2	2

2

Try Your Balancing Act

- Magnesium burns with such a brilliant white light that it is often used in emergency flares.
- Burning leaves a white powder called magnesium oxide.
- To write a balanced chemical equation for this and most other reactions, follow these four steps.

2

Try Your Balancing Act

- **Step 1** Write a chemical equation for the reaction using formulas and symbols.

$$Mg(s) + O_2(g) \rightarrow MgO(s)$$

- **Step 2** Count the atoms in reactants and products.

Atoms	Mg	+	O_2	→	2Hg
Mg	1				1
O			2		1

2

Try Your Balancing Act

- **Step 3** Choose coefficients that balance the equation.

- Remember, never change subscripts of a correct formula to balance an equation.

$$Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

2

Try Your Balancing Act

- **Step 4** Recheck the numbers of each atom on each side of the equation and adjust coefficients again if necessary.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

2

Question 1

In a chemical formula, how is the number of atoms of an element indicated?

Answer

In a chemical formula, subscripts are used with symbols for elements to indicate the number of atoms.

2

Question 2

What does it mean for a chemical equation to be balanced?

A. compounds exist in the same amounts both before and after a reaction

B. coefficients are the same for the reactants as for the products

2

C. there are the same number of atoms of each element on both sides of the chemical reaction

D. the rate of formation of products is equal to the rate of formation of reactants

2

Answer

The answer is C. Balancing an equation does not change what happens in the reaction.

2

Question 3

What is the correct balanced equation for the reaction of magnesium and oxygen?

A. $Mg(s) + O(g) \rightarrow MgO(s)$
B. $Mg(s) + O_2(g) \rightarrow MgO(s)$
C. $Mg_2(s) + O_2(g) \rightarrow 2MgO(s)$
D. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

2

Answer

The answer is D. Oxygen is a diatomic molecule. To balance an equation, change the coefficients, not the subscripts.

3

Types of Reactions

- There are literally millions of chemical reactions that occur every day.
- Chemists have defined five main categories of chemical reactions: combustion, synthesis, decomposition, single displacement, and double displacement.

3

Combustion Reactions

- If you have ever observed something burning, you have observed a combustion reaction.
- Our definition states that a **combustion reaction** occurs when a substance reacts with oxygen to produce energy in the form of heat and light.

3

Combustion Reactions

- Combustion reactions also produce one or more products that contain the elements in the reactants.

3

Synthesis Reactions

- In a **synthesis reaction**, two or more substances combine to form another substance. 
- The generalized formula for this reaction type is as follows: $A + B \rightarrow AB$.

3

Decomposition Reactions

- A decomposition reaction is just the reverse of a synthesis.
- Instead of two substances coming together to form a third, a **decomposition reaction** occurs when one substance breaks down, or decomposes, into two or more substances.

3

Decomposition Reactions

- The general formula for this type of reaction can be expressed as follows: $AB \rightarrow A + B$.
- Most decomposition reactions require the use of heat, light, or electricity.

3

Single Displacement

- When one element replaces another element in a compound, it is called a **single-displacement reaction**.
- Single-displacement reactions are described by the general equation $A + BC \rightarrow AC + B$.
- Here you can see that atom A displaces atom B to produce a new molecule AC, a single displacement reaction.

3

The Activity Series

- We can predict which metal will replace another using the diagram shown which lists metals according to how reactive they are.
- A metal will replace any less active metal.

3

Double Displacement

- In a **double-displacement reaction**, the positive ion of one compound replaces the positive ion of the other to form two new compounds. 
- A double displacement reaction takes place if a precipitate, water, or a gas forms when two ionic compounds in solution are combined.

3

Double Displacement

- A **precipitate** is an insoluble compound that comes out of solution during this type of reaction.

- The generalized formula for this type of reaction is as follows: $AB + CD \rightarrow AD + CB$.

3

Oxidation-Reduction Reactions

- One characteristic that is common to many chemical reactions is the tendency of the substances to lose or gain electrons.

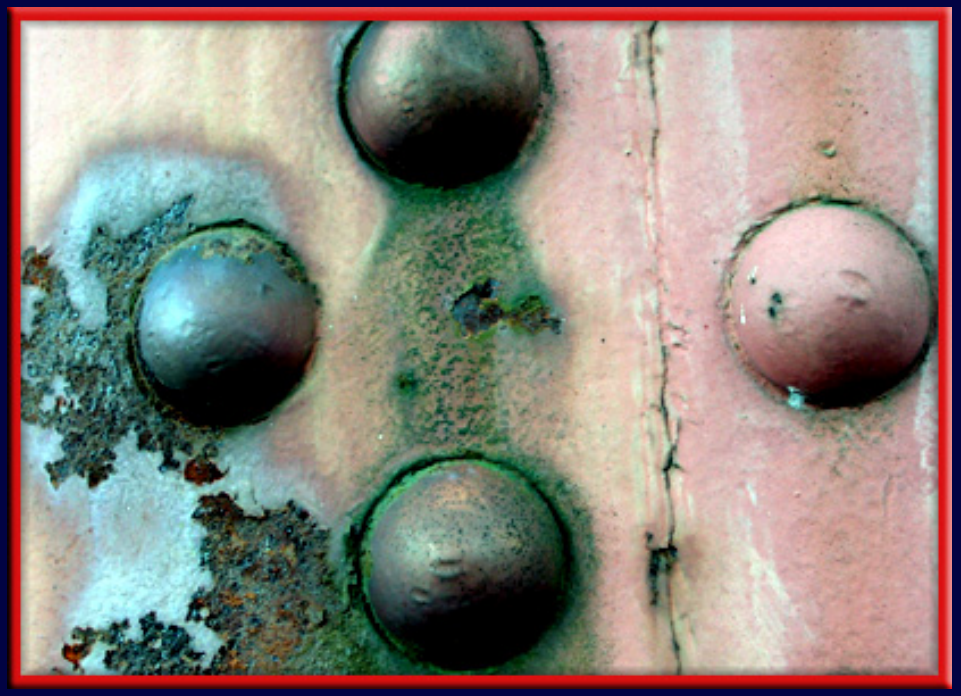
- Chemists use the term **oxidation** to describe the loss of electrons and the term **reduction** to describe the gain of electrons.

3

Oxidation-Reduction Reactions

- Chemical reactions involving electron transfer of this sort often involve oxygen, which is very reactive, pulling electrons from metallic elements.

- Corrosion of metal is a visible result.



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Oxidation-Reduction Reactions

- The substance that gains an electron or electrons obviously becomes more negative, so we say it is reduced.
- On the other hand, the substance that loses an electron or electrons then becomes more positive, and we say it is oxidized.

3

Oxidation-Reduction Reactions

- The electrons that were pulled from one atom were gained by another atom in a chemical reaction called reduction.
- Reduction is the partner to oxidation; the two always work as a pair, which is commonly referred to as redox.

3

Question 1

In a _____ reaction, two or more substances combine to form another substance.

A. combustion
B. displacement
C. decomposition
D. synthesis

3

Answer

The answer is D. The generalized formula for synthesis reactions is $A + B \rightarrow AB$.

3

Question 2

The opposite of a synthesis reaction is a _____ reaction.

A. combustion
B. double displacement
C. decomposition
D. single displacement

3

Answer

The answer is C. A decomposition reaction occurs when one substance breaks down into two or more substances.

3

Question 3

The reaction in which the positive ion of one compound replaces the positive ion of the other to form two new compounds is the _____ reaction.

A. combustion
B. double displacement
C. decomposition
D. single displacement

3

Answer

The answer is B. A double displacement takes place if a precipitate, water, or a gas form when two ionic compounds in solution are combined.

4

Chemical Reactions—Energy Exchanges

- A dynamic explosion is an example of a rapid chemical reaction.
- Most chemical reactions proceed more slowly, but all chemical reactions release or absorb energy.

4

Chemical Reactions—Energy Exchanges

- This energy can take many forms, such as heat, light, sound, or electricity.
- Chemical bonds are the source of this energy.

4

Chemical Reactions—Energy Exchanges

- When most chemical reactions take place, some chemical bonds in the reactants are broken, which requires energy.
- In order for products to be produced, new bonds must form. Bond formation releases energy.

4

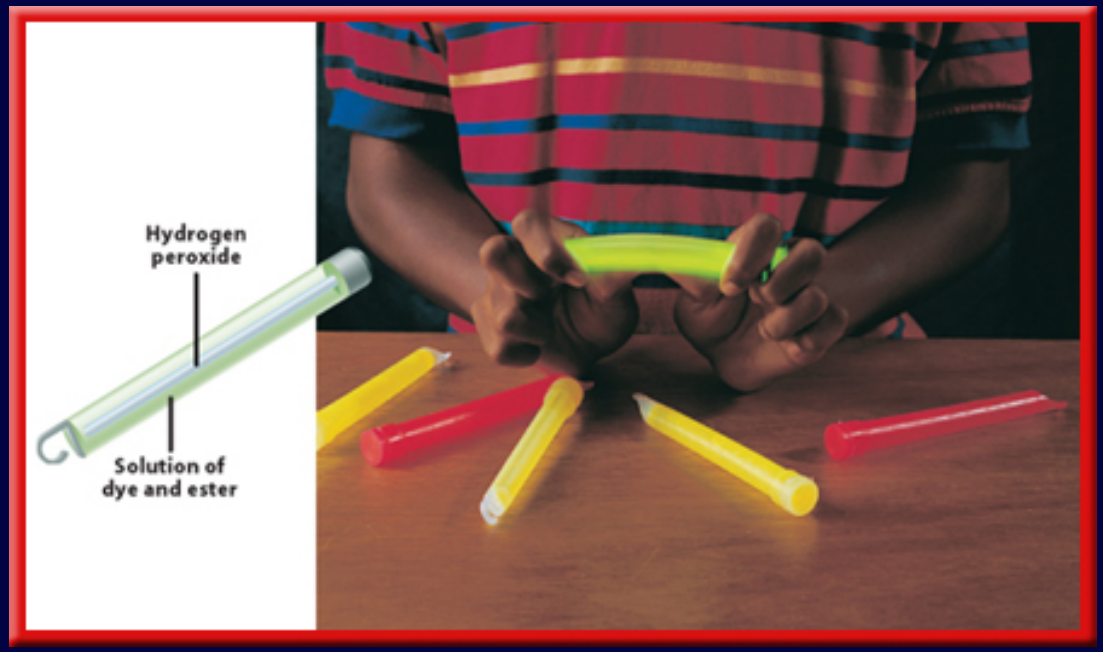
More Energy Out

- Chemical reactions that release energy are called **exergonic** (ek sur GAH nihk) **reactions**. 
- In these reactions less energy is required to break the original bonds than is released when new bonds form.

4

More Energy Out

- As a result, some form of energy, such as light or heat is given off by the reaction.
- The familiar glow from the reaction inside a glow stick is an example of an exergonic reaction, which produces visible light.



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Heat Release

- When the energy given off in a reaction is primarily in the form of heat, the reaction is called an **exothermic reaction**.
- The burning of wood and the explosion of dynamite are exothermic reactions.

4

More Energy In

- Sometimes a chemical reaction requires more energy to break bonds than is released when new ones are formed.
- These reactions are called **endergonic reactions**.
- The energy absorbed can be in the form of light, heat or electricity.

4

Heat Absorption

- When the energy needed is in the form of heat, the reaction is called an **endothermic reaction**. 
- Some reactions are so endothermic that they can cause water to freeze.
- One such endothermic reaction is that of barium hydroxide $(BaOH)_2$ and ammonium chloride (NH_4Cl) in water.

4

Heat Absorption

- Energy from the surrounding environment is absorbed, causing a cooling effect.

- Here, the reaction absorbs so much heat that a drop of water freezes and the beaker holding the reaction sticks to the wood.

4

Catalysts and Inhibitors

- Some reactions proceed too slowly to be useful.
- To speed them up, a catalyst can be added.
- A **catalyst** is a substance that speeds up a chemical reaction without being permanently changed itself.

4

Catalysts and Inhibitors

- When you add a catalyst to a reaction, the mass of the product that is formed remains the same, but it will form more rapidly.

4

Catalysts and Inhibitors

- At times, it is worthwhile to prevent certain reactions from occurring.
- Substances called **inhibitors** are used to slow down a chemical reaction.
- One thing to remember when thinking about catalysts and inhibitors is that they do not change the amount of product produced. They only change the rate of production.

4

Question 1

What is the difference between exergonic and exothermic?

Answer

An exergonic reaction is a chemical reaction that releases energy. An exothermic reaction is an exergonic reaction that releases heat.

4

Question 2

When heat is needed for a chemical reaction, it is called an _____ reaction.

A. endergonic
B. endothermic
C. exergonic
D. exothermic

4

Answer

The answer is B. In an endothermic reaction, energy is needed in the form of heat.

4

Question 3

What is the substance that speeds up a chemical reaction without being permanently changed itself?

Answer

A substance that speeds up a chemical reaction without being permanently changed itself is called a catalyst.

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