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GRADE 8



Louisiana Student Standards for Science

Correlated to Grade 8

Student Performance Expectations [PE]	Chapter and Lesson References
Matter And Its Interactions	
<p>8-MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.* [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of extended structures could include minerals such as but not limited to halite, agate, calcite, or sapphire. Examples of molecular-level models could include drawings, 3-D models, or computer representations showing different molecules with different types of atoms.]</p>	<p>Chapter 2</p> <p>Project-Based Learning Activity <i>Model Molecules</i> (online at ConnectED)</p>
<p>8-MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.* [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form synthetic materials. These natural resources may or may not be pure substances. Examples of new materials could include new medicine, foods, or alternative fuels, and focus is on qualitative as opposed to quantitative information.]</p>	<p>Chapter 13</p> <p>Project-Based Learning Activity <i>Protect Your Noggin</i> (online at ConnectED)</p>
<p>8-MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride, calcium chloride or a citric acid and baking soda (sodium bicarbonate) reaction in order to warm or cool an object.]</p>	<p>Chapter 3</p> <p>Project-Based Learning Activity <i>All Things Warm it Up!</i> (online at ConnectED)</p>
Energy	
<p>8-MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. [Clarification Statement: Emphasis is on the ability to maximize or minimize thermal energy transfer as it relates to devices used when an area loses electricity after a natural disaster. Examples of devices could include an insulated box or a solar cooker. Testing of the device relies on performance and not direct calculation of the total amount of thermal energy transferred.]</p>	<p>Chapter 3, 4</p> <p>Project-Based Learning Activity <i>Cookin' with the Sun</i> (online at ConnectED)</p>
<p>8-MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy (i.e. mechanical, thermal, or other forms of energy) before and after the transfer in the form of temperature changes or motion of object. This does not include the quantification of the energy transferred in the system.]</p>	<p>Chapter 4</p> <p>Project-Based Learning Activity <i>Tearin' It Up!</i> (online at ConnectED)</p>
Earth'S Place In The Universe	
<p>8-MS-ESS1-4 Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's geologic history. [Clarification Statement: Emphasis is on analyses of rock formations and fossils they contain to establish relative ages of major events in Earth's history. Major events could include the formation of mountain chains and ocean basins, adaptation and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion. The events in Earth's history happened in the past continue today. Scientific explanations can include models.]</p>	<p>Chapters 10, 11</p> <p>Project-Based Learning Activity <i>Puzzles Rock!</i> (online at ConnectED)</p>

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Student Performance Expectations [PE]	Chapter and Lesson References
Earth's Systems	
<p>8-MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.]</p>	<p>Chapter 5</p> <p>Project-Based Learning Activity <i>Rockin' Around the Park</i> (online at ConnectED)</p>
<p>8-MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of a large mountain ranges) or small (such as rapid landslides on microscopic geochemical reactions), and how many geosciences processes usually behave gradually but are punctuated by catastrophic events (such as earthquakes, volcanoes, and meteor impacts). Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]</p>	<p>Chapters 6, 7, 8</p> <p>Project-Based Learning Activity <i>When on Earth?</i> (online at ConnectED)</p>
<p>8-MS-ESS2-3 Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and sea floor structures to provide evidence of the past plate motions. [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).]</p>	<p>Chapters 8, 10</p> <p>Project-Based Learning Activity <i>Movin' Mountains</i> (online at ConnectED)</p>
Earth And Human Activity	
<p>8-MS-ESS3-1 Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).]</p>	<p>Chapter 13</p> <p>Project-Based Learning Activity <i>Where in the World...</i> (online at ConnectED)</p>
<p>8-MS-ESS3-2 Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects. [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]</p>	<p>Chapter 9</p> <p>Project-Based Learning Activity <i>Shake, Rattle, and Roll!</i> (online at ConnectED)</p>
<p>8-MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing human impact on the environment. [Clarification Statement: Examples of the design process may include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts may include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]</p>	<p>Chapter 14</p> <p>Project-Based Learning Activity <i>Who's Moving in Next Door?</i> (online at ConnectED)</p>



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Student Performance Expectations [PE]	Chapter and Lesson References
From Molecules To Organisms: Structures And Processes	
8-MS-LS1-4 Construct and use argument(s) based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of survival and successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, or vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds or creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, or hard shells on nuts that squirrels bury.]	Chapters 15, 16
8-MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, or fish growing larger in large ponds than they do in small ponds.]	Chapter 15 Project-Based Learning Activity <i>Ready, Set, Grow</i> (online at ConnectED)
Heredity: Inheritance And Variation Of Traits	
8-MS-LS3-1 Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.* [Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins. Examples include radiation treated plants, genetically modified organisms (e.g. roundup resistant crops, bioluminescence), or mutations both harmful and beneficial.]	Chapter 17 Project-Based Learning Activity <i>Model Mighty Mutations</i> (online at ConnectED)
Biological Evolution: Unity And Diversity	
8-MS-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.]	Chapter 18 Project-Based Learning Activity <i>Set in Stone</i> (online at ConnectED)
8-MS-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]	Chapter 18 Project-Based Learning Activity <i>It's All Relative</i> (online at ConnectED)
8-MS-LS4-3 Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.]	Chapter 18 Project-Based Learning Activity <i>If you've seen one....</i> (online at ConnectED)
8-MS-LS4-6 Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations of species over time. [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time. Students should be able to explain trends in data for the number of individuals with specific traits changing over time.]	Chapter 18 ; Project-Based Learning Activity <i>Population Probabilities</i> (online at ConnectED)

Table of Contents

Scientific Problem Solving NOS 2

Lesson 1 Scientific Inquiry NOS 4

Lesson 2 Measurement and Scientific Tools NOS 18

☑ **Skill Practice** How do geometric shapes differ in strength? NOS 25

Lesson 3 Case Study NOS 26

☑ **Lab** Build and Test a Bridge NOS 34

Unit 1 Interactions of Matter 2

Chapter 1 Understanding the Atom 6

Lesson 1 Discovering Parts of an Atom 8

Lesson 2 Protons, Neutrons, and Electrons—How Atoms Differ 21

☑ **Lab** Communicate Your Knowledge about the Atom 30

Chapter 2 Elements and Chemical Bonds 38

Lesson 1 Electrons and Energy Levels 40

Lesson 2 Compounds, Chemical Formulas, and Covalent Bonds 49

☑ **Skill Practice** How can you model compounds? 56

Lesson 3 Ionic and Metallic Bonds 57

☑ **Lab** Ions in Solution 64

Chapter 3 Chemical Reactions and Equations 72

Lesson 1 Understanding Chemical Reactions 74

☑ **Skill Practice** What can you learn from an experiment? 84

Lesson 2 Types of Chemical Reactions 85

Lesson 3 Energy Changes and Chemical Reactions 91

☑ **Lab** Design an Experiment to Test Advertising Claims 98

Chapter 4 Using Energy and Heat 106

Lesson 1 Forms of Energy 108

☑ **Skill Practice** How can you classify different types of energy? 116

Lesson 2 Energy Transfers and Transformations 117

Lesson 3 Particles in Motion 127

☑ **Lab** Power a Device with a Potato 136

Unit 2 Earth and Geological Changes 144

Chapter 5 Minerals and Rocks 148

Lesson 1 Minerals 150

Lesson 2 Rocks 160

☑ **Skill Practice** How are rocks similar and different? 167

Lesson 3 The Rock Cycle 168

☑ **Lab** Design a Forensic Investigation 174

Chapter 6	Weathering and Soil	182
Lesson 1	Weathering	184
	☞ Skill Practice What causes weathering?	192
Lesson 2	Soil	193
	☞ Lab Soil Horizons and Soil Formation	202
Chapter 7	Erosion and Deposition	210
Lesson 1	The Erosion-Deposition Process	212
Lesson 2	Landforms Shaped by Water and Wind	222
	☞ Skill Practice How do water erosion and deposition occur along a stream?	230
Lesson 3	Mass Wasting and Glaciers	231
	☞ Lab Avoiding a Landslide	238
Chapter 8	Plate Tectonics	246
Lesson 1	The Continental Drift Hypothesis	248
Lesson 2	Development of a Theory	256
	☞ Skill Practice How do rocks on the seafloor vary with age away from a mid-ocean ridge?	263
Lesson 3	The Theory of Plate Tectonics	264
	☞ Lab Movement of Plate Boundaries	274
Chapter 9	Earthquakes and Volcanoes	282
Lesson 1	Earthquakes	284
	☞ Skill Practice Can you locate an earthquake's epicenter?	296
Lesson 2	Volcanoes	298
	☞ Lab The Dangers of Mount Rainier	308
Chapter 10	Clues to Earth's Past	316
Lesson 1	Fossils	318
Lesson 2	Relative-Age Dating	328
	☞ Skill Practice Practice Can you correlate rock formations?	335
Lesson 3	Absolute-Age Dating	336
	☞ Lab Correlate Rocks Using Index Fossils	344
Chapter 11	Geologic Time	352
Lesson 1	Geologic History and the Evolution of Life	354
	☞ Skill Practice How has life changed over time?	361
Lesson 2	The Paleozoic Era	362
	☞ Skill Practice When did coal form?	369
Lesson 3	The Mesozoic Era	370
Lesson 4	The Cenozoic Era	378
	☞ Lab Modeling Geologic Time	386

Table of Contents

Unit 3 Water and Other Resources394

Chapter 12 Earth's Water 398

- Lesson 1** The Water Planet400
- Lesson 2** The Properties of Water 410
 - ☑ **Skill Practice** Why is liquid water denser than ice? 418
- Lesson 3** Water Quality 419
 - ☑ **Lab** Temperature and Water's Density426

Chapter 13 Using Natural Resources..... 434

- Lesson 1** Earth's Resources.....436
- Lesson 2** Pollution.....446
 - ☑ **Skill Practice** How can you communicate about pollution?.....453
- Lesson 3** Protecting Earth454
 - ☑ **Lab** How can you conserve a natural resource?.....462

Chapter 14 Environmental Impacts..... 470

- Lesson 1** People and the Environment.....472
 - ☑ **Skill Practice** What amount of Earth's resources do you use in a day?477
- Lesson 2** Impacts on the Land478
 - ☑ **Skill Practice** How will you design an environmentally safe landfill?.....487
- Lesson 3** Impacts on Water.....488
- Lesson 4** Impacts on the Atmosphere.....496
 - ☑ **Lab** Design a Green City.....504

Unit 4 Life: Changes and Interactions.....512

Chapter 15 Plant Processes and Reproduction516

- Lesson 1** Energy Processing in Plants.....518
- Lesson 2** Plant Responses.....526
 - ☑ **Skill Practice** What happens to seeds if you change the intensity of light?535
- Lesson 3** Plant Reproduction536
 - ☑ **Lab** Design a Stimulating Environment for Plants.....546

Chapter 16 Animal Behavior and Reproduction..... 554

- Lesson 1** Types of Behavior556
 - ☑ **Skill Practice** Can the color or surface of an area determine how a mealworm will move?565
- Lesson 2** Interacting with Others566
- Lesson 3** Animal Reproduction and Development574
 - ☑ **Lab** What changes an earthworm's behavior?582

Table of Contents

Chapter 17 Heredity and How Traits Change	590
Lesson 1 How are traits inherited?	592
Lesson 2 Genetics After Mendel	601
🔍 Skill Practice What can you learn by analyzing a pedigree?	609
Lesson 3 Adaptation and Evolution	610
🔍 Lab What's in a face?	618
Chapter 18 The Environment and Change Over Time	626
Lesson 1 Fossil Evidence of Evolution	628
🔍 Skill Practice Can you observe changes through time in collections of everyday objects?	637
Lesson 2 Theory of Evolution by Natural Selection	638
Lesson 3 Biological Evidence of Evolution	648
🔍 Lab Model Adaptations in an Organism	656

Student Resources

Science Skill Handbook	SR-1
Scientific Methods	SR-2
Safety Symbols	SR-11
Safety in the Science Laboratory	SR-12
Math Skill Handbook	SR-14
Math Review	SR-14
Science Application	SR-24
Foldables Handbook	SR-29
Reference Handbook	SR-40
Periodic Table of the Elements	SR-40
Diversity of Life: Classification of Living Organisms	SR-42
Use and Care of a Microscope	SR-46
Glossary	G-2
Index	I-2

Chemical Reactions and Equations



What happens to atoms and energy during a chemical reaction?

inquiry

How does it work?

An air bag deploys in less than the blink of an eye. How does the bag open so fast? At the moment of impact, a sensor triggers a chemical reaction between two chemicals. This reaction quickly produces a large amount of nitrogen gas. This gas inflates the bag with a pop.

- A chemical reaction can produce a gas. How is this different from a gas produced when a liquid boils?
- Where do you think the nitrogen gas that is in an air bag comes from? Do you think any of the chemicals in the air bag contain the element nitrogen?
- What do you think happens to atoms and energy during a chemical reaction?

Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

- 1 If a substance bubbles, you know a chemical reaction is occurring.
- 2 During a chemical reaction, some atoms are destroyed and new atoms are made.
- 3 Reactions always start with two or more substances that react with each other.
- 4 Water can be broken down into simpler substances.
- 5 Reactions that release energy require energy to get started.
- 6 Energy can be created in a chemical reaction.



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Lesson 1

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- What are some signs that a chemical reaction might have occurred?
- What happens to atoms during a chemical reaction?
- What happens to the total mass in a chemical reaction?

Vocabulary

chemical reaction p. 75

chemical equation p. 78

reactant p. 79

product p. 79

law of conservation of mass
p. 80

coefficient p. 82



Multilingual eGlossary

Understanding Chemical Reactions



PBL

Go to the resource tab in ConnectED to find the PBL *All Things Being Equal*.

Inquiry

Does it run on batteries?

Flashes of light from fireflies dot summer evening skies in many parts of the United States. But, firefly light doesn't come from batteries. Fireflies make light using a process called bioluminescence (bi oh lew muh NE cents). In this process, chemicals in the firefly's body combine in a two-step process and make new chemicals and light.

Darwin Dale/Science Source






Where did it come from?

Does a boiled egg have more mass than a raw egg? What happens when liquids change to a solid?

- 1 Read and complete a lab safety form.
- 2 Use a **graduated cylinder** to add 25 mL of **solution A** to a **self-sealing plastic bag**. Place a **stoppered test tube** containing **solution B** into the bag. Be careful not to dislodge the stopper.
- 3 Seal the bag completely, and wipe off any moisture on the outside with a **paper towel**. Place the bag on the **balance**. Record the total mass in your Science Journal.
- 4 Without opening the bag, remove the stopper from the test tube and allow the liquids to mix. Observe and record what happens.
- 5 Place the sealed bag and its contents back on the balance. Read and record the mass.



Think About This

1. What did you observe when the liquids mixed? How would you account for this observation?
2. Did the mass of the bag's contents change? If so, could the change have been due to the precision of the balance, or did the matter in the bag change its mass? Explain.
3.  **Key Concept** Do you think matter was gained or lost in the bag? How can you tell?

Changes in Matter

When you put liquid water in a freezer, it changes to solid water, or ice. When you pour brownie batter into a pan and bake it, the liquid batter changes to a solid, too. In both cases, a liquid changes to a solid. Are these changes the same?


Physical Changes

Recall that matter can undergo two types of changes—chemical or physical. A physical change does not produce new substances. The substances that exist before and after the change are the same, although they might have different physical properties. This is what happens when liquid water freezes. Its physical properties change from a liquid to a solid, but the water, H_2O , does not change into a different substance. Water molecules are always made up of two hydrogen atoms bonded to one oxygen atom regardless of whether they are solid, liquid, or gas.

Chemical Changes

Recall that during a chemical change, one or more substances change into new substances. The starting substances and the substances produced have different physical and chemical properties. For example, when brownie batter bakes, a chemical change occurs. Many of the substances in the baked brownies are different from the substances in the batter. As a result, baked brownies have physical and chemical properties that are different from those of brownie batter.

A chemical change also is called a chemical reaction. These terms mean the same thing. A **chemical reaction** is a process in which atoms of one or more substances rearrange to form one or more new substances. In this lesson, you will read what happens to atoms during a reaction and how these changes can be described using equations.

-  **Reading Check** What types of properties change during a chemical reaction?



Signs of a Chemical Reaction





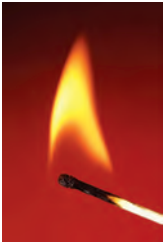

How can you tell if a chemical reaction has taken place? You have read that the substances before and after a reaction have different properties. You might think that you could look for changes in properties as a sign that a reaction occurred. In fact, changes in the physical properties of color, state of matter, and odor are all signs that a chemical reaction might have occurred. Another sign of a chemical reaction is a change in energy. If substances get warmer or cooler or if they give off light or sound, it is likely that a reaction has occurred. Some signs that a chemical reaction might have occurred are shown in **Figure 1**.

However, these signs are not proof of a chemical change. For example, bubbles appear when water boils. But, bubbles also appear when baking soda and vinegar react and form carbon dioxide gas. How can you be sure that a chemical reaction has taken place? The only way to know is to study the chemical properties of the substances before and after the change. If they have different chemical properties, then the substances have undergone a chemical reaction.



Key Concept Check What are some signs that a chemical reaction might have occurred?

Figure 1 You can detect a chemical reaction by looking for changes in properties and changes in energy of the substances that reacted.

Change in Properties			
Change in color Bright copper changes to green when the copper reacts with certain gases in the air.		Formation of bubbles Bubbles of carbon dioxide form when baking soda is added to vinegar.	
Change in odor When food burns or rots, a change in odor is a sign of chemical change.		Formation of a precipitate A precipitate is a solid formed when two liquids react.	
Change in Energy			
Warming or cooling Thermal energy is either given off or absorbed during a chemical change.		Release of light A firefly gives off light as the result of a chemical change.	

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What happens in a chemical reaction?


During a chemical reaction, one or more substances react and form one or more new substances. How are these new substances formed?

Atoms Rearrange and Form New Substances

To understand what happens in a reaction, first review substances. Recall that there are two types of substances—elements and compounds. Substances have a fixed arrangement of atoms. For example, in a single drop of water, there are trillions of oxygen and hydrogen atoms. However, all of these atoms are arranged in the same way—two atoms of hydrogen are bonded to one atom of oxygen. If this arrangement changes, the substance is no longer water. Instead, a different substance forms with different physical and chemical properties. This is what happens during a chemical reaction. Atoms of elements or compounds rearrange and form different elements or compounds.

Bonds Break and Bonds Form


How does the rearrangement of atoms happen? Atoms rearrange when **chemical bonds** between atoms break. Recall that constantly moving particles make up all substances, including solids. As particles move, they collide with one another. If the particles collide with enough energy, the bonds between atoms can break. The atoms separate, rearrange, and new bonds can form. The reaction that forms hydrogen and oxygen from water is shown in **Figure 2**. Adding electric energy to water molecules can cause this reaction. The added energy causes bonds between the hydrogen atoms and the oxygen atoms to break. After the bonds between the atoms in water molecules break, new bonds can form between pairs of hydrogen atoms and between pairs of oxygen atoms.

 **Key Concept Check** What happens to atoms during a chemical reaction?

REVIEW VOCABULARY

chemical bond

an attraction between atoms when electrons are shared, transferred, or pooled

Figure 2  Notice that no new atoms are created in a chemical reaction. The existing atoms rearrange and form new substances.

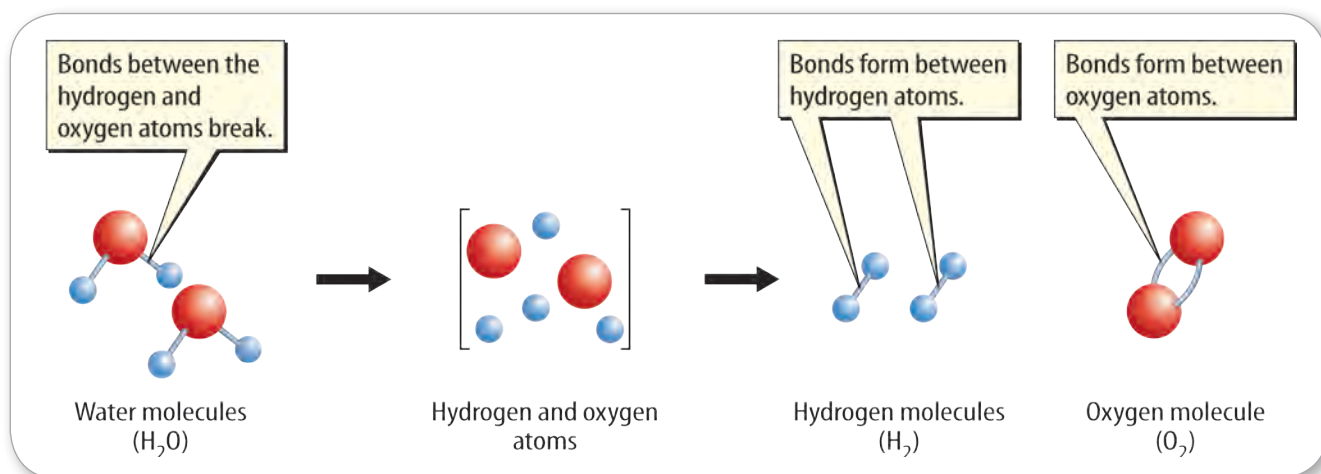









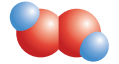
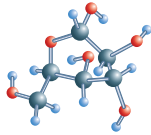





Table 1 Symbols and Formulas of Some Elements and Compounds

Substance		Formula	# of atoms
Carbon		C	C: 1
Copper		Cu	Cu: 1
Cobalt		Co	Co: 1
Oxygen		O ₂	O: 2
Hydrogen		H ₂	H: 2
Chlorine		Cl ₂	Cl: 2
Carbon dioxide		CO ₂	C: 1 O: 2
Carbon monoxide		CO	C: 1 O: 1
Water		H ₂ O	H: 2 O: 1
Hydrogen peroxide		H ₂ O ₂	H: 2 O: 2
Glucose		C ₆ H ₁₂ O ₆	C: 6 H: 12 O: 6
Sodium chloride		NaCl	Na: 1 Cl: 1
Magnesium hydroxide		Mg(OH) ₂	Mg: 1 O: 2 H: 2

 **Interactive Table**

Table 1 Symbols and subscripts describe the type and number of atoms in an element or a compound.

 **Visual Check** Describe the number of atoms in each element in the following: C, Co, CO, and CO₂.

Chemical Equations

Suppose your teacher asks you to produce a specific reaction in your science laboratory. How might your teacher describe the reaction to you? He or she might say something such as “react baking soda and vinegar to form sodium acetate, water, and carbon dioxide.” It is more likely that your teacher will describe the reaction in the form of a chemical equation. A **chemical equation** is a description of a reaction using element symbols and chemical formulas. Element symbols represent elements. Chemical formulas represent compounds.

Element Symbols

Recall that symbols of elements are shown in the periodic table. For example, the symbol for carbon is C. The symbol for copper is Cu. Each element can exist as just one atom. However, some elements exist in nature as diatomic molecules—two atoms of the same element bonded together. A formula for one of these diatomic elements includes the element’s symbol and the subscript 2. A subscript describes the number of atoms of an element in a compound. Oxygen (O₂) and hydrogen (H₂) are examples of diatomic molecules. Some element symbols are shown above the blue line in **Table 1**.

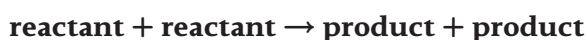
Chemical Formulas

When atoms of two or more different elements bond, they form a compound. Recall that a chemical formula uses elements’ symbols and subscripts to describe the number of atoms in a compound. If an element’s symbol does not have a subscript, the compound contains only one atom of that element. For example, carbon dioxide (CO₂) is made up of one carbon atom and two oxygen atoms. Remember that two different formulas, no matter how similar, represent different substances. Some chemical formulas are shown below the blue line in **Table 1**.



Writing Chemical Equations

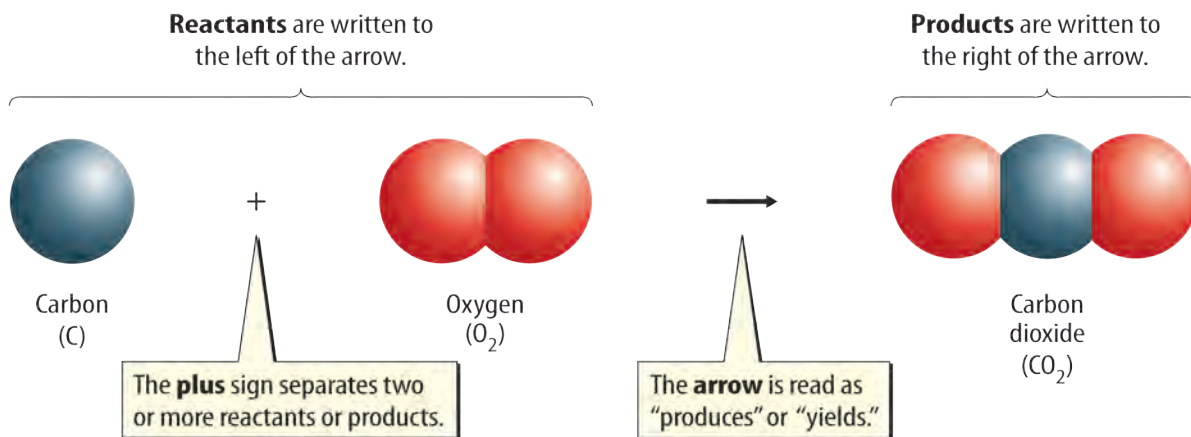
A chemical equation includes both the substances that react and the substances that are formed in a chemical reaction. *The starting substances in a chemical reaction are reactants.* The substances produced by the chemical reaction are **products**. **Figure 3** shows how a chemical equation is written. Chemical formulas are used to describe the reactants and the products. The reactants are written to the left of an arrow, and the products are written to the right of the arrow. Two or more reactants or products are separated by a plus sign. The general structure for an equation is:



When writing chemical equations, it is important to use correct chemical formulas for the reactants and the products. For example, suppose a certain chemical reaction produces carbon dioxide and water. The product carbon dioxide would be written as CO_2 and not as CO . CO is the formula for carbon monoxide, which is not the same compound as CO_2 . Water would be written as H_2O and not as H_2O_2 , the formula for hydrogen peroxide.

Figure 3 An equation is read much like a sentence. This equation is read as “carbon plus oxygen produces carbon dioxide.”

Parts of an Equation



MiniLab

10 minutes

How does an equation represent a reaction?



Sulfur dioxide (SO_2) and oxygen (O_2) react and form sulfur trioxide (SO_3). How does an equation represent the reaction?



- 1 Read and complete a lab safety form.
- 2 Use **yellow modeling clay** to model two atoms of sulfur. Use **red modeling clay** to model six atoms of oxygen.
- 3 Make two molecules of SO_2 with a sulfur atom in the middle of each molecule. Make one molecule of O_2 . Sketch the models in your Science Journal.
- 4 Rearrange atoms to form two molecules of SO_3 . Place a sulfur atom in the middle of each molecule. Sketch the models in your Science Journal.

Analyze and Conclude

1. **Identify** the reactants and the products in this chemical reaction.
2. **Write** a chemical equation for this reaction.
3. **Explain** What do the letters represent in the equation? The numbers?
4. **Key Concept** In terms of chemical bonds, what did you model by pulling molecules apart and building new ones?



WORD ORIGIN

product

from Latin *producere*, means "bring forth"

FOLDABLES

Make a vertical four-tab book. Label it as shown. Use it to study the steps of balancing equations.

1. Write the unbalanced equation.
2. Count the atoms.
3. Add coefficients.
4. Write the balanced equation.

Conservation of Mass

A French chemist named Antoine Lavoisier (AN twan • luh VWAH see ay) (1743–1794) discovered something interesting about chemical reactions. In a series of experiments, Lavoisier measured the masses of substances before and after a chemical reaction inside a closed container. He found that the total mass of the reactants always equaled the total mass of the **products**. Lavoisier's results led to the law of conservation of mass. *The **law of conservation of mass** states that the total mass of the reactants before a chemical reaction is the same as the total mass of the products after the chemical reaction.*

Atoms are conserved.

The discovery of atoms provided an explanation for Lavoisier's observations. Mass is conserved in a reaction because atoms are conserved. Recall that during a chemical reaction, bonds break and new bonds form. However, atoms are not destroyed, and no new atoms form. All atoms at the start of a chemical reaction are present at the end of the reaction. **Figure 4** shows that mass is conserved in the reaction between baking soda and vinegar.

Figure 4 As this reaction takes place, the mass on the balance remains the same, showing that mass is conserved.



Key Concept Check What happens to the total mass of the reactants in a chemical reaction?

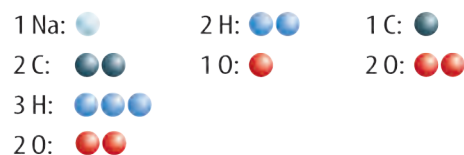
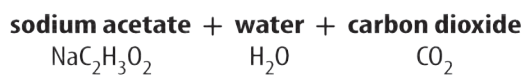
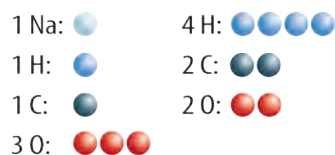
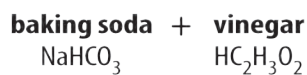
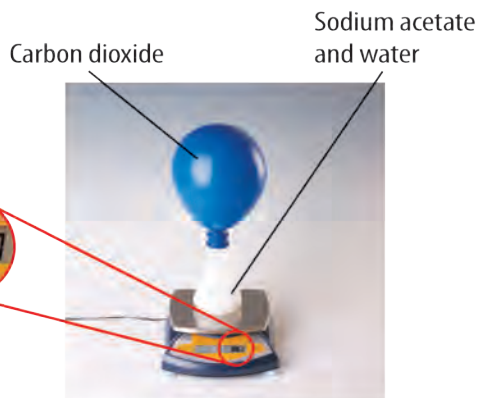
Conservation of Mass

The baking soda is contained in a balloon. The balloon is attached to a flask that contains vinegar.

When the balloon is tipped up, the baking soda pours into the vinegar. The reaction forms a gas that is collected in the balloon.



Mass is equal.

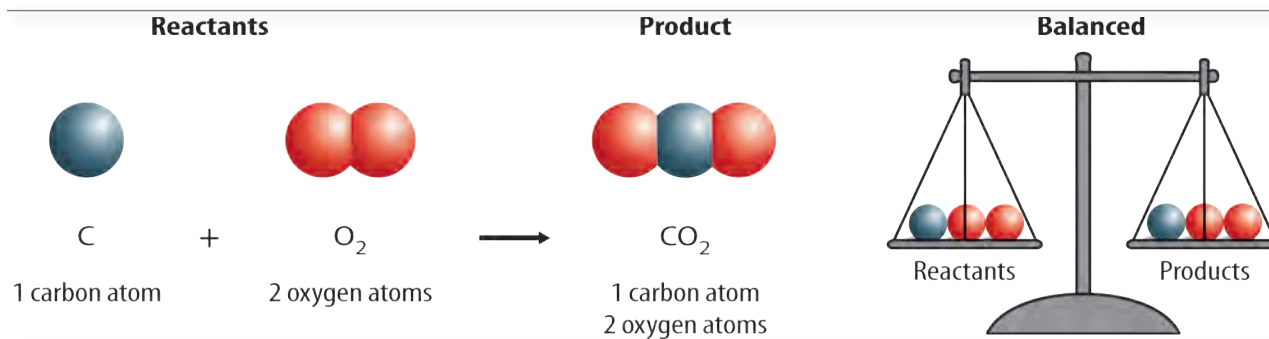


Atoms are equal.



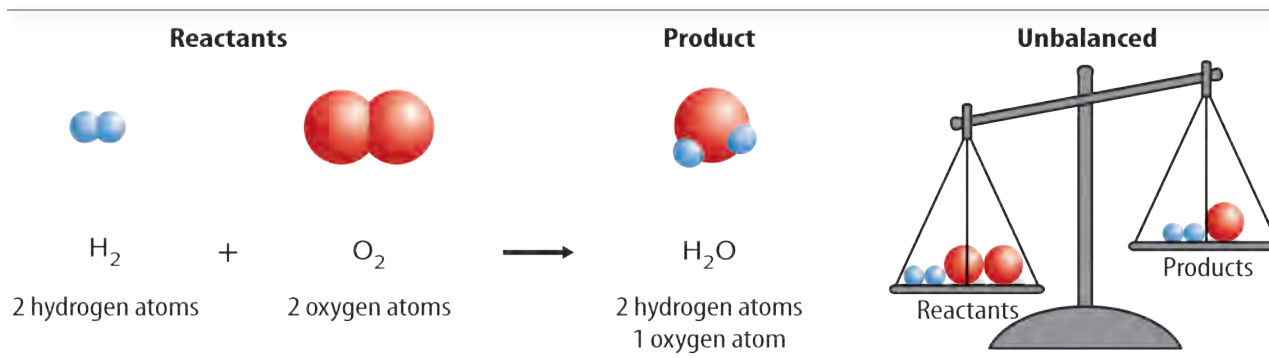
Is an equation balanced?

How does a chemical equation show that atoms are conserved? An equation is written so that the number of atoms of each element is the same, or balanced, on each side of the arrow. The equation showing the reaction between carbon and oxygen that produces carbon dioxide is shown below. Remember that oxygen is written as O_2 because it is a diatomic molecule. The formula for carbon dioxide is CO_2 .



Is there the same number of carbon atoms on each side of the arrow? Yes, there is one carbon atom on the left and one on the right. Carbon is balanced. Is oxygen balanced? There are two oxygen atoms on each side of the arrow. Oxygen also is balanced. The atoms of all elements are balanced. Therefore, the equation is balanced.

You might think a balanced equation happens automatically when you write the symbols and formulas for reactants and products. However, this usually is not the case. For example, the reaction between hydrogen (H_2) and oxygen (O_2) that forms water (H_2O) is shown below.



Count the number of hydrogen atoms on each side of the arrow. There are two hydrogen atoms in the product and two in the reactants. They are balanced. Now count the number of oxygen atoms on each side of the arrow. Did you notice that there are two oxygen atoms in the reactants and only one in the product? Because they are not equal, this equation is not balanced. To accurately represent this reaction, the equation needs to be balanced.



Balancing Chemical Equations

When you balance a chemical equation, you count the atoms in the reactants and the products and then add coefficients to balance the number of atoms. A **coefficient** is a number placed in front of an element symbol or chemical formula in an equation. It is the number of units of that substance in the reaction. For example, in the formula $2\text{H}_2\text{O}$, the 2 in front of H_2O is a coefficient. This means that there are two molecules of water in the reaction. Only coefficients can be changed when balancing an equation. Changing subscripts changes the identities of the substances that are in the reaction.

If one molecule of water contains two hydrogen atoms and one oxygen atom, how many H and O atoms are in two molecules of water ($2\text{H}_2\text{O}$)? Multiply each by 2.

$$\begin{aligned}2 \times 2 \text{ H atoms} &= 4 \text{ H atoms} \\2 \times 1 \text{ O atom} &= 2 \text{ O atoms}\end{aligned}$$

When no coefficient is present, only one unit of that substance takes part in the reaction. **Table 2** shows the steps of balancing a chemical equation.



Personal Tutor

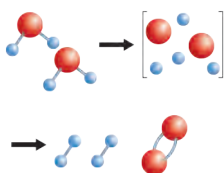
Table 2 Balancing a Chemical Equation

<p>1 Write the unbalanced equation. Make sure that all chemical formulas are correct.</p>	$\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ <p style="text-align: center;"><i>reactants</i> <i>products</i></p>
<p>2 Count atoms of each element in the reactants and in the products.</p> <p>a. Note which, if any, elements have a balanced number of atoms on each side of the equation. Which atoms are not balanced?</p> <p>b. If all of the atoms are balanced, the equation is balanced.</p>	$\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ <p style="text-align: center;"><i>reactants</i> <i>products</i></p> <p style="text-align: center;"><i>H = 2</i> <i>H = 2</i></p> <p style="text-align: center;"><i>O = 2</i> <i>O = 1</i></p>
<p>3 Add coefficients to balance the atoms.</p> <p>a. Pick an element in the equation that is not balanced, such as oxygen. Write a coefficient in front of a reactant or a product that will balance the atoms of that element.</p> <p>b. Recount the atoms of each element in the reactants and the products. Note which atoms are not balanced. Some atoms that were balanced before might no longer be balanced.</p> <p>c. Repeat step 3 until the atoms of each element are balanced.</p>	$\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ <p style="text-align: center;"><i>reactants</i> <i>products</i></p> <p style="text-align: center;"><i>H = 2</i> <i>H = 4</i></p> <p style="text-align: center;"><i>O = 2</i> <i>O = 2</i></p> $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ <p style="text-align: center;"><i>reactants</i> <i>products</i></p> <p style="text-align: center;"><i>H = 4</i> <i>H = 4</i></p> <p style="text-align: center;"><i>O = 2</i> <i>O = 2</i></p>
<p>4 Write the balanced chemical equation including the coefficients.</p>	$2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$

Visual Check In row 2 above, which element is not balanced? In the top of row 3, which element is not balanced?



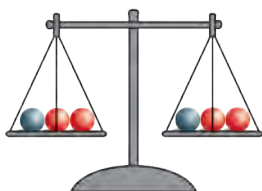
Visual Summary



A chemical reaction is a process in which bonds break and atoms rearrange, forming new bonds.



A chemical equation uses symbols to show reactants and products of a chemical reaction.



The mass and the number of each type of atom do not change during a chemical reaction. This is the law of conservation of mass.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think **NOW?**

You first read the statements below at the beginning of the chapter.

1. If a substance bubbles, you know a chemical reaction is occurring.
2. During a chemical reaction, some atoms are destroyed and new atoms are made.

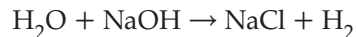
Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

- 1 Define *reactants* and *products*.

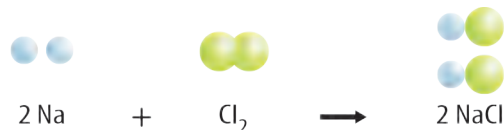
Understand Key Concepts

- 2 Which is a sign of a chemical reaction?
 - A. chemical properties
 - B. physical properties
 - C. a gas forms change
 - D. a solid forms change
- 3 Explain why subscripts cannot change when balancing a chemical equation.
- 4 Infer Is the reaction below possible? Explain why or why not.

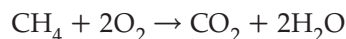


Interpret Graphics

- 5 Describe the reaction below by listing the bonds that break and the bonds that form.



- 6 Interpret Copy and complete the table to determine if this equation is balanced:

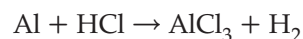


Is this reaction balanced? Explain.

Type of Atom	Number of Atoms in the Balanced Chemical Equation	
	Reactants	Products

Critical Thinking

- 7 Balance this chemical equation. Hint: Balance Al last and then use a multiple of 2 and 3.





What can you learn from an experiment?

Materials



test tubes and rack

ammonium hydroxide (NH_4OH)

aluminum foil

sodium bicarbonate (NaHCO_3)

Also needed:

copper foil, tongs, salt water, copper sulfate solution (CuSO_4), 25-mL graduated cylinder, Bunsen burner, plastic spoon, toothpick, ring stand and clamp, splints, matches, paper towel

Safety



Observing reactions allows you to compare different types of changes that can occur. You can then design new experiments to learn more about reactions.

Learn It

If you have never tested for a chemical reaction before, it is helpful to **follow a procedure**. A procedure tells you which materials to use and what steps to take.

Try It

- 1 Read and complete a safety form.
- 2 Copy the table into your Science Journal. During each procedure, record observations in the table.
- 3a Dip a strip of aluminum foil into salt water in a test tube for about 1 min to remove the coating.
- 3b Place 5 mL of copper sulfate solution in a test tube. Lift the aluminum foil from the salt water. Drop it into the test tube of copper sulfate so that the bottom part is in the liquid. Look for evidence of a chemical change. Set the test tube in a rack, and do the other procedures.
- 4 Use tongs to hold a small piece of copper foil in a flame for 3 min. Set the foil on a heat-proof surface, and allow it to cool. Use a toothpick to examine the product.
- 5 Place a spoonful of sodium bicarbonate in a dry test tube. Clamp the tube to a ring stand at a 45° angle. Point the mouth of the tube away from people. Move a burner flame back and forth under the tube. Observe the reaction. Test for carbon dioxide with a lighted wood splint.
- 6 Add 1 drop of ammonium hydroxide to a test tube containing 5 mL of copper sulfate solution.
- 7 Pour the liquid from the test tube in step 3b into a clean test tube. Dump the aluminum onto a paper towel. Record your observations of both the liquid and the solid.

Apply It

- 8 Using the table, write a balanced equation for each reaction.
- 9 Why did the color of the copper sulfate disappear in step 3b?
- 10 **Key Concept** How can you tell the difference between types of reactions by the number and type of reactants and products?

Step	Reactants	Products	Observations and Evidence of Chemical Reaction
3 + 7	$\text{Al} + \text{CuSO}_4$	$\text{Cu} + \text{Al}_2(\text{SO}_4)_3$	
4	$\text{Cu} + \text{O}_2$	CuO	
5	NaHCO_3	$\text{CO}_2 + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$	
6	$\text{NH}_4\text{OH} + \text{CuSO}_4$	$(\text{NH}_4)_2\text{SO}_4 + \text{Cu}(\text{OH})_2$	

Lesson 2

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- How can you recognize the type of chemical reaction by the number or type of reactants and products?
- What are the different types of chemical reactions?

Vocabulary

synthesis p. 87

decomposition p. 87

single replacement p. 88

double replacement p. 88

combustion p. 88




Multilingual eGlossary



What's Science Got to do With It?

Types of Chemical Reactions



Inquiry

Where did it come from?

When lead nitrate, a clear liquid, combines with potassium iodide, another clear liquid, a yellow solid appears instantly. Where did it come from? Here's a hint—the name of the solid is lead iodide. Did you guess that parts of each reactant combined and formed it? You'll learn about this and other types of reactions in this lesson.



What combines with what? 

The reactants and the products in a chemical reaction can be elements, compounds, or both. In how many ways can these substances combine?

- 1 Read and complete a lab safety form.
- 2 Divide a **sheet of paper** into four equal sections labeled A, B, Y, and Z. Place **red paper clips** in section A, **yellow clips** in section B, **blue clips** in section Y, and **green clips** in section Z.
- 3 Use another sheet of paper to copy the table shown to the right. Turn the paper so that a long edge is at the top. Print *REACTANTS* → *PRODUCTS* across the top then complete the table.
- 4 Using the paper clips, model the equations listed in the table. Hook the clips together to make diatomic elements or compounds. Place each clip model onto your paper over the matching written equation.
- 5 As you read this lesson, match the types of equations to your paper clip equations.

	REACTANTS → PRODUCTS
1	$AY \rightarrow A + Y$
2	$B + Z \rightarrow BZ$
3	$2A_2 + Y_2 \rightarrow 2A_2Y$
4	$A + BY \rightarrow B + AY$
5	$Z + BY \rightarrow Y + BZ$
6	$AY + BZ \rightarrow AZ + BY$

Think About This


1. Which equation represents hydrogen combining with oxygen and forming water? How do you know?
2.  **Key Concept** How could you use the number and type of reactants to identify a type of chemical reaction?

Figure 5 When dynamite explodes, it chemically changes into several products and releases energy.



Patterns in Reactions

If you have ever used hydrogen peroxide, you might have noticed that it is stored in a dark bottle. This is because light causes hydrogen peroxide to change into other substances. Maybe you have seen a video of an explosion demolishing an old building, like in **Figure 5**. How is the reaction with hydrogen peroxide and light similar to a building demolition? In both, one reactant breaks down into two or more products.

The breakdown of one reactant into two or more products is one of four major types of chemical reactions. Each type of chemical reaction follows a unique pattern in the way atoms in reactants rearrange to form products. In this lesson, you will read how chemical reactions are classified by recognizing patterns in the way the atoms recombine.

©Adrian Buck/Alamy

Types of Chemical Reactions


There are many different types of reactions. It would be impossible to memorize them all. However, most chemical reactions fit into four major categories. Understanding these categories of reactions can help you predict how compounds will react and what products will form.

Synthesis

A **synthesis** (SIHN thuh sus) is a type of chemical reaction in which two or more substances combine and form one compound. In the synthesis reaction shown in **Figure 6**, magnesium (Mg) reacts with oxygen (O₂) in the air and forms magnesium oxide (MgO). You can recognize a synthesis reaction because two or more reactants form only one product.

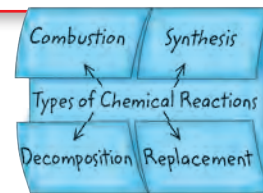
Decomposition

In a **decomposition** reaction, one compound breaks down and forms two or more substances. You can recognize a decomposition reaction because one reactant forms two or more products. For example, hydrogen peroxide (H₂O₂), shown in **Figure 6**, decomposes and forms water (H₂O) and oxygen gas (O₂). Notice that decomposition is the reverse of synthesis.

 **Key Concept Check** How can you tell the difference between synthesis and decomposition reactions?

FOLDABLES[®]

Make a horizontal four-door book. Label it as shown. Use it to organize your notes about the different types of chemical reactions.



WORD ORIGIN

synthesis
from Greek *syn-*, means “together”; and *tithenai*, means “put”



Animation

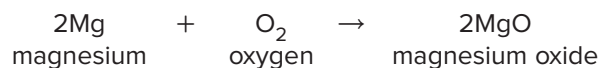
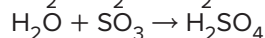
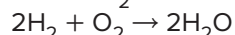
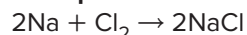
Figure 6 Synthesis and decomposition reactions are opposites of each other.

Synthesis and Decomposition Reactions

Synthesis Reactions



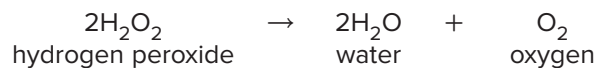
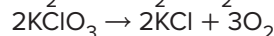
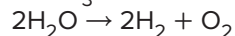
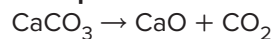
Examples:



Decomposition Reactions



Examples:

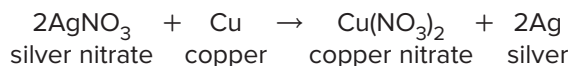
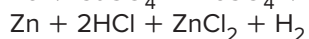
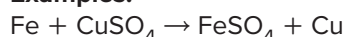


Replacement Reactions

Single Replacement



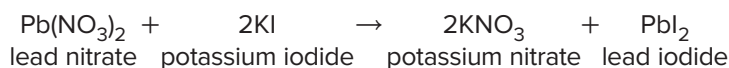
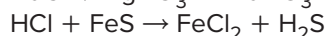
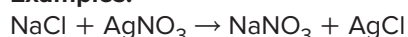
Examples:



Double Replacement



Examples:



▲ **Figure 7** In each of these reactions, an atom or group of atoms replaces another atom or group of atoms.

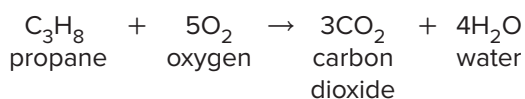
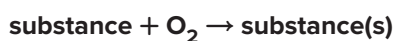
Replacement

In a replacement reaction, an atom or group of atoms replaces part of a compound. There are two types of replacement reactions. In a **single-replacement** reaction, one element replaces another element in a compound. In this type of reaction, an element and a compound react and form a different element and a different compound. In a **double-replacement** reaction, the negative ions in two compounds switch places, forming two new compounds. In this type of reaction, two compounds react and form two new compounds. **Figure 7** describes these replacement reactions.

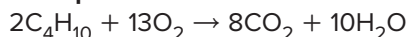
Combustion

Combustion is a chemical reaction in which a substance combines with oxygen and releases energy. This energy usually is released as thermal energy and light energy. For example, burning is a common combustion reaction. The burning of fossil fuels, such as propane (C_3H_8) shown in **Figure 8**, produces the energy we use to cook food, power vehicles, and light cities.

Combustion Reactions



Example:



▲ **Figure 8** Combustion reactions always contain oxygen (O_2) as a reactant and often produce carbon dioxide (CO_2) and water (H_2O).



Key Concept Check What are the different types of chemical reactions?



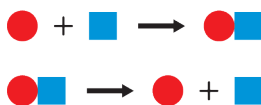
Lesson 2 Review



Visual Summary



Chemical reactions are classified according to patterns seen in their reactants and products.



In a synthesis reaction, there are two or more reactants and one product. A decomposition reaction is the opposite of a synthesis reaction.



In replacement reactions, an element, or elements, in a compound is replaced with another element or elements.

FOLDABLES®

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think **NOW?**

You first read the statements below at the beginning of the chapter.

- Reactions always start with two or more substances that react with each other.
- Water can be broken down into simpler substances.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

- Contrast** synthesis and decomposition reactions using a diagram.
- A reaction in which parts of two substances switch places and make two new substances is a(n) _____.

Understand Key Concepts

- Classify** the reaction shown below.
$$2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$$

A. combustion C. single replacement
B. decomposition D. synthesis
- Write a balanced equation that produces H_2 and O_2 from H_2O . Classify this reaction.
- Classify** In which two groups of reactions can this reaction be classified?



Interpret Graphics

- Complete** this table to identify four types of chemical reactions and the patterns shown by the reactants and the products.

Type of Reaction	Pattern of Reactants and Products
Synthesis	at least two reactants; one product

Critical Thinking

- Design** a poster to illustrate single- and double-replacement reactions.
- Infer** The combustion of methane (CH_4) produces energy. Where do you think this energy comes from?

How does a light stick work?

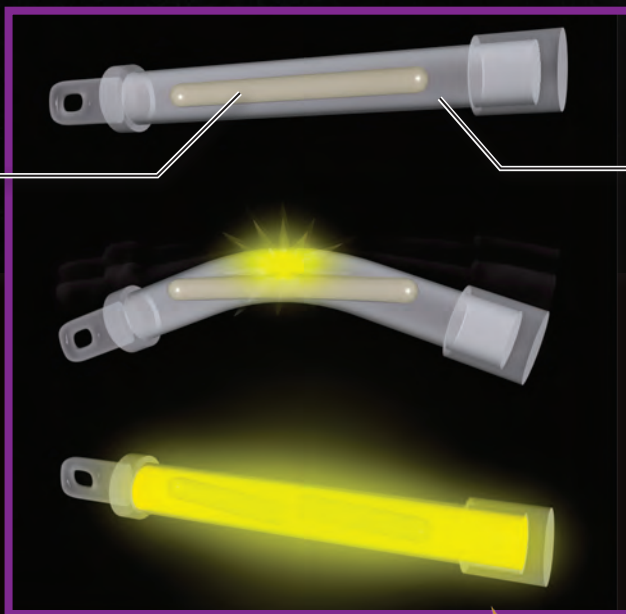
What makes it glow?

Glowing neon necklaces, bracelets, or sticks—chances are you’ve worn or used them. Light sticks—also known as glow sticks—come in brilliant colors and provide light without electricity or batteries. Because they are lightweight, portable, and waterproof, they provide an ideal light source for campers, scuba divers, and other activities in which electricity is not readily available. Light sticks also are useful in emergency situations in which an electric current from battery-powered lights could ignite a fire.

Light sticks give off light because of a chemical reaction that happens inside the tube. During the reaction, energy is released as light. This is known as chemiluminescence (ke mee lew muh NE sunts).



A light stick consists of a plastic tube with a glass tube inside it. Hydrogen peroxide fills the glass tube.



A solution of phenyl oxalate ester and fluorescent dye surround the glass tube.

When you bend the outer plastic tube, the inner glass tube breaks, causing the hydrogen peroxide, ester, and dye to mix together.

When the solutions mix together, they react. Energy produced by the reaction causes the electrons in the dye to produce light.

It's Your Turn

RESEARCH AND REPORT Research bioluminescent organisms, such as fireflies and sea animals. How is the reaction that occurs in these organisms similar to or different from that in a glow stick? Work in small groups, and present your findings to the class.

Lesson 3

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- Why do chemical reactions always involve a change in energy?
- What is the difference between an endothermic reaction and an exothermic reaction?
- What factors can affect the rate of a chemical reaction?

Vocabulary

endothermic p. 93

exothermic p. 93

activation energy p. 94

catalyst p. 96

enzyme p. 96

inhibitor p. 96



Multilingual eGlossary

Energy Changes and Chemical Reactions

Inquiry

Energy from Bonds?

A deafening roar, a blinding light, and the power to lift 2 million kg—what is the source of all this energy? Chemical bonds in the fuel store all the energy needed to launch a space shuttle. Chemical reactions release the energy in these bonds.




Where's the heat?

Does a chemical change always produce a temperature increase?

- 1 Read and complete a lab safety form.
- 2 Copy the table into your Science Journal.
- 3 Use a **graduated cylinder** to measure 25 mL of **citric acid solution** into a **foam cup**. Record the temperature with a **thermometer**.
- 4 Use a **plastic spoon** to add a rounded spoonful of **solid sodium bicarbonate** to the cup. Stir.
- 5 Use a **clock** or **stopwatch** to record the temperature every 15 s until it stops changing. Record your observations during the reaction.
- 6 Add 25 mL of **sodium bicarbonate solution** to a **second foam cup**. Record the temperature. Add a spoonful of **calcium chloride**. Repeat step 5.

Think About This

1. What evidence do you have that the changes in the two cups were chemical reactions?
2. What happened to the temperature in the two cups? How would you explain the changes?
3.  **Key Concept** Based on your observations and past experience, would a change in temperature be enough to convince you that a chemical change had taken place? Why or why not? What else could cause a temperature change?

Time	Temperature (°C)	
	Citric Acid Solution	Sodium Bicarbonate Solution
Starting temp.		
15 s		
30 s		
45 s		
1 min		
1 min, 15 s		
1 min, 30 s		
1 min, 45 s		
2 min		
2 min, 15 sec		

Energy Changes

What is about 1,500 times heavier than a typical car and 300 times faster than a roller coaster? Do you need a hint? The energy it needs to move this fast comes from a chemical reaction that produces water. If you guessed a space shuttle, you are right!

It takes a large amount of energy to launch a space shuttle. The shuttle's main engines burn almost 2 million L of liquid hydrogen and liquid oxygen. This chemical reaction produces water vapor and a large amount of energy. The energy produced heats the water vapor to high temperatures, causing it to expand rapidly. When the water expands, it pushes the shuttle into orbit. Where does all this energy come from?

Chemical Energy in Bonds

Recall that when a chemical reaction occurs, chemical bonds in the reactants break and new chemical bonds form. Chemical bonds contain a form of energy called chemical energy. Breaking a bond absorbs energy from the surroundings. The formation of a chemical bond releases energy to the surroundings. Some chemical reactions release more energy than they absorb. Some chemical reactions absorb more energy than they release. You can feel this energy change as a change in the temperature of the surroundings. Keep in mind that in all chemical reactions, energy is conserved.



Key Concept Check Why do chemical reactions involve a change in energy?

Endothermic Reactions—Energy Absorbed

Have you ever heard someone say that the sidewalk was hot enough to fry an egg? To fry, the egg must absorb energy. *Chemical reactions that absorb thermal energy are **endothermic** reactions.* For an endothermic reaction to continue, energy must be constantly added.



In an endothermic reaction, more energy is required to break the bonds of the reactants than is released when the products form. Therefore, the overall reaction absorbs energy. The reaction on the left in **Figure 9** is an endothermic reaction.

Exothermic Reactions—Energy Released

Most chemical reactions release energy as opposed to absorbing it. An **exothermic** reaction is a chemical reaction that releases thermal energy.



In an exothermic reaction, more energy is released when the products form than is required to break the bonds in the reactants. Therefore, the overall reaction releases energy. The reaction shown on the right in **Figure 9** is exothermic.



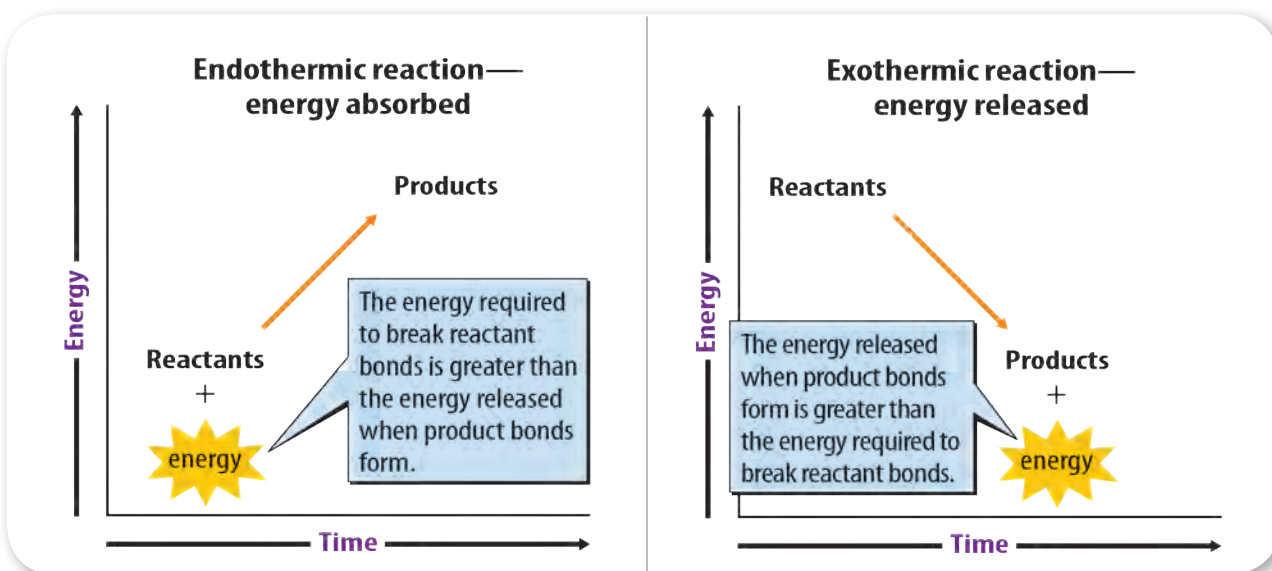

 **Key Concept Check** What is the difference between an endothermic reaction and an exothermic reaction?

Figure 9  Whether a reaction is endothermic or exothermic depends on the amount of energy contained in the bonds of the reactants and the products.



 **Visual Check** Why does one arrow point upward and the other arrow point downward in these diagrams?

FOLDABLES®

Make a vertical three-tab Venn book. Label it as shown. Use it to compare and contrast energy in chemical reactions.



WORD ORIGIN

exothermic

from Greek *exo-*, means “outside”; and *therm*, means “heat”



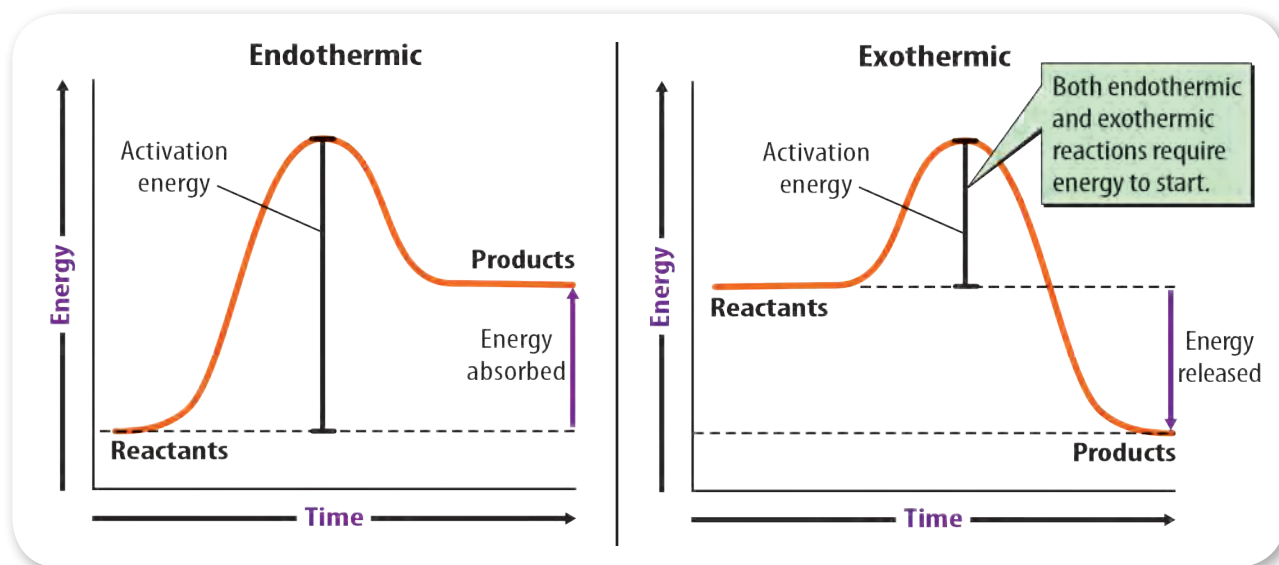


Figure 10 Both endothermic and exothermic reactions require activation energy to start the reaction.

Visual Check How can a reaction absorb energy to start but still be exothermic?

Activation Energy

You might have noticed that some chemical reactions do not start by themselves. For example, a newspaper does not burn when it comes into contact with oxygen in air. However, if a flame touches the paper, it starts to burn.

All reactions require energy to start the breaking of bonds. This energy is called activation energy. **Activation energy** is the minimum amount of energy needed to start a chemical reaction. Different reactions have different activation energies. Some reactions, such as the rusting of iron, have low activation energy. The energy in the surroundings is enough to start these reactions. If a reaction has high activation energy, more energy is needed to start the reaction. For example, wood requires the thermal energy of a flame to start burning. Once the reaction starts, it releases enough energy to keep the reaction going. **Figure 10** shows the role activation energy plays in endothermic and exothermic reactions.

Reaction Rates

Some chemical reactions, such as the rusting of a bicycle wheel, happen slowly. Other chemical reactions, such as the explosion of fireworks, happen in less than a second. The rate of a reaction is the speed at which it occurs. What controls how fast a chemical reaction occurs? Recall that particles must collide before they can react. Chemical reactions occur faster if particles collide more often or move faster when they collide. There are several factors that affect how often particles collide and how fast particles move.

Reading Check How do particle collisions relate to reaction rate?

Surface Area

Surface area is the amount of exposed, outer area of a solid. Increased surface area increases reaction rate because more particles on the surface of a solid come into contact with the particles of another substance. For example, if you place a piece of chalk in vinegar, the chalk reacts slowly with the acid. This is because the acid contacts only the particles on the surface of the chalk. But, if you grind the chalk into powder, more chalk particles contact the acid, and the reaction occurs faster.

Temperature

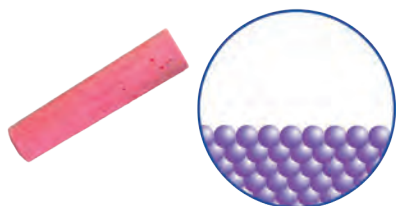
Imagine a crowded hallway. If everyone in the hallway were running, they would probably collide with each other more often and with more energy than if everyone were walking. This is also true when particles move faster. At higher temperatures, the average speed of particles is greater. This speeds reactions in two ways. First, particles collide more often. Second, collisions with more energy are more likely to break chemical bonds.

Concentration and Pressure

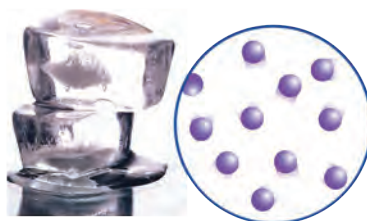
Think of a crowded hallway again. Because the concentration of people is higher in the crowded hallway than in an empty hallway, people probably collide more often. Similarly, increasing the concentration of one or more reactants increases collisions between particles. More collisions result in a faster reaction rate. In gases, an increase in pressure pushes gas particles closer together. When particles are closer together, more collisions occur. Factors that affect reaction rate are shown in **Figure 11**.

Figure 11  Several factors can affect reaction rate.

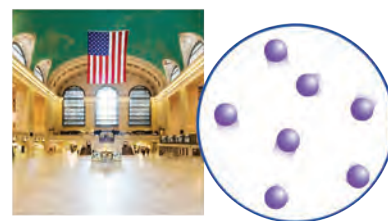
Slower Reaction Rate



Less surface area

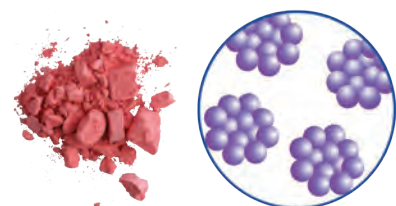


Lower temperature



Lower concentration

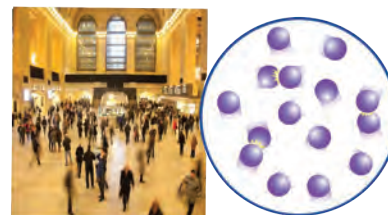
Faster Reaction Rate



More surface area



Higher temperature

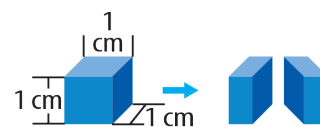


Higher concentration

Math Skills

Use Geometry

The surface area (SA) of one side of a 1-cm cube is $1\text{ cm} \times 1\text{ cm}$, or 1 cm^2 . The cube has 6 equal sides. Its total SA is $6 \times 1\text{ cm}^2$, or 6 cm^2 . What is the total SA of the two solids made when the cube is cut in half?



- 1 The new surfaces made each have an area of $1\text{ cm} \times 1\text{ cm} = 1\text{ cm}^2$.
- 2 Multiply the area by the number of new surfaces. $2 \times 1 = 2\text{ cm}^2$
- 3 Add the SA of the original cube to the new SA. $6\text{ cm}^2 + 2\text{ cm}^2$
The total SA is 8 cm^2 .

Practice

Calculate the amount of SA gained when a 2-cm cube is cut in half.



Math Practice



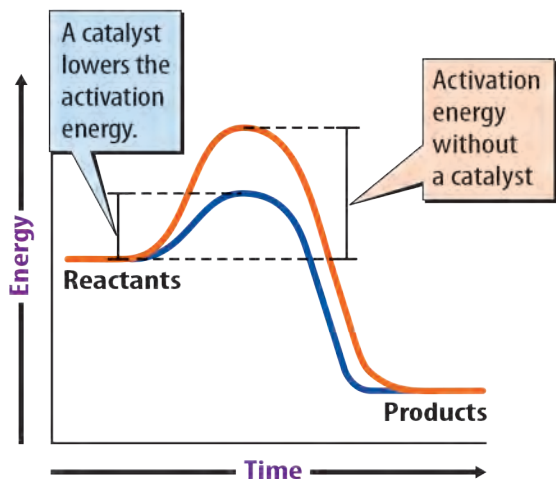


Figure 12 The blue line shows how a catalyst can increase the reaction rate.

Catalysts

A **catalyst** is a substance that increases reaction rate by lowering the activation energy of a reaction. One way catalysts speed reactions is by helping reactant particles contact each other more often. Look at **Figure 12**. Notice that the activation energy of the reaction is lower with a catalyst than it is without a catalyst. A catalyst isn't changed in a reaction, and it doesn't change the reactants or products. Also, a catalyst doesn't increase the amount of reactant used or the amount of product that is made. It only makes a given reaction happen faster. Therefore, catalysts are not considered reactants in a reaction.

You might be surprised to know that your body is filled with catalysts called enzymes. An **enzyme** is a catalyst that speeds up chemical reactions in living cells. For example, the enzyme protease (PROH tee ays) breaks the protein molecules in the food you eat into smaller molecules that can be absorbed by your intestine. Without enzymes, these reactions would occur too slowly for life to exist.

Inhibitors

Recall that an enzyme is a molecule that speeds reactions in organisms. However, some organisms, such as bacteria, are harmful to humans. Some medicines contain molecules that attach to enzymes in bacteria. This keeps the enzymes from working properly. If the enzymes in bacteria can't work, the bacteria die and can no longer infect a human. The active ingredients in these medicines are called inhibitors. An **inhibitor** is a substance that slows, or even stops, a chemical reaction. Inhibitors can slow or stop the reactions caused by enzymes.

Inhibitors are also important in the food industry. Preservatives in food are substances that inhibit, or slow down, food spoilage.



Key Concept Check What factors can affect the rate of a chemical reaction?

MiniLab

20 minutes

Can you speed up a reaction?



Can you speed up the decomposition of hydrogen peroxide (H_2O_2)? The reaction is $\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O}$ and O_2 .



- 1 Read and complete a lab safety form.
- 2 Use **tape** to label three **test tubes** 1, 2, and 3. Place the tubes in a **test-tube rack**.
- 3 Add 10 mL of **hydrogen peroxide** to each test tube.
- 4 Observe tube 1 for changes. Add a small piece of **raw potato** to tube 2. Record observations in your Science Journal.
- 5 Add a pinch of **dry yeast** to tube 3. Shake the tube gently. Record observations.
- 6 Use **matches** to light a **wood splint**, then blow it out, leaving a glowing tip. One at a time, hold each test tube at a 45° angle and insert the glowing splint into the tube just above the liquid. Record your observations.

Analyze and Conclude

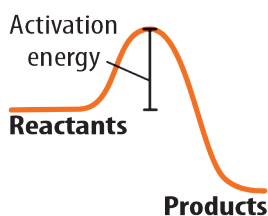
1. **Draw Conclusions** What was the chemical reaction when the potato and yeast were added?
2. **Key Concept** Why is the reaction in tube 3 faster than in the other two tubes?

Visual Summary

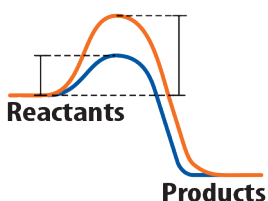
Endothermic



Chemical reactions that release energy are exothermic, and those that absorb energy are endothermic.



Activation energy must be added to a chemical reaction for it to proceed.



Catalysts, including enzymes, speed up chemical reactions. Inhibitors slow them down.

FOLDABLES®

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think **NOW?**

You first read the statements below at the beginning of the chapter.

5. Reactions that release energy require energy to get started.
6. Energy can be created in a chemical reaction.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

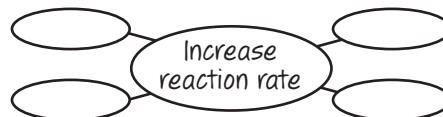
- 1 The smallest amount of energy required by reacting particles for a chemical reaction to begin is the _____.

Understand Key Concepts

- 2 How does a catalyst increase reaction rate?
 - A. by increasing the activation energy
 - B. by increasing the amount of reactant
 - C. by increasing the contact between particles
 - D. by increasing the space between particles
- 3 **Contrast** endothermic and exothermic reactions in terms of energy.
- 4 **Explain** When propane burns, heat and light are produced. Where does this energy come from?

Interpret Graphics

- 5 **List** Copy and complete the graphic organizer to describe four ways to increase the rate of a reaction.



Critical Thinking

- 6 **Infer** Explain why keeping a battery in a refrigerator can extend its life.
- 7 **Infer** Explain why a catalyst does not increase the amount of product that can form.

Math Skills



Math Practice

- 8 An object measures 4 cm × 4 cm × 4 cm.
 - a. What is the surface area of the object?
 - b. What is the total surface area if you cut the object into two equal pieces?



Materials



graduated cylinder



balance



droppers



baking soda



plastic spoon

Also needed: various brands of liquid and solid antacids (both regular and maximum strength), beakers, universal indicator in dropper bottle, 0.1M HCl solution, stirrers

Safety



Design an Experiment to Test Advertising Claims

Antacids contain compounds that react with excess acid in your stomach and prevent a condition called heartburn. Suppose you work for a laboratory that tests advertising claims about antacids. What kinds of procedures would you follow? How would you decide which antacid is the most effective?

Ask a Question

Ask a question about the claims that you would like to investigate. For example: what does *most effective* mean? What would make an antacid the strongest?

Make Observations

- 1 Read and complete a lab safety form.
- 2 Study the selection of antacids available for testing. You will use a 0.1M HCl solution to simulate stomach acid. Use the questions below to discuss with your lab partners which advertising claim you might test and how you might test it.
- 3 In your Science Journal, write a procedure for each variable that you will test to answer your question. Include the materials and steps you will use to test each variable. Place the steps of each procedure in order. Have your teacher approve your procedures.
- 4 Make a chart or table to record observations during your experiments.

Questions

Which advertising claim will I test? What question am I trying to answer?
What will be the independent and the dependent variables for each test? Recall that the independent variable is the variable that is changed. A dependent variable changes when you change the independent variable.
What variables will be held constant in each test?
How many different procedures will I use, and what equipment will I need?
How much of each antacid will I use? How many antacids will I test?
How will I use the indicator?
How many times will I do each test?
How will I record the data and observations?
What will I analyze to form a conclusion?

(t to b, 2, 5) Hutchings Photography/Digital Light Source, (3-4) Jacques Cornell/McGraw-Hill Education

Form a Hypothesis

- 5 Write a hypothesis for each variable. Your hypothesis should identify the independent variable and state why you think changing the variable will alter the effectiveness of an antacid tablet.

Test Your Hypothesis

- 6 On day 2, use the available materials to perform your experiments. Accurately record all observations and data for each test.
- 7 Add any additional tests you think you need to answer your questions.
- 8 Examine the data you have collected. If the data are not conclusive, what other tests can you do to provide more information?
- 9 Write all your observations and measurements in your Science Journal. Use tables to record any quantitative data.

Analyze and Conclude

- 10 **Infer** What do you think advertisers mean when they say their product is most effective?
- 11 **Draw Conclusions** If you needed an antacid, which one would you use, based on the limited information provided from your experiments? Explain your reasoning.
- 12 **Analyze** Would breaking an antacid tablet into small pieces before using it make it more effective? Why or why not?
- 13 **THE BIG IDEA** **The Big Idea** How does understanding chemical reactions enable you to analyze products and their claims?

Communicate Your Results

Combine your data with other teams. Compare the results and conclusions. Discuss the validity of advertising claims for each brand of antacid.

Inquiry Extension

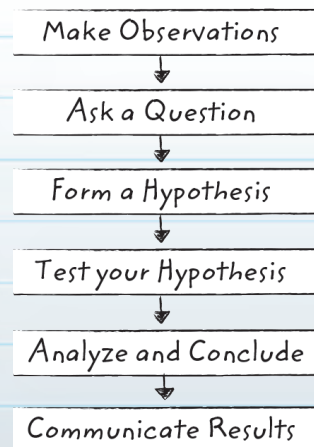
Research over-the-counter antacids that were once available by prescription only. Do they work in the same way as the antacids you tested? Explain.



Lab TIPS

- ✓ Think about how you might measure the amount of acid the tablet neutralizes. Would you add the tablet to the acid or the acid to the tablet? What does the indicator show you?
- ✓ Try your tests on a small scale before using the full amounts to see how much acid you might need.
- ✓ Always get your teacher's approval before trying any new test.

Remember to use scientific methods.



Chapter 3 Study Guide

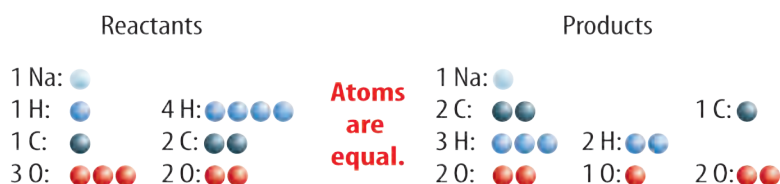


Atoms are neither created nor destroyed in chemical reactions. Energy can be released when chemical bonds form or absorbed when chemical bonds are broken.

Key Concepts Summary

Lesson 1: Understanding Chemical Reactions

- There are several signs that a **chemical reaction** might have occurred, including a change in temperature, a release of light, a release of gas, a change in color or odor, and the formation of a solid from two liquids.
- In a chemical reaction, atoms of **reactants** rearrange and form **products**.
- The total mass of all the reactants is equal to the total mass of all the products in a reaction.



Vocabulary

chemical reaction p. 189
chemical equation p. 192
reactant p. 193
product p. 193
law of conservation of mass p. 194
coefficient p. 196

Lesson 2: Types of Chemical Reactions

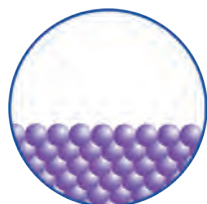
- Most chemical reactions fit into one of a few main categories—synthesis, decomposition, combustion, and single- or double-replacement.
- **Synthesis** reactions create one product.
Decomposition reactions start with one reactant.
Single- and **double-replacement** reactions involve replacing one element or group of atoms with another element or group of atoms. **Combustion** reactions involve a reaction between one reactant and oxygen, and they release thermal energy.



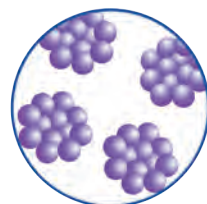
synthesis p. 201
decomposition p. 201
single replacement p. 202
double replacement p. 202
combustion p. 202

Lesson 3: Energy Changes and Chemical Reactions

- Chemical reactions always involve breaking bonds, which requires energy, and forming bonds, which releases energy.
- In an **endothermic** reaction, the reactants contain less energy than the products. In an **exothermic** reaction, the reactants contain more energy than the products.
- The rate of a chemical reaction can be increased by increasing the surface area, the temperature, or the concentration of the reactants or by adding a **catalyst**.



Less surface area



More surface area

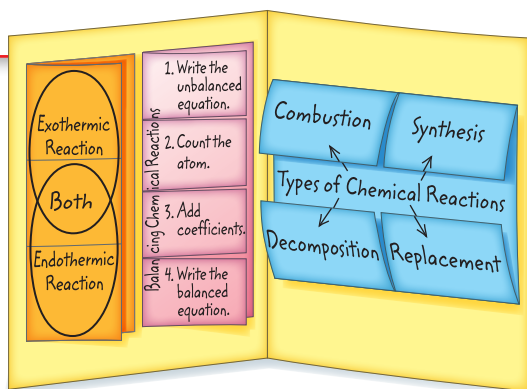
endothermic p. 207
exothermic p. 207
activation energy p. 208
catalyst p. 210
enzyme p. 210
inhibitor p. 210



FOLDABLES®

Chapter Project

Assemble your lesson Foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter.



Use Vocabulary

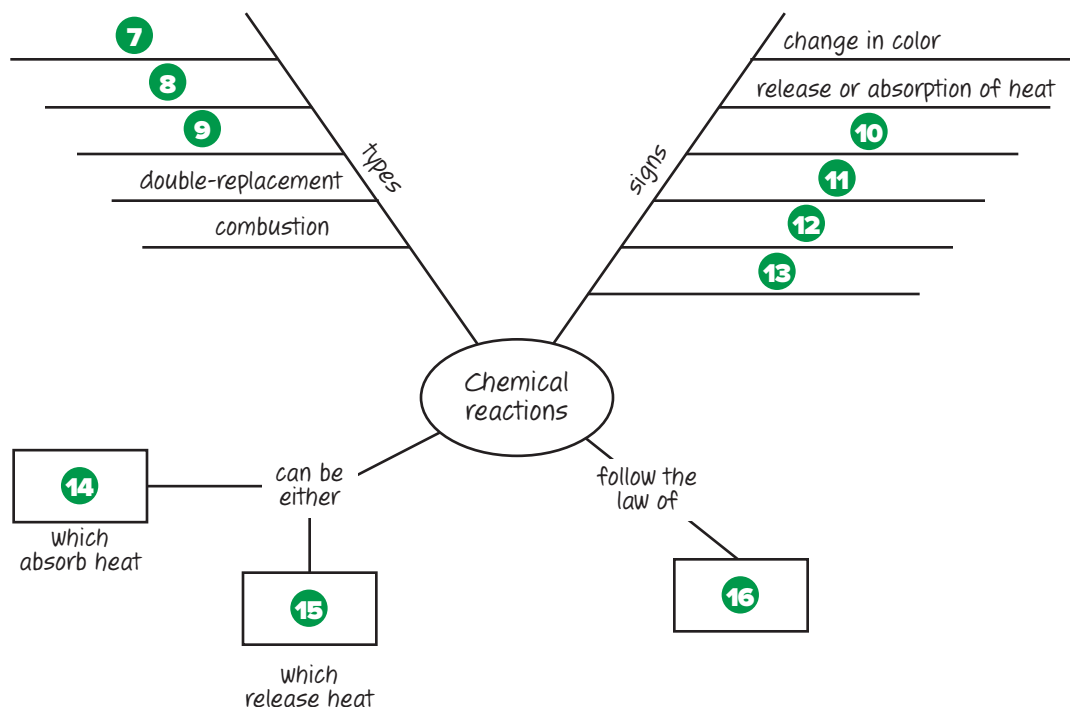
- 1 When water forms from hydrogen and oxygen, water is the _____.
- 2 A(n) _____ uses symbols instead of words to describe a chemical reaction.
- 3 In a(n) _____ reaction, one element replaces another element in a compound.
- 4 When Na_2CO_3 is heated, it breaks down into CO_2 and Na_2O in a(n) _____ reaction.
- 5 The chemical reactions that keep your body warm are _____ reactions.
- 6 Even exothermic reactions require _____ to start.

Link Vocabulary and Key Concepts



Interactive Concept Map

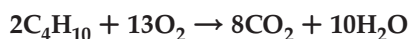
Copy this concept map, and then use vocabulary terms from the previous page and other terms from the chapter to complete the concept map.



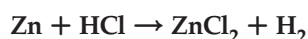
Chapter 3 Review

Understand Key Concepts

- 1 How many carbon atoms react in this equation?



- A. 2
B. 4
C. 6
D. 8
- 2 The chemical equation below is unbalanced.



Which is the correct balanced chemical equation?

- A. $\text{Zn} + \text{H}_2\text{Cl}_2 \rightarrow \text{ZnCl}_2 + \text{H}_2$
B. $\text{Zn} + \text{HCl} \rightarrow \text{ZnCl} + \text{H}$
C. $2\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
D. $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
- 3 When iron combines with oxygen gas and forms rust, the total mass of the products
- A. depends on the reaction conditions.
B. is less than the mass of the reactants.
C. is the same as the mass of the reactants.
D. is greater than the mass of the reactants.

- 4 Potassium nitrate forms potassium oxide, nitrogen, and oxygen in certain fireworks.



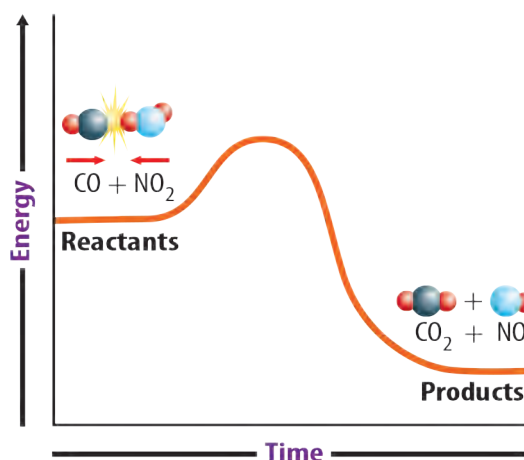
This reaction is classified as a

- A. combustion reaction.
B. decomposition reaction.
C. single-replacement reaction.
D. synthesis reaction.
- 5 Which type of reaction is the reverse of a decomposition reaction?
- A. combustion
B. synthesis
C. double-replacement
D. single-replacement

- 6 The compound NO_2 can act as a catalyst in the reaction that converts ozone (O_3) to oxygen (O_2) in the upper atmosphere. Which statement is true?

- A. More oxygen is created when NO_2 is present.
B. NO_2 is a reactant in the chemical reaction that converts O_3 to O_2 .
C. This reaction is more exothermic in the presence of NO_2 than in its absence.
D. This reaction occurs faster in the presence of NO_2 than in its absence.

- 7 The graph below is an energy diagram for the reaction between carbon monoxide (CO) and nitrogen dioxide (NO_2).



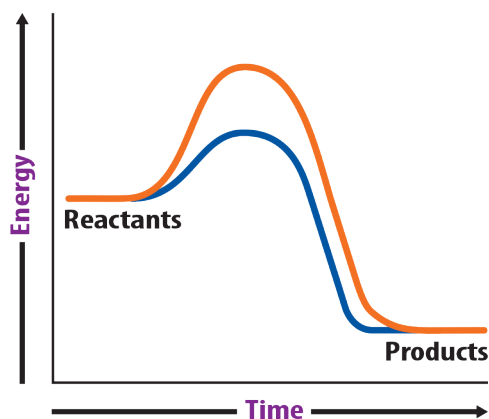
Which is true about this reaction?

- A. More energy is required to break reactant bonds than is released when product bonds form.
B. Less energy is required to break reactant bonds than is released when product bonds form.
C. The bonds of the reactants do not require energy to break because the reaction releases energy.
D. The bonds of the reactants require energy to break, and therefore the reaction absorbs energy.



Critical Thinking

- 8 Predict** The diagram below shows two reactions—one with a catalyst (blue) and one without a catalyst (orange).



How would the blue line change if an inhibitor were used instead of a catalyst?

- 9 Analyze** A student observed a chemical reaction and collected the following data:

Observations before the reaction	A white powder was added to a clear liquid.
Observations during the reaction	The reactants bubbled rapidly in the open beaker.
Mass of reactants	4.2 g
Mass of products	4.0 g

The student concludes that mass was not conserved in the reaction. Explain why this is not a valid conclusion. What might explain the difference in mass?

- 10 Explain Observations** How did the discovery of atoms explain the observation that the mass of the products always equals the mass of the reactants in a reaction?


 Writing in Science

- 11 Write instructions** that explain the steps in balancing a chemical equation. Use the following equation as an example.



REVIEW

THE
BIG
IDEA

- 12** Explain how atoms and energy are conserved in a chemical reaction.
- 13** When a car air bag inflates, sodium azide (NaN_3) decomposes and produces nitrogen gas (N_2) and another product. What element does the other product contain? How do you know?



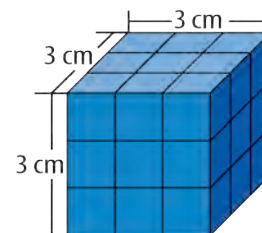
Math Skills



Math Practice

Use Geometry

- 14** What is the surface area of the cube shown below? What would the total surface area be if you cut the cube into 27 equal cubes?



- 15** Suppose you have ten cubes that measure 2 cm on each side.
- What is the total surface area of the cubes?
 - What would the surface area be if you glued the cubes together to make one object that is two cubes wide, one cube high, and five cubes long? Hint: draw a picture of the final cube and label the length of each side.

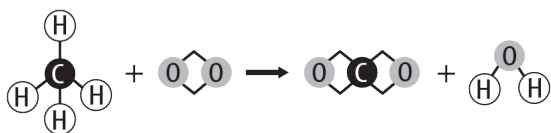
Standardized Test Practice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Multiple Choice

- 1 How can you verify that a chemical reaction has occurred?
- A Check the temperature of the starting and ending substances.
 - B Compare the chemical properties of the starting substances and ending substances.
 - C Look for a change in state.
 - D Look for bubbling of the starting substances.

Use the figure below to answer questions 2 and 3.



- 2 The figure above shows models of molecules in a chemical reaction. Which substances are reactants in this reaction?
- A CH_4 and CO_2
 - B CH_4 and O_2
 - C CO_2 and H_2O
 - D O_2 and H_2O
- 3 Which equation shows that atoms are conserved in the reaction?
- A $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
 - B $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
 - C $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
 - D $2\text{CH}_4 + \text{O}_2 \rightarrow 2\text{CO}_2 + \text{H}_2\text{O}$

- 4 Which occurs before new bonds can form during a chemical reaction?
- A The atoms in the original substances are destroyed.
 - B The bonds between atoms in the original substances are broken.
 - C The atoms in the original substances are no longer moving.
 - D The bonds between atoms in the original substances get stronger.

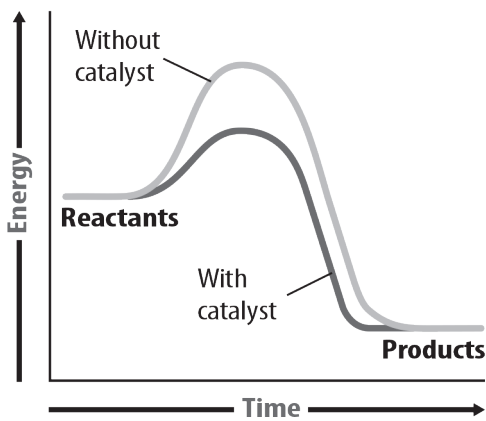
Use the figure below to answer question 5.



- 5 The figure above uses shapes to represent a chemical reaction. What kind of chemical reaction does the figure represent?
- A decomposition
 - B double-replacement
 - C single-replacement
 - D synthesis
- 6 Which type of chemical reaction has only one reactant?
- A decomposition
 - B double-replacement
 - C single-replacement
 - D synthesis
- 7 Which element is always a reactant in a combustion reaction?
- A carbon
 - B hydrogen
 - C nitrogen
 - D oxygen



Use the figure below to answer question 8.

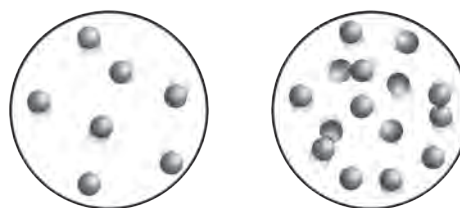


- 8 The figure above shows changes in energy during a reaction. The lighter line shows the reaction without a catalyst. The darker line shows the reaction with a catalyst. Which is true about these two reactions?
- A The reaction with the catalyst is more exothermic than the reaction without the catalyst.
 - B The reaction with the catalyst requires less activation energy than the reaction without the catalyst.
 - C The reaction with the catalyst requires more reactants than the reaction without the catalyst.
 - D The reaction with the catalyst takes more time than the reaction without the catalyst.

Constructed Response

- 9 Explain the role of energy in chemical reactions.
- 10 How does a balanced chemical equation illustrate the law of conservation of mass?
- 11 Many of the reactions that occur when something decays are decomposition reactions. What clues show that this type of reaction is taking place? What happens during a decomposition reaction?

Use the figure below to answer questions 12 and 13.



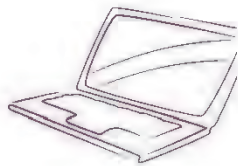
- 12 Compare the two gas samples represented in the figure in terms of pressure and concentration.
- 13 Describe the conditions that would increase the rate of a reaction.

NEED EXTRA HELP?													
If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13
Go to Lesson...	1	1	1	1	2	2	2	3	3	1	2	3	3

Warm It Up!

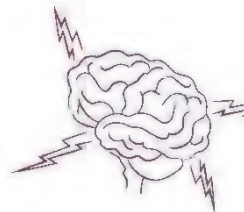
Your sister Sasha is going on a school camping trip to a location where temperatures will be as low as 0°C. You know that under these conditions, your sister's hands could become dangerously cold. To avoid this, you decide to design, construct, and test a hand-warmer heat pack that Sasha can take on her trip. The heat pack should be able to be activated by Sasha when needed. It should also be portable and lightweight.

Get Started!



- Research to learn more about the chemistry behind how hand-warmer heat packs function.
- Research to find out more about different types of commercial heat packs. Note the designs and ingredients of these products.
- Based on your research and the design criteria, create a design for your sister's hand-warmer heat pack.
- Make a list of the materials needed to construct your hand-warmer.

Brainstorm Solutions!



Outline how you plan to construct and test your hand-warmer. Consider the points below as you complete your outline.

- Which chemical reaction will you use that will release thermal energy in your hand-warmer? Explain your choice.
- Which variables might affect the amount of thermal energy released?
- How will you put the materials in your hand-warmer together?
- What criteria will you use to test whether your hand-warmer is effective, safe, and easy to use?
- What kinds of data will you collect from your tests?

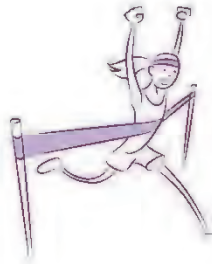
Work Through It!



- Obtain the materials and construct your hand-warmer design.
- Perform tests on your hand-warmer.
- Analyze your results. Does the hand-warmer meet the design criteria? Explain.

- Based on your test results, do you think you should modify your hand-warmer? Why or why not?
- If needed, modify your design and retest.

Finish Up!



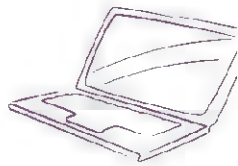
- Analyze your heat pack to see if it meets the project's design requirements.
- Is your design one that your sister could take with her on her camping trip? Why or why not? Support your answer with your testing data.
- What instructions would you need to provide with your hand-warmer so that Sasha can use it correctly?
- Would Sasha be able to use the hand-warmer only once? If so, how could your design be altered for multiple uses?
- How could you develop your model hand-warmer into one that could be sold commercially?

Cookin' with the Sun

You and a group of friends are on a camping trip. You brought a lot of food that you plan to cook. Just as you are talking about lunch, someone notices a sign in the forest. It reads: "DUE TO DROUGHT, NO OPEN FIRES ALLOWED!"

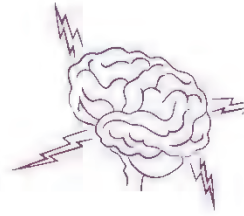
You and your friends discuss the problem and decide that you can use items around you to design, construct, and test a cooker that can be used to prepare your meals. Your cooker will use thermal energy from the Sun.

Get Started!



- After looking through your backpacks, the car, and the neighboring campsites, you and your friends find the following materials: an empty cardboard box with its lid, scissors, aluminum foil, tape, plastic wrap, some black garbage bags, several sheets of newspaper, and a pencil. Someone even brought a thermometer!
- Determine how each material can be used to collect, concentrate, and store thermal energy from the Sun. Consider the following:
 - What materials might best absorb heat inside the cooker?
 - How can you insulate the cooker so it maximizes the heat contained in it?
 - How will you transfer the Sun's thermal energy into your device?
 - How will thermal energy enter the solar cooker and become trapped inside it?
 - What time of the day should you operate your solar cooker?

Brainstorm Solutions!



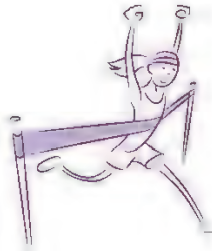
- Using the materials available, have each of your friends provide a design for a solar cooker.
- Discuss each design and determine which might best maximize thermal energy transfer.
- Based on your choice of best design, make a detailed, labeled drawing of your design.
- Discuss with your friends how you will build and test the cooker.

Work Through It!



- Using your chosen design and the available materials, construct your solar cooker.
- Analyze the device for potential weaknesses, and, if necessary, modify the device to eliminate the possible problems.
- Test the solar cooker to determine whether it is likely to cook food. What criteria will you use to determine if the cooker will cook your food to a safe temperature?
- Develop a plan for data collection.
- Use the results of your test to further modify the solar cooker, if necessary.

Finish Up!



- What time of day did you choose to test your solar cooker? Why?
- What types of data did you collect during your tests?
- What conclusions can you reach concerning the ability of your solar cooker to maximize thermal energy transfer?
- How could you improve the design of the solar cooker to increase the thermal energy it captures from the Sun? What changes would you make if any material was available?
- What are some factors beyond your control that might reduce the ability of your cooker to maximize the transfer of the Sun's thermal energy to the cooker? Explain your answer.

GRADE 8

- Unit 1 Interactions of Matter
 - Unit 2 Earth and Geological Changes
 - Unit 3 Water and Other Resources
 - Unit 4 Life: Changes and Interactions
-

GRADE 6

- Unit 1 Motion and Energy
 - Unit 2 Exploring Earth
 - Unit 3 Exploring the Universe
 - Unit 4 Understanding Matter
 - Unit 5 Exploring Life
-

GRADE 7

- Unit 1 Energy and Matter
 - Unit 2 Earth: A Dynamic Planet
 - Unit 3 Life: Structure and Function
 - Unit 4 Heredity and Changes Over Time
 - Unit 5 Exploring Ecology
-

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