Standards: S8P1.d, S8P1.f, S8CS5.b

The Periodic Table of Elements

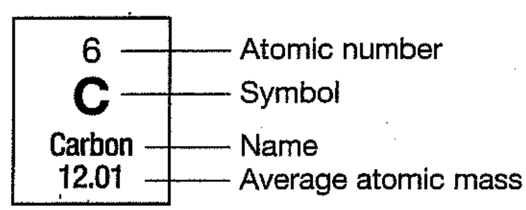
Key Words • element • periodic table of elements • atomic number • atomic mass • model • period • group • metal • nonmetal • metalloid • chemical property • reactivity • ion • inert

Getting the Idea

Recall from Lesson 1 that an **element** is a pure substance that does not break down into simpler substances by ordinary chemical means. In this lesson, you will learn how scientists use and organize information about the elements.

Information about Elements

The **periodic table of elements** presents and organizes information about all the elements. The table is a chart that arranges the elements in an order according to their properties, or characteristics. Each element has a box in the periodic table that contains information specific to that element. The box contains the element's name and its unique chemical symbol. Most symbols are one or two letters. The first letter of any symbol is always a capital letter. If there is a second letter, it is a lowercase letter. Usually, the symbol is related to the name of the element. Sometimes it comes from the Latin name for the element. For example, the symbol for iron is Fe. The Latin word for iron is *ferrum*.



Look at the box for the element carbon, which has the symbol C. You can see that the atomic number of carbon is 6. The **atomic number** identifies the number of protons in the nucleus of one atom of an element. This determines the identity of the element. A carbon atom always contains 6 protons. Because atoms are generally neutral in charge, the number of protons in an atom is equal to the number of electrons. Thus, the atomic number also indicates how many electrons an atom of an element normally has.

The next, larger number is the **atomic mass.** Atomic mass is given in atomic mass units, amu. Recall from Lesson 1 that virtually all of an atom's mass is contained in protons and neutrons in the atom's nucleus. While the atoms of an element always have the same number of protons, they can have different numbers of neutrons. This is why atomic mass usually has a decimal: it is the *average* atomic mass of an element's different atoms. Notice that carbon's atomic mass is 12.01. Out of every hundred carbon atoms, about 99 have a mass of 12 amu. One has an extra neutron, and a mass of 13 amu. That particular atom causes the average mass of carbon to have a decimal.

The Periodic Table

Atomic number — 14
Symbol — **Si**
Atomic mass — 28.086
Name — Silicon

Mass numbers in parentheses are those of the most stable or most common isotopes.

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 (VIII)	9 (VIII)	10 (VIII)	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.008 Hydrogen																	2 **He** 4.003 Helium
2	3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.811 Boron	6 **C** 12.011 Carbon	7 **N** 14.007 Nitrogen	8 **O** 15.999 Oxygen	9 **F** 18.998 Fluorine	10 **Ne** 20.179 Neon
3	11 **Na** 22.989 Sodium	12 **Mg** 24.305 Magnesium											13 **Al** 26.982 Aluminum	14 **Si** 28.086 Silicon	15 **P** 30.974 Phosphorus	16 **S** 32.066 Sulfur	17 **Cl** 35.453 Chlorine	18 **Ar** 39.948 Argon
4	19 **K** 39.098 Potassium	20 **Ca** 40.078 Calcium	21 **Sc** 44.956 Scandium	22 **Ti** 47.867 Titanium	23 **V** 50.943 Vanadium	24 **Cr** 51.996 Chromium	25 **Mn** 54.938 Manganese	26 **Fe** 55.845 Iron	27 **Co** 58.933 Cobalt	28 **Ni** 58.693 Nickel	29 **Cu** 63.546 Copper	30 **Zn** 65.390 Zinc	31 **Ga** 69.723 Gallium	32 **Ge** 72.610 Germanium	33 **As** 74.922 Arsenic	34 **Se** 78.960 Selenium	35 **Br** 79.904 Bromine	36 **Kr** 83.800 Krypton
5	37 **Rb** 85.468 Rubidium	38 **Sr** 87.620 Strontium	39 **Y** 88.906 Yttrium	40 **Zr** 91.224 Zirconium	41 **Nb** 92.906 Niobium	42 **Mo** 95.940 Molybdenum	43 **Tc** (97.907) Technetium	44 **Ru** 101.070 Ruthenium	45 **Rh** 102.906 Rhodium	46 **Pd** 106.42 Palladium	47 **Ag** 107.868 Silver	48 **Cd** 112.411 Cadmium	49 **In** 114.818 Indium	50 **Sn** 118.710 Tin	51 **Sb** 121.760 Antimony	52 **Te** 127.60 Tellurium	53 **I** 126.905 Iodine	54 **Xe** 131.293 Xenon
6	55 **Cs** 132.906 Cesium	56 **Ba** 137.327 Barium	57 **La** 138.906 Lanthanum	72 **Hf** 178.490 Hafnium	73 **Ta** 180.948 Tantalum	74 **W** 183.84 Tungsten	75 **Re** 186.207 Rhenium	76 **Os** 190.230 Osmium	77 **Ir** 192.217 Iridium	78 **Pt** 195.084 Platinum	79 **Au** 196.967 Gold	80 **Hg** 200.590 Mercury	81 **Tl** 204.383 Thallium	82 **Pb** 207.200 Lead	83 **Bi** 208.980 Bismuth	84 **Po** (208.982) Polonium	85 **At** (209.987) Astatine	86 **Rn** (222.018) Radon
7	87 **Fr** (223.019) Francium	88 **Ra** (226.025) Radium	89 **Ac** (227.028) Actinium	104 **Rf** (263.113) Rutherfordium	105 **Db** (262.114) Dubnium	106 **Sg** (266.122) Seaborgium	107 **Bh** (264.125) Bohrium	108 **Hs** (269.134) Hassium	109 **Mt** (268.139) Meitnerium	110 **Ds** (272.146) Darmstadium	111 **Rg** (272.154) Roentgenium	112 **Uub** (277)	113 **Uut** (284)	114 **Uuq** (289)	115 **Uup** (288)	116 **Uuh** (292)		118 **Uuo** (294)

Series														
Lanthanide Series	58 **Ce** 140.116 Cerium	59 **Pr** 140.908 Praseodymium	60 **Nd** 144.242 Neodymium	61 **Pm** (144.913) Promethium	62 **Sm** 150.360 Samarium	63 **Eu** 151.964 Europium	64 **Gd** 157.250 Gadolinium	65 **Tb** 158.925 Terbium	66 **Dy** 162.500 Dysprosium	67 **Ho** 164.930 Holmium	68 **Er** 167.259 Erbium	69 **Tm** 168.934 Thulium	70 **Yb** 173.040 Ytterbium	71 **Lu** 174.967 Lutetium
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The periodic table is a useful model that can help you understand the properties of elements. It might seem strange to call a chart a model, but a **model** is simply any way to show an object or an idea. A model can be a diagram, like the periodic table. Each box in the table is a model of the atom it stands for. The diagram of a carbon atom shown in Lesson 1 is also a model. A model can be a three-dimensional representation of an object, such as a stick-and-ball model that represents an atom or molecule. Scientists use these kinds of models to show objects that are very large or very small. Other types of models are maps, computer programs, and mathematical equations.

Arranging Elements on the Periodic Table

The periodic table arranges elements in horizontal rows in order of increasing atomic number. Each horizontal row in the periodic table is called a **period**. Periods are numbered from 1 to 7. The electrons in an atom are found in orbitals, or energy levels. All elements in a period have the same number of energy levels. Elements in the first row have one energy level. Elements in the second row have two energy levels. Elements in the third row have three energy levels, and so on.

A vertical column in the periodic table is a **group**. Groups are numbered from 1 to 18. A group is also called a chemical family because elements in the same group have the same number of electrons in their outer energy level. This causes elements in the same family to have similar properties. Some families in the periodic table have names. Group 1 is called the alkali metals. Group 2 is called the alkaline earth metals. Groups 3 to 12 form the biggest family of all, the transition metals. Group 17 elements are the halogens. Group 18 elements are the noble gases.

Metals, Nonmetals, and Metalloids

More than 75 percent of the elements in the periodic table are metals. **Metals** are located to the left of the dark, step-like line starting in Group 13 and ending in Group 16. (The gas hydrogen, the first element of the table, is an exception.) They are usually shiny, malleable (can be pounded into thin sheets), ductile (can be stretched into wires), and are usually solid at room temperature (mercury is an exception). Metals are good conductors of heat and electricity.

Nonmetals are elements that are not metals. The nonmetals include all the elements in Groups 17 and 18 and some of the elements in Groups 14, 15, and 16 located above or to the right of the step-like line. Many nonmetals are gases at room temperature. These include nitrogen, oxygen, fluorine, chlorine, and the noble gases. Solid nonmetals are substances that are generally dull in appearance, usually brittle, and poorly conductive of heat and electricity. One nonmetal, bromine, is a liquid at room temperature.

Metalloids are substances that have some characteristics of both metals and nonmetals. Metalloids are semiconductors, or partial conductors, of electricity. The metalloids are located along the step-like line of the periodic table in Groups 13, 14, 15, and 16. The metalloids are boron, silicon, germanium, arsenic, antimony, and tellurium.

Chemical Properties of Chemical Families

A **chemical property** is a characteristic that determines how a substance will interact with other substances during a chemical reaction. You cannot observe a chemical property of a substance without changing the substance. For example, combustibility is a substance's ability to catch fire. Hydrogen is an extremely combustible element. Other combustible elements include nonmetals in the upper-right-hand part of the periodic table.

An important chemical property of elements is reactivity. **Reactivity** describes how likely an element is to react and form bonds with other elements. The most reactive metals are the alkali metals in Group 1. Although hydrogen is the first element and seems to be in Group 1, it is not an alkali metal. Hydrogen is a distinctive element with properties that do not closely resemble those of elements in any other group.

The alkaline earth metals, located in Group 2, are also reactive but are slightly less reactive and harder than Group 1 metals. The reactivity of both the Group 1 and Group 2 metals increases with increasing atomic number.

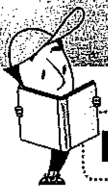
Groups 3 through 12 include the transition metals. A property of transition elements is that they often form ions of various colors. An **ion** is an atom that has a positive or negative charge. Ions form when atoms gain or lose electrons. Recall from Lesson 1 that the number of protons and electrons in an atom are the same. If an atom loses an electron, it has more positive charges than negative charges. As a result, the atom has an overall positive charge. It has become a positive ion. If an atom gains an electron, it has more negative charges than positive charges. It has become a negative ion.

The halogens are nonmetals in Group 17. The halogens are the most reactive nonmetals. Reactivity in nonmetals increases as atomic number decreases, so fluorine is the most reactive nonmetal. Halogens react with alkali metals to form salts.

The noble gases, located in Group 18, are the least reactive of all elements. At one time, noble gases were considered **inert**—unable to react chemically. However, in 1962, scientists produced a substance containing xenon (Xe) and fluorine (Fl). Since then, scientists have produced other substances involving noble gases. They remain the most stable family of elements, however, and are least likely to react.

Discussion Question

Some printed versions of the periodic table place hydrogen (H) apart from the rest of the elements. Why do you think that this is sometimes done?



Lesson Review

Use the element box from the periodic table shown below to answer questions 1 and 2.

19 **K** Potassium 39.098

1. What is the name and atomic number for the element represented above?

A. K, 19
B. K, 39.098
C. Potassium, 19
D. Potassium, 39.098

2. An atom of the element shown above has how many protons?

A. 18
B. 19
C. 39
D. 58

3. Radium is an element found in Group 2 and Period 7. In a normal radium atom, how many electron energy levels are present?

A. 2
B. 6
C. 7
D. 8

4. A student is investigating a sample of an element. The student observes that the element is solid, shiny, and can be bent into a new shape. The student is **most likely** observing

A. carbon.
B. oxygen.
C. hydrogen.
D. aluminum.

5. Which of the following is a chemical symbol representing an element?

A. C
B. CO
C. CO_2
D. H_2O

Standards: S8P1.c, S8P1.d

States of Matter

Key Words • state of matter • solid • liquid • gas • plasma • melting point • evaporation • vaporization • boiling point • condensation • freezing point

Getting the Idea

You probably know that ice, liquid water, and water vapor are all forms of the same substance: water (H_2O). If they are all the same substance, why do they have different physical qualities? The answer is energy. Substances can change forms if enough heat energy is added or taken away. Matter changes form because of the attractive force between the particles in matter and the way in which the particles move.

States of Matter

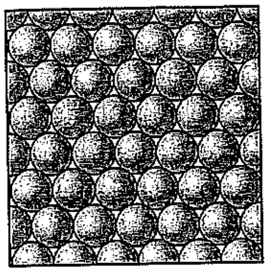
The **state of matter** is the physical form in which matter exists. All matter is made of particles that are always moving. These particles are arranged differently in each state of matter. On Earth, matter generally exists in a solid, liquid, or gas state. A **solid** has a definite shape and a definite volume. The particles of a solid are usually packed closely together, often in patterns or crystal formations. The particles vibrate and move, but they do not slip past one another. This is why solids maintain a definite shape and a definite volume.

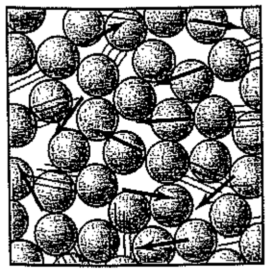
A **liquid** does not have a definite shape but does have a definite volume. The particles of a liquid are in contact with one another. The particles in liquids move quickly enough to slip past one another. Because the particles can slip past one another, a liquid takes the shape of whatever container holds it.

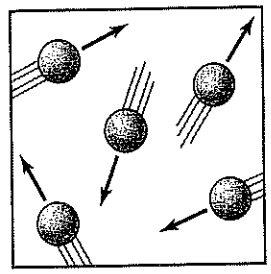
A **gas** has neither a definite shape nor a definite volume. The particles of gases are not normally in contact with each other. They move quickly in straight lines until they bump into other gas particles or the walls of the container. When a gas particle hits another particle or the wall of the container, it bounces off and continues to move. Gases take the shape and volume of the container that holds them. The volume of a gas changes depending on the volume of its container.

Plasma is another state of matter. Like a gas, plasma does not have a definite shape or definite volume. Plasma forms only at very high temperatures, such as those existing in stars. At such high temperatures, atoms collide with greater force. This gives electrons enough energy to overcome their attraction to protons. This results in loose electrons and positively charged ions that make plasma electrically conductive. Plasma is quite common throughout the universe, but rare on Earth. On Earth, plasma exists in lightning bolts and inside some lightbulbs.

The pictures below illustrate the general arrangement of the particles that make up solids, liquids, and gases. The spheres in these models represent the particles of a pure substance.


Solid


Liquid


Gas

Temperature and Changes of State

Particles of matter are always moving. The particles that make up a substance move more when the substance is warmer. The energy of motion is called kinetic energy. Temperature is a measure of the average kinetic energy of the particles in a substance. The faster the particles in a substance move, the higher the temperature of the substance. The slower the particles move, the lower the temperature.

Matter can change from one state to another. A change of state is the physical change that takes place when a substance changes from the solid, liquid, or gas state into another state. A change of state requires that matter either absorb or release energy. Most often, the energy absorbed or released is thermal energy, or heat. The temperatures at which substances change from one state to another are unique for each substance.

As energy is added to a solid, the particles in the solid move faster. If enough energy is added, the solid changes to a liquid. This change from a solid to a liquid is called melting. The temperature at which a substance melts is called the **melting point.**

If enough energy is added to a liquid, particles in the liquid will move fast enough for the liquid to change into a gas. This change can happen in two ways. If the liquid changes to a gas only at the surface, the process is called **evaporation.** This is how a puddle of water dries up on a sunny day. If the change happens throughout the gas, and bubbles form inside the liquid and rise to the surface, the change is called **vaporization.** This is how water changes to water vapor when a pot of water is heated on a stove. The temperature at which vaporization, or boiling, occurs is called the **boiling point.**

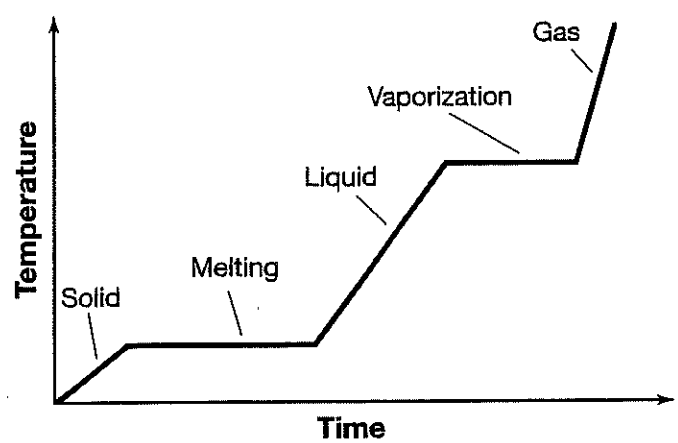
As energy is removed from a substance, the particles that make up the substance move more slowly. If enough energy is removed from a gas, the gas turns into a liquid. **Condensation** is the process of a gas changing states to become a liquid. Dew is water vapor that condenses as the air temperature drops at night.

The change from liquid to solid is called freezing, and the temperature at which a substance freezes is called the **freezing point**. The freezing point and melting point for most substances are the same. For example, when the temperature of water falls below 0°Celsius, the water freezes to form ice. When the temperature rises above 0°Celsius, the ice melts and forms a liquid.

Did You Know? **Most substances become denser as they freeze because their particles are packed more closely together. Water is a rare exception. Water expands when it freezes. As a result, solid water (ice) actually has a greater volume—and therefore a lower density—than an equal amount of liquid water.**

Remember that temperature is the average kinetic energy of the particles in a substance. The graph below shows how the temperature of a substance changes as it is heated. As you can see, the substance's temperature stays the same during changes of state. However, the total amount of thermal energy (heat) in the substance is always changing. As heat is added to or removed from a substance, the temperature of the substance increases or decreases until the substance begins changing its state of matter. When heat is added, the particles that make up a substance usually move farther apart. When heat is removed, the particles that make up a substance usually move closer together.

Heating Curve



Discussion Question

A substance changes from a solid to a liquid during the process of melting. What happens to the temperature and arrangement of the particles in the substance as it melts?

Lesson Review

1. What type of arrangement and movement do particles in a liquid display?

   A. Particles are closely packed together and they vibrate back and forth.

   B. Particles are not in contact with each other and they move very quickly.

   C. Particles are in contact with each other, but they are able to slip past one another.

   D. Particles are not in contact with one another and are moving at extreme speeds.

2. In which state of matter do particles spread and fill the volume of the container that holds them?

   A. solid

   B. liquid

   C. gas

   D. ice

3. What happens to the temperature of a solid as it melts?

   A. It stays the same.

   B. It increases.

   C. It decreases.

   D. It increases and then decreases.

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Standards: S8P1.d, S8P1.e, S8CS3.a, S8CS3.f

Chapter 1 • Lesson 4

Physical and Chemical Changes

Key Words: • physical property • density • melting point • boiling point • chemical property • reactivity • combustibility • physical change • chemical change • chemical reaction • precipitate

Getting the Idea

Imagine you have a container of water and a container of mineral oil. Both are clear liquids. How can you tell the liquids apart? You can distinguish the liquids by examining their properties. A property is any characteristic that can be used to identify and describe matter.

Physical Properties

A **physical property** is a characteristic that can be observed or measured without changing the identity of a substance. Color, hardness, magnetism, and state are physical properties of matter. Each of these properties can be observed or measured using simple tools.

Every substance has physical properties that make the substance unique. Thus, physical properties can help you identify a substance. **Density** is a physical property that describes how much matter is packed into a certain space. You can measure density as a ratio of mass to volume. Mass is the amount of matter that makes up an object. Mass is expressed in units such as kilograms (kg) and grams (g). Volume is the amount of space that matter occupies. The volume of solids is expressed in units such as cubic centimeters (cm^3). Liquid volume is expressed in units such as liters (L) and milliliters (mL). You can calculate density using this formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \text{ or } D = \frac{m}{V}$$

Consider this example: What is the density of a piece of iron with a volume of 2 cm^3 and a mass of 15.74 g? By plugging these values into the density equation, you get:

$$D = \frac{m}{V} = \frac{15.74\text{g}}{2\text{cm}^3} = 7.87 \text{ g/cm}^3$$

This means there are 7.87 grams packed into every cubic centimeter of iron. Because density is the quotient of mass and volume, the unit for density shows this relationship. Density is expressed in g/cm^3, which is read as "grams per cubic centimeter." You might also see cubic centimeters expressed as cc.

Density is a physical property that can be used to identify a substance. For example, the density of pure water is 1 g/mL. The density of lead is about 11.3 g/cm^3. The density of pure gold is 19.3 g/cm^3. All samples of pure gold have that density. If a sample thought to be gold has a density that is not 19.3 g/cm^3, you know that the sample is not pure gold. It is another substance, or possibly some combination of gold and other metals.

Did You Know?

Most liquids have densities close to that of water. Mercury, a liquid metal, is a notable exception. Mercury has a density of about 13.5 g/mL, more than thirteen times the density of water. This physical property makes mercury useful for certain applications.

Melting point and boiling point are also physical properties of matter. Recall from Lesson 3 that **melting point** is the temperature at which a solid substance melts to form a liquid. The melting point of water is 0°C. **Boiling point** is the temperature at which bubbles of gas form throughout a liquid and begin rising to the surface. The boiling point of water is 100°C.

Like density, melting and boiling points can be used to identify a substance. For example, if a colorless liquid boils at 78°C, you know the substance is not water. If you refer to a table that lists the boiling points of different substances, you will find that ethanol boils at 78°C. But before you can be sure that the substance is ethanol, you need to determine the density or other properties of the liquid. It is possible that another substance has this boiling point.

Other physical properties include the ability to conduct heat and electricity. Metals are generally better conductors of heat and electricity than nonmetals. Solubility, or the ability of a substance to dissolve, is also a physical property. For example, salt is soluble in water. If you mix salt and water, the salt dissolves. Other substances do not dissolve in water. Magnetism is a more unique physical property. A substance is said to be magnetic if it is attracted to a magnet. Iron, cobalt, and nickel are magnetic elements.

Chemical Properties

A **chemical property** is a characteristic that determines how one substance will interact with other substances during a chemical reaction. Examples of chemical properties include reactivity, the ability to burn, the ability to rust, reaction to light, and reaction with acids.

Reactivity describes how likely the atoms or molecules of a substance are to form bonds with atoms of other substances. Recall from Lesson 2 that the alkali metals in Group 1 of the periodic table are very reactive. The inert gases, in Group 18 of the periodic table, are not very reactive. These elements rarely react with other substances.

Every substance has chemical properties that make it unique. Like physical properties, chemical properties can help identify a substance. Unlike physical properties, however, chemical properties cannot be observed without changing the substance. For example, **combustibility**, or the ability to burn, is a chemical property of ethanol. When ethanol burns, it combines with oxygen in the air to form new substances that have different properties.

Physical and Chemical Changes

Matter can be changed in a variety of ways. For example, matter changes when a piece of paper is ripped into smaller pieces. Matter also changes when the gases hydrogen and oxygen join together to form the liquid water. The types of changes that matter undergoes are classified into two groups: physical changes and chemical changes.

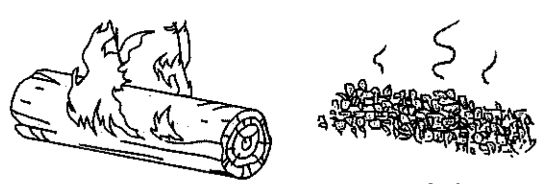
A **physical change** alters the physical properties of a substance without changing the identity of the substance. Physical changes cause a change in properties such as shape, volume, mass, or state. Many physical changes can be reversed to change the matter back into its former condition. For example, consider an ice cube that melts to form liquid water. The change can be reversed: the melted water can freeze and become ice.

Ice melting is a physical change.

A **chemical change** occurs when one substance is changed into a new substance with different properties. Chemical bonds are broken or formed as atoms are rearranged. During a chemical change, the identity of a substance is changed. For example, when you make a chocolate cake, you use sugar, eggs, flour, and chocolate to make the batter. When you bake the batter, its identity changes. The batter becomes a cake in which the identities of the original substances have changed. Baking a cake involves chemical changes.

A **chemical reaction** is the process by which new substances are formed during a chemical change. Some signs that indicate a chemical reaction has occurred include the formation of gases or a change in color. Substances that react chemically may give off heat or light. Another sign of a chemical reaction is the formation of a precipitate. A **precipitate** is a solid that forms from a chemical reaction that takes place in a solution. Unlike a physical change, it is difficult to reverse the effects of a chemical change. After baking a cake, for example, you can no longer separate the sugar, eggs, flour, and chocolate.

A combustion reaction is a chemical reaction that occurs when oxygen combines with certain other substances to release heat. An example of a combustion reaction can be seen when a propane barbecue grill is lit. Propane is used in barbecue grills because propane burns in the presence of oxygen. When propane gas burns, heat is emitted, or released. Carbon dioxide and water are produced. Combustion also occurs when wood burns.



A log burning involves chemical changes.

Discussion Question

How does the process of eating and digesting food involve both physical changes and chemical changes?

Lesson Review

1. Which of the following is an example of a chemical change?

   A. water evaporating

   B. carbon joining with oxygen to form carbon dioxide

   C. ice cream melting

   D. salt dissolving in water to form a solution

2. What happens during a physical change?

   A. New substances are formed.

   B. The identity of the substance is changed.

   C. A chemical reaction occurs.

   D. A substance changes form but does not lose its identity.

3. What two quantities must be known to calculate the density of a sample of matter?

   A. color and mass

   B. mass and volume

   C. length and mass

   D. solubility and mass

4. A sample of aluminum has a volume of 3.0 cm^3 and a mass of 8.1 g. What is the density of aluminum?

   A. 2.7 g/cm^3

   B. 5.1 g

   C. 11.1 cm^3

   D. 24.3 g/cm^3

Chapter 1 • Lesson 5

Standards: S8P1.g, S8CS2.b, S8CS3.a

Conservation of Matter

Key Words • reactant • product • law of conservation of matter • compound • molecule • subscript

Getting the Idea

The evaporation of a puddle of water and rust forming on a metal are both examples of changes in matter. In one example, water evaporates in a physical change. In the other, a new substance is formed by a chemical change. However, the total amount of matter remains the same in both examples. Matter is neither created nor destroyed, even when a new substance is formed.

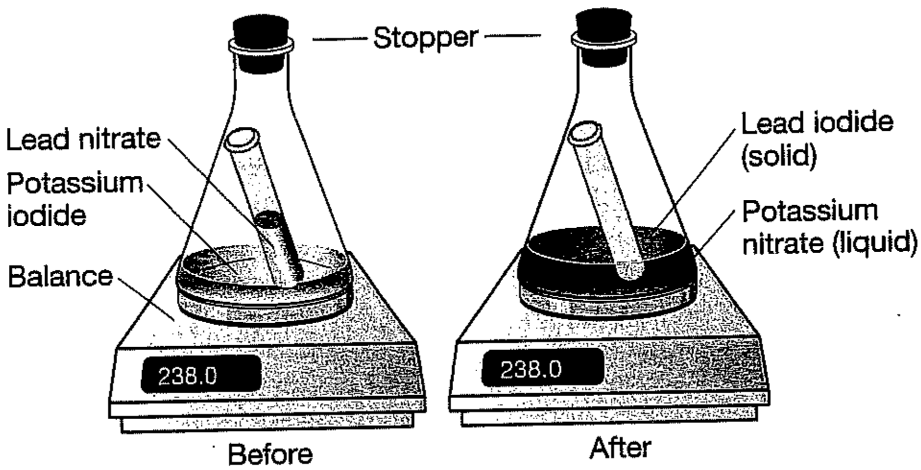
The Law of Conservation of Matter

In a chemical reaction, the **reactants** are the substances that are present before the reaction occurs and that are changed by the reaction. The **products** are the substances present after the reaction takes place. By measuring the masses of the reactants and products in chemical reactions, scientists developed the law of conservation of matter. The **law of conservation of matter** states that matter cannot be created or destroyed. Matter may change from one form to another. Atoms might be rearranged to form new substances. But the same number of atoms exists before and after the changes. The total mass of the matter does not change.

An Example of Conservation of Matter

The experimental setup shown on the next page illustrates the law of conservation of matter. In this setup, a test tube that contains lead nitrate is placed upright inside a flask that contains potassium iodide. This is shown on the left side of the illustration. The reactants cannot mix because the test tube is upright. Notice the stopper in the mouth of the flask. It forms a closed system, or a space in which matter cannot enter or leave. The system is then placed on a balance so its mass can be measured.

After the mass is measured, the entire system is turned upside down so the lead nitrate in the test tube can mix with the potassium iodide. (These are the reactants.) A chemical reaction occurs that forms lead iodide and potassium nitrate. (These are the products.)



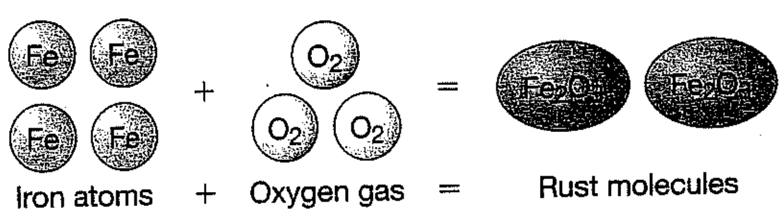
Notice that the total mass of the system is 238.0 grams both before and after the reaction. Because the flask was sealed with the stopper, no matter could enter or leave the system. The fact that the mass did not increase or decrease shows that matter was neither created nor destroyed during the reaction. This is true for all chemical reactions.

The Formation of Rust

Iron is a hard, solid, gray-colored metal. Rust is a flaky, orange-red solid. When iron reacts chemically with oxygen gas in the air, the elements form rust, a compound known as iron oxide. Recall from Lesson 1 that a **compound** is a pure substance that forms when two or more different kinds of atoms join chemically. The word equation for the formation of rust is written below:

iron + oxygen → iron oxide

Now look at the diagram below to see the chemical reaction in greater detail.



Iron atoms and oxygen gas combine in a new way to make rust molecules.

The reactants in this chemical reaction are four iron (Fe) atoms and three molecules of oxygen gas (O_2). Recall from Lesson 1 that a **molecule** is the smallest unit of a compound that has the properties of that compound. A molecule of oxygen is written as O_2. A small number written to the right and slightly below a chemical symbol is a **subscript**. It indicates the number of atoms of that element in the molecule or compound. In this case, the subscript indicates there are two oxygen atoms in the molecule. Since there are three oxygen molecules among the reactants, there are a total of six oxygen atoms involved.

Now look at the product of this reaction—iron oxide. Notice that two molecules of iron oxide are formed. Each molecule of iron oxide has the formula Fe_2O_3. This formula shows that each molecule of iron oxide contains two iron atoms and three oxygen atoms. Because there are two molecules of iron oxide, there are four iron atoms and six oxygen atoms in the product. The number of iron atoms and oxygen atoms in the product is the same as the number of those atoms in the reactants.

All chemical reactions follow the law of conservation of matter. Refer back to the diagram showing how rust forms. The atoms of the reactants are rearranged to form the atoms in the product: no new atoms are added and no atoms are destroyed. The total mass of the reactants equals the total mass of the products.

Determining the Mass of Reactants and Products

Tin fluoride is often added to toothpaste to prevent cavities. The following reaction shows how tin fluoride forms, and is another example of conservation of matter:

tin + hydrogen fluoride → tin fluoride + hydrogen

If this reaction combines 118.7 grams of tin and 40.02 grams of hydrogen fluoride, the total mass of the reactants is 158.72 grams. Under ideal conditions, this reaction will produce 156.71 grams of tin fluoride and 2.01 grams of hydrogen. If you add the masses of the products, you will find that the mass of the products is 158.72 grams, which is the same as the mass of the reactants. Thus, the total mass of the reactants equals the total mass of the products, and matter was neither created nor destroyed during the reaction.

Mass Conservation in a Chemical Reaction

Mass of Reactants	Mass of Products
158.72 g	158.72 g

Discussion Question

How can a chemical reaction be compared to shuffling a deck of cards?

Lesson Review

1. What does the law of conservation of matter state?

   A. The total mass of the reactants is greater than the total mass of the products.

   B. The total mass of the reactants is less than the total mass of the products.

   C. The total mass of the reactants equals the total mass of the products.

   D. Matter cannot change form.

2. Look at the incomplete chemical equation below.

   $$Na_2O + H_2O \rightarrow ?$$

   The reactants are shown. How many oxygen (O) atoms must be present in the product that forms from this reaction?

   A. 1

   B. 2

   C. 3

   D. 4

3. During a chemical reaction, methane (CH_4) and oxygen (O_2) combine to produce carbon dioxide (CO_2) and water (H_2O). The balanced chemical equation identifies the reactants and products for this reaction, along with some of their masses.

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

   $$16\text{ g} + ? \rightarrow 44\text{ g} + 36\text{ g}$$

   What mass of oxygen (O_2) is required for this reaction to occur?

   A. 16 g

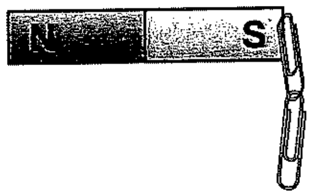
   B. 36 g

   C. 44 g

   D. 64 g

Chapter 1 Review

Use the diagram below to answer question 1.



1. The paper clips stick to the bar magnet. What property of the paper clips is demonstrated by this?
   A. reactivity
   B. density
   C. solubility
   D. magnetism

2. Which of these statements is NOT part of the law of conservation of matter?
   A. Mass of reactants equals mass of products.
   B. Reactants and products are the same compounds.
   C. Matter cannot be created.
   D. Matter cannot be destroyed.

3. Where are the metalloids in the periodic table?
   A. in the far left column
   B. in the far right column
   C. in the top row
   D. along the step-like line

4. Which of these is NOT released as part of a combustion reaction?
   A. oxygen
   B. carbon dioxide
   C. light
   D. heat

5. Which of these is NOT evidence of a chemical change?
   A. change in color
   B. release of light
   C. change in shape
   D. release of a gas

Use the diagram below to answer question 6.

	9 **F** 18.998 Fluorine	10 **Ne** 20.179 Neon
16 **S** 32.065 Sulfur	17 **Cl** 35.453 Chlorine	18 **Ar** 39.948 Argon

6. A small portion of the periodic table is shown above. Which two elements are in the same group or chemical family?
   A. fluorine and neon
   B. fluorine and chlorine
   C. chlorine and argon
   D. sulfur and chlorine

7. Which of these statements about chemical reactions is true?
   A. Products are changed into reactants.
   B. The mass of products is less than the mass of reactants.
   C. Products and reactants contain the same total number of atoms.
   D. The molecules of products are larger than the molecules of reactants.

8. If you heat a liquid to determine the temperature at which it changes to a gas, you are measuring
   A. a physical property called boiling point.
   B. a chemical property called reactivity.
   C. a physical property called conductivity.
   D. a chemical property of reaction with acids.

9. A sample of silver has a volume of 4.0 cm^3 and a mass of 42 g. What is the density of silver?
   A. 0.1 g/cm^3
   B. 10.5 g/cm^3
   C. 38 g/cm^3
   D. 46 g/cm^3

10. Which state of matter is found more often in stars than on Earth?

    A. solid
    B. liquid
    C. gas
    D. plasma

11. When substances are combined to form a mixture, they

    A. form chemical bonds.
    B. form a new substance.
    C. lose their original properties.
    D. keep their individual properties.

12. Which of these statements about carbon dioxide is false?

    A. Carbon dioxide is chemically reactive.
    B. Carbon dioxide is an element.
    C. Carbon dioxide contains chemical bonds.
    D. Carbon dioxide exists as molecules.

13. Which formula represents a molecule?

    A. B
    B. Br_2
    C. Be
    D. Ba

14. In which state of matter do particles move the fastest?

    A. solid
    B. liquid
    C. gas
    D. plasma

15. Which of these is a physical property?

    A. ability to dissolve in water
    B. combustibility
    C. reactivity
    D. ability to rust

16. A student completely dissolves some salt in a beaker of water. Which of these statements does NOT describe the salt and water?
    A. It is a mixture.
    B. It is a solution.
    C. It is a compound.
    D. It is homogeneous.

17. In which state of matter are particles packed closest together and only able to vibrate?
    A. solid
    B. liquid
    C. gas
    D. plasma

18. The elements in the far-right column of the periodic table
    A. are very reactive.
    B. are metalloids.
    C. are metals.
    D. are inert gases.

19. Look at the equation below.

    iron oxide + carbon → iron + carbon dioxide

    The total mass of the reactants is 360 grams. The reaction produces 132 grams of carbon dioxide. How much iron is produced?
    A. 132 grams
    B. 228 grams
    C. 328 grams
    D. 492 grams