Phase Changes and States of Matter

Chemistry Reader

Name: ____________________

...or composition.
...mainly copper.
...led a **substance.**
...also referred to as
...ce **has identical**
...**composition.**
...but there are dif-
...n scratch the sur-
...pper is better than
...ld and copper are
...ets without break-
...color, conductivity,
...**physical property** is
...erved or measured

...nces. The states of
...ough scientists use
...in this book it will be
...l properties can help
...substance that was
...be water. A colorless
...would most certainly
...hanol.

...current—gold or copper?

...ances	
...lting point (°C)	Boiling point (°C)
−249	−246
−218	−183
−101	−34

States of Matter

Depending on the circumstances, you use three different words to refer to water—water, ice, and steam. Water, which is a common substance, exists in three different physical states. So can most other substances. **Three states of matter are solid, liquid, and gas.** Certain characteristics that can distinguish these three states of matter are summarized in Figure 2.3.

Solids A **solid** is a form of matter that has a definite shape and volume. The shape of a solid doesn't depend on the shape of its container. The particles in a solid are packed tightly together, often in an orderly arrangement, as shown in Figure 2.3a. As a result, solids are almost incompressible; that is, it is difficult to squeeze a solid into a smaller volume. In addition, solids expand only slightly when heated.

Liquids Look at Figure 2.3b. The particles in a liquid are in close contact with one another, but the arrangement of particles in a liquid is not rigid or orderly. Because the particles in a liquid are free to flow from one location to another, a liquid takes the shape of the container in which it is placed. However, the volume of the liquid doesn't change as its shape changes. The volume of a liquid is fixed or constant. Thus, a **liquid** is a form of matter that has an indefinite shape, flows, yet has a fixed volume. Liquids are almost incompressible, but they tend to expand slightly when heated.

Interactive Textbook

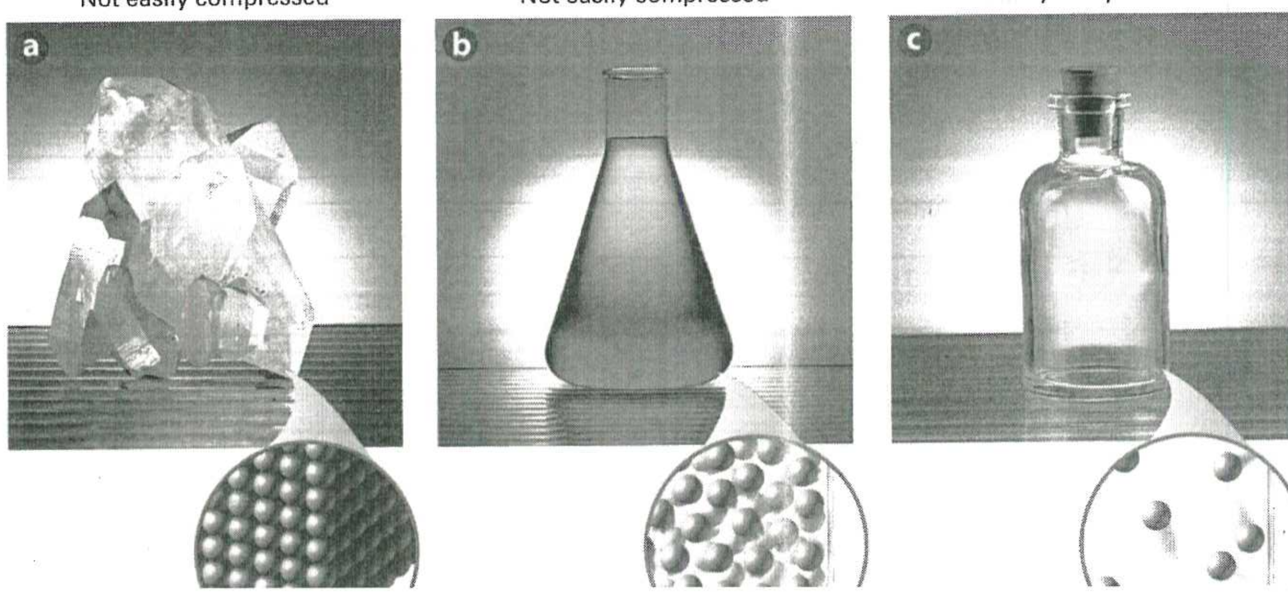
Animation 1 Relate the states of matter to the arrangements of their particles.

with **ChemASAP**

Solid
Definite shape
Definite volume
Not easily compressed

Liquid
Indefinite shape
Definite volume
Not easily compressed

Gas
Indefinite shape
Indefinite volume
Easily compressed



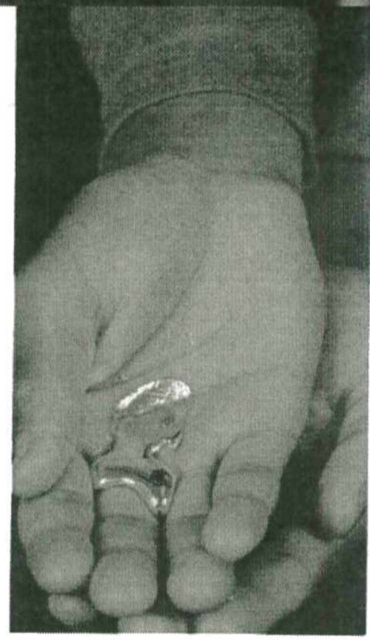


Figure 2.4 The silvery substance in the photograph is gallium, which has a melting point of 30°C. **Inferring** ***What can you infer about the temperature of the hand holding the gallium?***

Gases Like a liquid, a gas takes the shape of its container. But unlike a liquid, a gas can expand to fill any volume. A **gas** is a form of matter that takes both the shape and volume of its container. Look back at Figure 2.3c. As shown in the model, the particles in a gas are usually much farther apart than the particles in a liquid. Because of the space between particles, gases are easily compressed into a smaller volume.

The words *vapor* and *gas* are sometimes used interchangeably. But there is a difference. The term *gas* is used for substances, like oxygen, that exist in the gaseous state at room temperature. (*Gaseous* is the adjective form of *gas*.) **Vapor** describes the gaseous state of a substance that is generally a liquid or solid at room temperature, as in water vapor.

Checkpoint ***When should the term vapor be used instead of gas?***

Physical Changes

The melting point of gallium metal is 30°C. Figure 2.4 shows how heat from a person's hand can melt a sample of gallium. The shape of the sample changes during melting as the liquid begins to flow, but the composition of the sample does not change. Melting is an example of a physical change. During a **physical change,** some properties of a material change, but the composition of the material does not change.

Words such as *boil, freeze, melt,* and *condense* are used to describe physical changes. So are words such as *break, split, grind, cut,* and *crush.* However, there is a difference between these two sets of words. Each set describes a different type of physical change. **Physical changes can be classified as reversible or irreversible.** Melting is an example of a reversible physical change. If a sample of liquid gallium is cooled below its melting point, the liquid will become a solid. All physical changes that involve a change from one state to another are reversible. Cutting hair, filing nails, and cracking an egg are examples of irreversible physical changes.

2.1 Section Assessment

1. **Key Concept** Name two categories used to classify properties of matter.
2. **Key Concept** Explain why all samples of a given substance have the same intensive properties.
3. **Key Concept** Name three states of matter.
4. **Key Concept** Describe the two categories used to classify physical changes.

8. Explain why samples of gold and copper can have the same extensive properties, but not the same intensive properties.

Elements Handbook

Read about the metal indium on page R16. What is the melting point of indium? Which other metal has

Small-Scale LAB

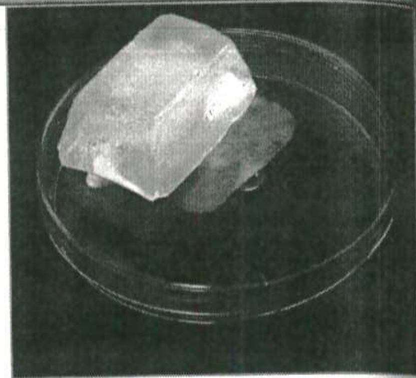
The Behavior of Liquids and Solids

Purpose
To explore and explain some behaviors of liquids and solids.

Materials
- plastic Petri dish
- water
- ice
- rubbing alcohol
- graph paper, 1-cm
- calcium chloride

Procedure
1. In your notebook, make a copy of the table shown below. Add a column for your observations. In the experiments, you will place substances labeled A and B inside the Petri dish and substances labeled C on top of the dish.
2. For Experiment 1, place one drop of water in the Petri dish. Replace the cover and place a small piece of ice on top of the cover.
3. After a few minutes, observe the interior surface of the Petri dish cover and the contents of the dish. Record your observations. Clean and dry the Petri dish and cover.
4. Repeat Steps 2 and 3 for Experiments 2–5, using the materials listed in the table. For Experiment 4, place the Petri dish on the graph paper so that you can place the water and the calcium chloride about 3 cm apart.

Experiment	Substance A	Substance B	Substance C
1	drop of water		ice cube
2	drop of water		drop of water
3	drop of rubbing alcohol		drop of water
4	drop of water	piece of $CaCl_2$	
5		several pieces of $CaCl_2$	ice cube



Analyze
Using your experimental data, record the answers to the following questions beneath your data table.
1. Explain your observations in Experiment 1 in terms of the behavior of liquids.
2. Why is ice not needed for cloud formation in Experiment 2?
3. What differences do you observe about the behavior of rubbing alcohol in Experiment 3 and the behavior of water in the previous experiments? Explain.
4. What happens to solid calcium chloride in a humid environment?
5. Propose an explanation for no cloud formation in Experiment 5.

You're The Chemist
1. **Analyze It!** Place a drop of water and a drop of rubbing alcohol about 3 cm apart in a Petri dish. Cover the dish and place it on a piece of graph paper. Be careful not to mix the contents. Observe what happens to the size of the water drop over time.
2. **Analyze It!** Add a drop of bromthymol blue (BTB) to a drop of vinegar. What happens?
3. **Design It!** Vinegar is a solution of water and ethanoic acid, CH_3COOH. Design and carry out an experiment to see if ethanoic acid will evaporate from a drop of vinegar. Does ethanoic acid evaporate?
4. **Design It!** Design and carry out an experiment to see if ammonia will evaporate from a drop of aqueous ammonia.

13.4 Changes of State

Connecting to Your World Familiar weather events can remind you that water exists on Earth as a liquid, a solid, and a vapor. A spring shower brings liquid raindrops and a winter blizzard delivers solid snowflakes. On a humid summer day, you may be uncomfortable because there is a high concentration of water vapor in the air. As water cycles through the atmosphere, the oceans, and Earth's crust, it undergoes repeated changes of state. In this section, you will learn what conditions can control the state of a substance.

Guide for Reading

Key Concepts
- When can sublimation occur?
- How are the conditions at which phases are in equilibrium represented on a phase diagram?

Vocabulary
sublimation
phase diagram
triple point

Reading Strategy
Predicting In your notebook, predict what causes ice cubes that are left in the freezer for a long time to get smaller.

Sublimation

If you hang wet laundry on a clothesline on a very cold day, the water in the clothes quickly freezes to ice. Eventually, however, the clothes become dry although the ice never thaws. The ice changes directly to water vapor without melting and passing through the liquid state. The change of a substance from a solid to a vapor without passing through the liquid state is called **sublimation.** Sublimation can occur because solids, like liquids, have a vapor pressure. **Sublimation occurs in solids with vapor pressures that exceed atmospheric pressure at or near room temperature.**

Iodine is another example of a substance that undergoes sublimation. This violet-black solid ordinarily changes into a purple vapor without passing through a liquid state. Notice in Figure 13.14 how dark crystals of iodine deposit on the underside of a watch glass placed on top of a beaker containing solid iodine that is being heated. The iodine vapor sublimes from iodine crystals in the bottom of the beaker and condenses to form crystals on the watch glass.

Sublimation has many useful applications. If freshly brewed coffee is frozen and the water vapor is removed with a vacuum pump, the result is freeze-dried coffee. Solid carbon dioxide (dry ice) is often used as a coolant for goods, such as ice cream, that must remain frozen during shipment. Dry ice has a low temperature of −78°C. Because it sublimes, it does not produce a liquid as ordinary ice does when it melts. Solid air fresheners contain a variety of substances that sublime at room temperature. Sublimation is also useful for separating substances. Organic chemists use sublimation to separate mixtures and to purify compounds.

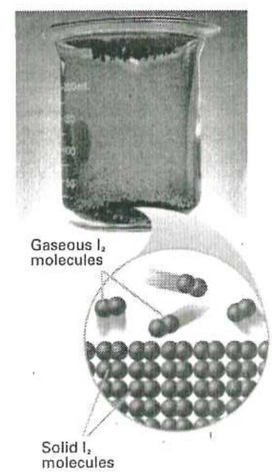


Figure 13.14 When solid iodine is heated, the crystals sublime, going directly from the solid to the gaseous state. When the vapor cools, it goes directly from the gaseous to the solid state.

Quick LAB

Sublimation

Purpose
To observe the sublimation of air freshener.

Materials
- small pieces of solid air freshener
- small shallow container
- 2 clear 8 oz plastic cups
- hot tap water
- ice
- 3 thick cardboard strips

Procedure

1. Place a few pieces of air freshener in one of the cups. **CAUTION** *Work in a well-ventilated room.*
2. Bend the cardboard strips and place them over the rim of the cup that has the air freshener pieces.
3. Place the second cup inside the first. The base of the second cup should not touch the air freshener. Adjust the cardboard as necessary. This assembly is your sublimator.
4. Fill the top cup with ice. Do not get any ice or water in the bottom cup.
5. Fill the shallow container about one-third full with hot tap water.
6. Carefully place your sublimator in the hot water. Observe what happens.

Analyze and Conclude

1. Define sublimation.
2. What do you think would happen if the water in the shallow container were at room temperature? If it were boiling?
3. Why is it possible to separate the substances in some mixtures by sublimation?

Phase Diagrams

Interactive Textbook
Simulation 14 Predict the physical states present at different points on a phase diagram.
with ChemASAP

The relationships among the solid, liquid, and vapor states (or phases) of a substance in a sealed container can be represented in a single graph. The graph is called a **phase diagram.** A phase diagram gives the conditions of temperature and pressure at which a substance exists as solid, liquid, and gas (vapor). **The conditions of pressure and temperature at which two phases exist in equilibrium are indicated on a phase diagram by a line separating the phases.**

Figure 13.15 shows the phase diagram for water. In each of the colored regions on the phase diagram, water is in a single phase. The curving line that separates water's vapor phase from its liquid phase are the equilibrium conditions for liquid and vapor. The line also illustrates how the vapor pressure of water varies with temperature. The other two curving lines give the conditions for equilibrium between liquid water and ice and between water vapor and ice. The point on the diagram at which all three curves meet is called the triple point. The **triple point** describes the only set of conditions at which all three phases can exist in equilibrium with one another. For water, the triple point is a temperature of 0.016°C and a pressure of 0.61 kPa (0.0060 atm). Figure 13.16 shows water at its triple point.

By referring to Figure 13.15, you can determine what happens if you melt ice or boil water at pressures less than 101.3 kPa. A decrease in pressure lowers the boiling point and raises the melting point. An increase in pressure will raise the boiling point and lower the melting point.

Checkpoint *What are the variables that are plotted on a phase diagram?*

Go Online SciLINKS
For: Links on Phase Diagrams
Visit: www.SciLinks.org
Web Code: cdn-1134

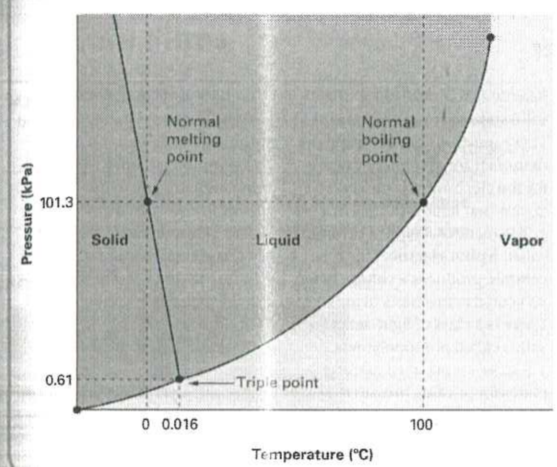


Figure 13.15 The phase diagram of water shows the relationship among pressure, temperature, and physical states of water.

INTERPRETING GRAPHS

a. Analyzing Data At the triple point of water, what are the values of temperature and pressure?
b. Inferring What states of matter are present at the triple point of water?
c. Analyzing Data Assuming standard pressure, at what temperature is there an equilibrium between water vapor and liquid water? Between liquid water and ice?

Look at Figure 13.15. Follow the equilibrium line between liquid water and water vapor to the triple point. Below the triple point, the vapor and liquid cannot exist in equilibrium. Increasing the pressure won't change the vapor to a liquid. The solid and the vapor are in equilibrium at temperatures below 0.016°C. With an increase in pressure, the vapor begins to behave more like a solid. For example, it is no longer easily compressed.

Figure 13.15 also illustrates how an increase in pressure affects the melting point of ice. For years, the accepted hypothesis for how ice skaters move along the ice was the following. The blades of the skates exert pressure, which lowers the melting point of the ice. The ice melts and a film of water forms under the blades of the skates. This film acts as a lubricant, enabling the skaters to glide gracefully over the ice. This hypothesis fails to explain why skiers also glide along very nicely on another solid form of water—snow. Wide skis exert much less pressure per unit area of snow than narrow skate blades exert on ice. Recent research shows that the surface of ice has a slippery, water-like surface layer that exists well below ice's melting point. Even ice that is at −129°C has this layer. A new hypothesis proposes that the liquid-like surface layer provides the lubrication needed for smooth skating and skiing.

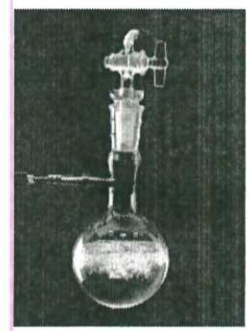


Figure 13.16 At the triple point, ice, liquid water, and water vapor can exist at equilibrium. Freezing, melting, boiling, and condensation can all occur at the same time, as shown in the flask.

HANDS-ON CHEMISTRY • MINI-LAB •

Full or Empty?

Materials

- clay
- funnel
- empty soft drink bottle with cap
- water
- large safety pin

Part I: Procedure

1. Use clay to secure a funnel to an empty soft drink bottle. Make sure that the mouth of the bottle is completely covered.
2. Pour water into the funnel, and observe what happens.
3. Develop a method that allows the water to go smoothly into the bottle.
4. Develop a method that allows the water to stay in the funnel.
5. Develop a method that allows the water to periodically squirt into the bottle.

Results/Analysis (Part I)

1. List your observations from step 2.
2. Discuss each of your methods for steps 3–5, and explain why each method works.

Part II: Procedure

1. Fill a plastic soft drink bottle with water, and replace the cap tightly.
2. Using a large safety pin, poke a hole in the side of the container and observe what happens.
3. Hold the bottle over a sink, and unscrew the cap. Observe what happens.

Results/Analysis (Part II)

1. List your observations from step 2, and explain them.
2. List your observations from step 3, and explain them.
3. Relate your findings to those from Part I of this activity.

SECTION 2.1 REVIEW QUESTIONS

1. How do atoms, compounds, and elements differ?
2. Consider the letters in the word *chemistry*. Use them to make as many word "compounds" as is possible with 9 elements. How is an element different from a compound?
3. Draw an "atom" picture of a solid, a liquid, and a gas. Describe the essential differences among them.

RESEARCH LINKS CLASSZONE.COM

SECTION 2.2

Properties of Matter

Objectives

- *To learn to distinguish between physical and chemical properties*
- *To learn to distinguish between physical and chemical changes*

Key Terms

- Physical properties
- Chemical properties
- Physical changes
- Chemical change

A. Physical and Chemical Properties and Changes

When you see a friend, you immediately respond and call him or her by name. We can recognize a friend because each person has unique characteristics or properties. The person may be thin and tall, may have brown hair and blue eyes, and so on. These characteristics are examples of **physical properties**. Substances also have physical properties. The typical physical properties of a substance include odor, color, volume, state (gas, liquid, or solid), density, melting point, and boiling point.

We can also describe a pure substance in terms of its **chemical properties**, which refer to its ability to form new substances. An example of a chemical change is wood burning in a fireplace, giving off heat and gases and leaving a residue of ashes. In this process, the wood is changed to several new substances. Other examples of chemical changes include the rusting of steel, the digestion of food, and the growth of plants. In a chemical change a given substance changes to a fundamentally different substance or substances.

Physical property Characteristic of a substance that can change without the substance's becoming a different substance

Chemical property Characteristic that describes the ability of a substance to change to a different substance

Active Reading Question

Describe three physical properties of your shampoo.

EXAMPLE 2.1

Identifying Physical and Chemical Properties

Classify each of the following as a physical or a chemical property.

a. The boiling point of a certain alcohol is 78 °C.
b. Diamonds are very hard.
c. Sugar ferments to form alcohol.
d. A metal wire conducts an electric current.

Solution

Items (a), (b), and (d) are physical properties; they describe characteristics of each substance, and no change in composition occurs. A metal wire has the same composition before and after an electric current has passed through it. Item (c) is a chemical property of sugar. Fermentation of sugars involves the formation of a new substance, alcohol.

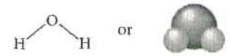
Gallium metal has such a low melting point (30 °C) that it melts from the heat of a hand.

Practice Problem • Exercise 2.1

Which of the following are physical properties and which are chemical properties?

a. Gallium metal melts in your hand.
b. This page is white.
c. The copper sheets that form the "skin" of the Statue of Liberty have acquired a greenish coating over the years.

Matter can undergo changes in both its physical and its chemical properties. To illustrate the fundamental differences between physical and chemical changes, we will consider water. As we have seen, a sample of water contains a very large number of individual units (called molecules), each made up of two atoms of hydrogen and one atom of oxygen—the familiar H_2O, which can be represented as:



Here the letters stand for atoms and the lines show attachments, called bonds, between atoms. The molecular model on the right represents water in a more three-dimensional fashion.

What is really occurring when water undergoes the following changes?

When ice melts, the rigid solid becomes a mobile liquid that takes the shape of its container. Continued heating brings the liquid to a boil, and the water becomes a gas or vapor that seems to disappear into the air. The changes that occur as the substance goes from solid to liquid to gas are represented in **Figure 2.8.** In ice the water molecules are locked into fixed positions. In the liquid the molecules are still very close together, but some motion is occurring; the positions of the molecules are no longer fixed as they are in ice. In the gaseous state the molecules are much farther apart and move randomly, hitting each other and the walls of the container.

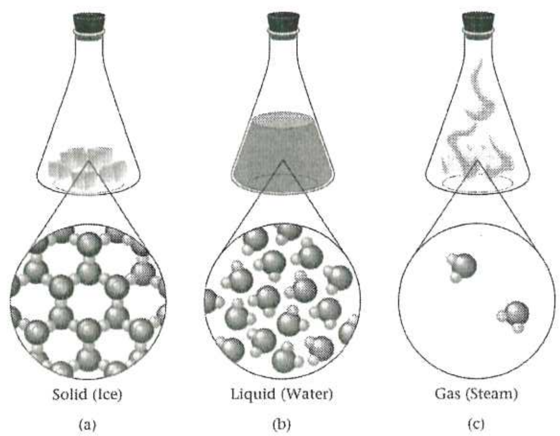
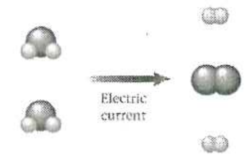


Figure 2.8
The three states of water, red spheres represent oxygen atoms and blue spheres represent hydrogen atoms. (a) Solid: The water molecules are locked into rigid positions and are close together. (b) Liquid: The water molecules are still close together but can move around to some extent.
(c) Gas: The water molecules are far apart and move randomly.

The most important thing about all these changes is that the water molecules are still intact. The motions of individual molecules and the distances between them change, *but H_2O molecules are still present.* These changes of state are **physical changes** because they do not affect the composition of the substance. In each state we still have water (H_2O), not some other substance.

Now suppose that we run an electric current through water as illustrated in **Figure 2.9**. Something very different happens. The water disappears and is replaced by two new gaseous substances, hydrogen and oxygen. An electric current actually causes the water molecules to come apart—the water *decomposes* to hydrogen and oxygen. We can represent this process as follows:



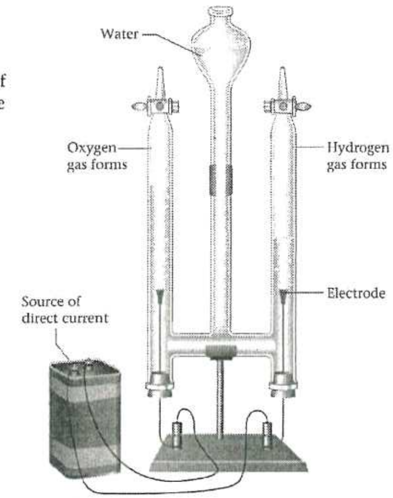


Figure 2.9
Electrolysis, the decomposition of water by an electric current, is a chemical process.

This is a **chemical change** because water (consisting of H_2O molecules) has changed into different substances: hydrogen (containing H_2 molecules) and oxygen (containing O_2 molecules). In this process, the H_2O molecules have been replaced by O_2 and H_2 molecules. Let us summarize as follows.

Physical and Chemical Changes

1. A *physical change* involves a change in one or more physical properties, but no change in the fundamental components that make up the substance. The most common physical changes are changes of state: solid ⟺ liquid ⟺ gas.
2. A *chemical change* involves a change in the fundamental components of the substance; a given substance changes into a different substance or substances. Chemical changes are called reactions: silver tarnishes by reacting with substances in the air; a plant forms a leaf by combining various substances from the air and soil; and so on.

Physical change
Change that does not affect the composition of a substance

Chemical change
Change in which a substance becomes a different substance

Active Reading Question

Why are changes of state, for example, liquid water changing to steam, not considered to be chemical changes?

SECTION 2.1

The Nature of Matter

Key Terms
- Matter
- Atoms
- Compounds
- Molecule
- Elements
- Solid
- Liquid
- Gas

Objectives
- *To learn about the composition of matter*
- *To learn the difference between elements and compounds*
- *To define the three states of matter*

A. The Particulate Nature of Matter

Matter, the "stuff" of which the universe is composed, has two characteristics: it has mass and it occupies space. Matter comes in a great variety of forms: the stars, the air that you are breathing, the gasoline that you put in your car, the chair on which you are sitting, the turkey in the sandwich you may have eaten for lunch, the tissues in your brain that allow you to read and understand this sentence, and so on.

As we look around our world, we are impressed by the great diversity of matter. Given the many forms and types of matter, it seems difficult to believe that all matter is composed of a small number of fundamental particles. It is surprising that the fundamental building blocks in chocolate cake are very similar to the components of air.

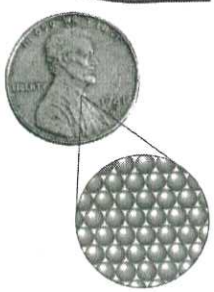


Figure 2.1
The surface of the copper penny is made of copper atoms represented as they would be seen through the lens of a very powerful electronic microscope.

The Atomic Nature of Matter

How do we know that matter is composed of the tiny particles we call atoms? After all, they are far too small to be seen with the naked eye. It turns out that after literally thousands of years of speculation, we can finally "see" the atoms that are present in matter. In recent years scientists have developed a device called a scanning tunneling microscope (STM) that, although it works quite differently from an optical microscope, can produce images of atoms.

For example, look at the penny shown in **Figure 2.1.** The small objects represent tiny copper atoms. When chemists look at other metals with powerful microscopes, they see atoms in these substances as well. You can see an example of another metal in **Figure 2.2.**

With ultra-high magnification, objects appear more similar. All objects are made up of small particles called atoms.

Figure 2.2
A scanning tunneling microscope image of nickel metal. Each peak represents a nickel atom.

All matter consists of tiny particles called atoms. But when you look at objects such as nails or pennies, you don't see these particles. Why not? The atoms are very tiny and can be seen only with a powerful magnifying instrument. You may have encountered the same concept in your life when you looked at a beach from a distance. The sand looks uniform—you can't see the separate particles. As you get close, however, the individual grains of sand become apparent. Observe the Impressionist painting by Seurat shown in the photo on the following page. From a distance the scene looks normal. Only when you stand very close to the painting do you see that it is composed of tiny dots of paint.

So, the conclusion is that although objects in the macroscopic world typically look quite continuous and uniform, they are really particulate in nature—they are made of atoms. We can "see" them with powerful electronic microscopes.

Active Reading Question

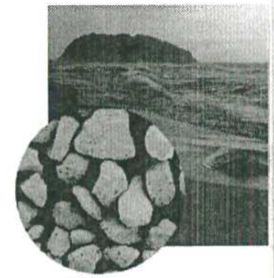
How do we know that all matter is made of atoms?

B. Elements and Compounds

We have just considered the most important idea in chemistry: matter is composed of tiny particles we call **atoms**. If all matter is made up of tiny particles called atoms, are all atoms alike? That is, is copper metal made of the same kind of atoms as gold? The answer is no. Copper atoms and gold atoms are different. Scientists have learned that all matter is composed from about 100 different types of atoms. For example, air is mostly gaseous oxygen and nitrogen. The nitrogen atoms are different from the oxygen atoms, which in turn are different from copper atoms, which differ from gold atoms.

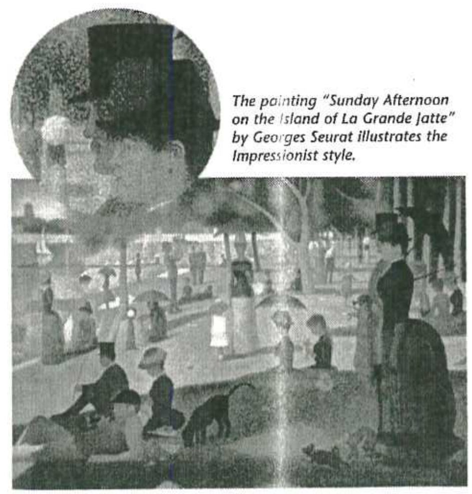
Atom
Fundamental unit of which elements are made

You can think of the matter in the universe like the words in a book. If you break all the words in this book apart into their component letters, you will end up with "large piles" of only 26 letters. The English alphabet allows you to construct thousands of words from just 26 letters. Similarly, all the matter in the universe is constructed by putting approximately 100 types of atoms together in various ways. The different types of matter are like the different words in a book. When we separate all of the universe into its atoms, we find approximately 100 different atoms. We call these 100 types of atoms the *elements* of the universe.



Sand on a beach looks uniform from a distance, but up close the irregular sand grains are visible.

To illustrate this idea, consider the letters A, D, and M. Using these letters you can make many words, such as MAD, DAM, DAD, and MADAM (can you think of others?). Each word represents something very different. Thus, with only three letters, you can represent several unique things or ideas.



The painting "Sunday Afternoon on the Island of La Grande Jatte" by Georges Seurat illustrates the Impressionist style.

Top Ten Elements in the Universe

Element	Percent (by atoms)
Hydrogen	73.9
Helium	24.0
Oxygen	1.1
Carbon	0.46
Neon	0.13
Iron	0.11
Nitrogen	0.097
Silicon	0.065
Magnesium	0.058
Sulfur	0.044

CRITICAL THINKING

The scanning tunneling microscope allows us to "see" atoms.

What if you were sent back in time before the invention of the scanning tunneling microscope? Write a paragraph giving evidence to support the theory that all matter is made of atoms and molecules.

Compounds

In much the same way that we can use a few letters to make thousands of words, we can use a few types of atoms to construct all matter. For example, consider the atoms hydrogen, oxygen, and carbon:

Notice that we represent atoms by using spheres. We get this idea from the highly magnified pictures of metals that show the atoms. Notice in Figure 2.1 that atoms look like spheres.

We can combine the hydrogen, oxygen, and carbon atoms in a variety of ways. Just as letters combine to form different words, atoms combine to form different compounds. **Compounds** are substances made by bonding atoms together in specific ways. These substances contain two or more different types of atoms bound together in a particular way. A specific compound consists of the same particles throughout. Table 2.1 shows some examples of atoms combined into compounds.

Table 2.1

Some Common Compounds

Atom Combinations	Name	Characteristics
	carbon monoxide	Carbon monoxide is a poisonous gas.
	carbon dioxide	You breathe out carbon dioxide as a waste material, and plants use carbon dioxide to make oxygen.
	water	Water is the most important liquid on Earth.
	hydrogen peroxide	Hydrogen peroxide is used to disinfect cuts and bleach hair.

Consider a glass of water. If you could magically travel inside the water and examine its individual parts, you would see particles consisting of two hydrogen atoms bonded to an oxygen atom:

Molecule
A collection of atoms bonded together that behave as a unit

We call this particle a molecule. A **molecule** is made up of atoms that are "stuck" together. A glass of water, for example, contains a huge number of molecules packed closely together (see **Figure 2.3**).

Carbon dioxide is another example of a compound. For example, "dry ice"—solid carbon dioxide—contains molecules of the type packed together as shown in **Figure 2.4**.

Notice that the particles (molecules) in water are all the same. Likewise, all the molecules in dry ice are the same. However, the molecules in water differ from the molecules in dry ice. Water and carbon dioxide are different compounds.

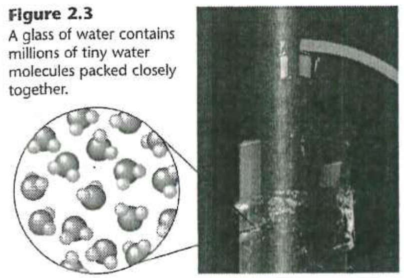


Figure 2.3
A glass of water contains millions of tiny water molecules packed closely together.

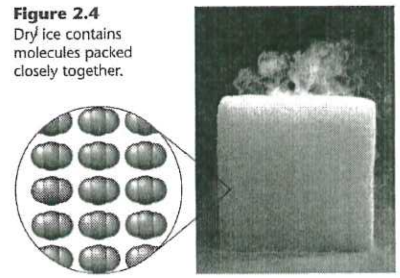


Figure 2.4
Dry ice contains molecules packed closely together.

Elements

Just as hydrogen, oxygen, and carbon can form the compounds carbon dioxide and water, atoms of the same type can also combine with one another to form molecules. For example, hydrogen atoms can pair up, as can oxygen atoms. For reasons we will consider later, carbon atoms form much larger groups, leading to substances such as diamond, graphite, and buckminsterfullerene.

Because pure hydrogen and oxygen each contains only one type of atom, the substances are called elemental substances or, more commonly, **elements**. Elements are substances that contain only one type of atom. For example, pure gold contains only gold atoms, elemental copper contains only copper atoms, and so on. Thus an element contains only one kind of atom; a sample of iron contains many atoms, but they are all iron atoms. Samples of certain pure elements do contain molecules; for example, hydrogen gas contains H—H (usually written H_2) molecules, and oxygen gas contains O—O (O_2) molecules. However, any pure sample of an element contains only atoms of that element, *never* any atoms of any other element. **Figure 2.5** shows examples of elements.

Elements
Substances containing only one type of atom

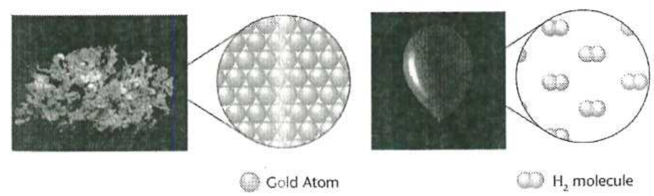


Figure 2.5
Gold and hydrogen are both elements. Gold consists of gold atoms packed together as a solid. Hydrogen is an element that is composed of molecules of hydrogen, not single atoms.