SCIENCES
هيكل العلوم - انسباير

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1	List the series of procedure to use the scientific methods to solve problem, and diffrentiate between theory and scientific law	textbook, figure 3	6, 11

Modeling Sometimes an investigation involves building a model that resembles something, such as a model of a new space vehicle, and then testing the model to see how it acts. Other models represent processes or objects that cannot be seen with the unaided eye, such as the models of the atom. Often, a scientist will use information from several types of investigations when attempting to learn about the natural world.

Scientific Methods

Although scientists do not always follow a rigid set of steps, investigations often follow a general pattern. The pattern of investigation procedures is called the **scientific methods.** Six common steps found in the scientific methods are shown in **Figure 3.** A scientist might add new steps, repeat some steps many times, or skip steps altogether.

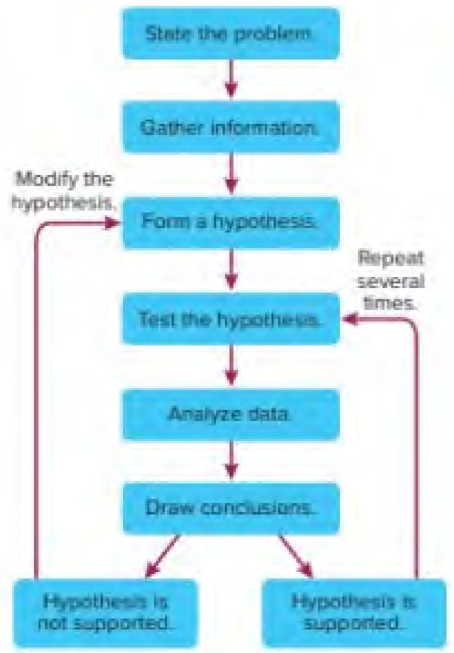

Figure 3 The series of procedures shown here is one way to use scientific methods to solve a problem.

State the problem

To begin the process, a scientist must state what he or she is going to investigate. Many investigations begin when someone observes an event in nature and wonders why or how it occurs. The question of "why" or "how" is the problem.

Scientists once posed questions about why objects fall to Earth, what causes day and night, and how to generate electricity for daily use. Many times, a statement of a problem arises when an investigation is complete and its results lead to new questions. For example, once scientists understood why we experience day and night, they wanted to know why Earth rotates.

Sometimes a new question is posed when an investigation runs into trouble. For example, some early work on guided missiles found the instruments in the nose cone did not always work properly. The original problem statement involved how to guide missiles during flight. The new statement involved how to protect the instruments in the nose cone.

Get It?
Identify What is the first step in a scientific investigation, and what form does it usually take?

Research and gather information

Before beginning an investigation, scientists research what is already known about the problem. They gather and examine observations and interpretations from reliable sources. This background helps scientists fine-tune their question and form a hypothesis.

Scientific Theories and Laws

A scientific **theory** is an explanation based on knowledge gained from many observations and investigations. It is not a guess. If scientists repeat an investigation and the results always support the hypothesis, the hypothesis can be called a theory. As new information becomes available, theories can be modified.

A **scientific law** is a statement about what happens in nature and that seems to be true all the time. Laws describe specific relationships under given conditions. They don't explain why or how something happens. Gravity is an example of a scientific law. The law of gravity states that any one mass will attract another mass.

A theory can be used to explain a law, but theories do not become laws. For example, many theories have been proposed to explain how the law of gravity works. Even so, there are few accepted theories in science and even fewer laws.

Figure 8 Science can't answer all questions, like questions about opinions and values. This piece of art might look very beautiful to one person but not to another.

Discuss *Can anyone prove that a piece of art is beautiful? Explain.*

The Limitations of Science

Science can help you explain many things, but science cannot explain or solve every question. It is scientists' job to develop hypotheses that can be tested and verified. Questions that cannot be tested and verified, such as those about opinions and values, are not scientific. You might take a survey to gather opinions about a piece of art, such as the painting in **Figure 8**, but it would not prove the opinions to be true or false.

Check Your Progress

Summary

- Scientists ask questions and perform investigations to learn more about the natural world.
- Scientists use scientific methods to test their hypotheses.
- Models help scientists visualize concepts.
- A theory is a possible explanation for observations, while a scientific law describes a pattern but does not explain why things happen.

Demonstrate Understanding

1. **Define** Summarize the steps you might use to carry out an investigation using scientific methods.
2. **Explain** what a law is, what a theory is, and why a theory cannot become a law.

Explain Your Thinking

3. **Analyze** What is the dependent variable in an experiment that shows how the volume of a gas changes with changes in temperature?
4. **MATH Connection** An experiment to determine how many breaths a squirrel takes per minute yields this data: minute 1: 65 breaths; minute 2: 73 breaths; minute 3: 67 breaths; minute 4: 71 breaths; minute 5: 62 breaths. Calculate the average number of breaths per minute.

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2	Define Matter and how to classify it (mixtures & pure substances) and give examples for every category, diffrentiate between physical change and chemical change and the resulted matter from each change	Textbook, figure 11	384, 389, 390

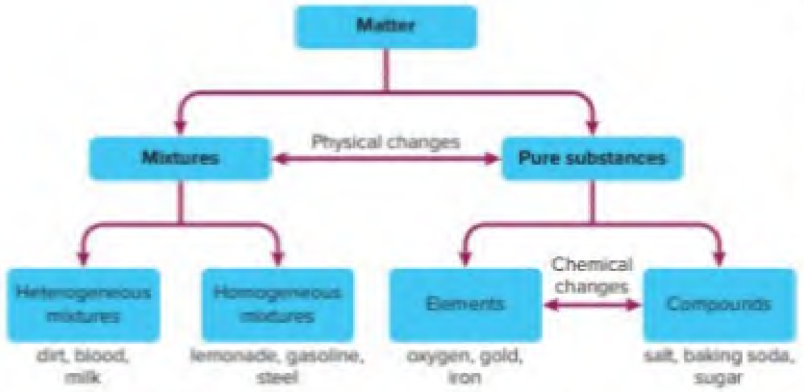

Figure 11 The concept map shows that mixtures can be either heterogeneous or homogeneous. Pure substances can be elements or compounds.

Examine *Where on this chart would you classify pizza?*

Solutions A **solution** is the same thing as a homogeneous mixture. The most familiar solutions might be solids dissolved in liquids, but solutions can also be mixtures of a solid and a gas, a solid and a solid, a gas and a liquid, and so on. Tea, vinegar, steel alloys, and the compressed gas used by divers are all examples of solutions.

Comparing mixtures and substances

Mixtures, unlike compounds, do not always contain the same proportions of the substances of which they are made. Additionally, unlike pure substances, mixtures can be physically separated. A substance has a fixed composition, whereas mixtures can have widely different compositions. These differences are summarized in **Figure 11**.

Check Your Progress

Summary

- An element is a substance with the same kind of atoms.
- There are approximately 90 naturally occurring elements found on Earth and over 25 that have been created in laboratories.
- A compound is a substance that has two or more elements chemically combined in a fixed proportion.
- Mixtures can be heterogeneous or homogeneous and can be separated by physical means.

Demonstrate Understanding

1. **Distinguish** a substance from a mixture. Give two examples of each.
2. **Compare and Contrast** How is a compound similar to a homogeneous mixture? How is it different?
3. **Identify** three elements and three compounds. How are they similar? How are they different?
4. **Summarize** Make a table that compares the properties of suspensions, colloids, and solutions.

Explain Your Thinking

5. **Infer** Why do the words "Shake well before using" indicate that the fruit juice in a carton is a suspension? Why are these words not used on a milk container?
6. **MATH Connection** The weather report this morning stated there is a thick fog in your town. Visibility is less than 500 feet. How many kilometers in front of your vehicle can you see?

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Detecting Chemical Change

If you leave a pan of chili cooking unattended on the stove for too long, your nose soon tells you that something is wrong. Instead of a spicy aroma, you detect an unpleasant smell that alerts you that something is burning. This burnt odor is a clue that a new substance has formed.

The identity changes

The smell of rotten eggs and the formation of rust on bikes and car fenders are also signs that a chemical change has taken place. A change of one substance to another is a **chemical change**. Bubble formation produced by the foaming of an antacid tablet in a glass of water is a sign of new substances being produced. In some chemical changes, a rapid release of energy—detected as heat, light, and sound—is a clue that changes are occurring. A display of fireworks in the night sky is an example. **Figure 17** illustrates another visual clue—the formation of a solid precipitate. What is another example of a chemical change that produces a solid?

Get It?
Define What is a chemical change?

Heating, cooling, and the formation of bubbles or solids in a liquid are all indicators that a reaction is taking place. However, the only sure proof is that a new substance is produced. Consider the following examples. The heat, light, and sound produced when hydrogen gas combines with oxygen in a rocket engine are clear evidence that a chemical reaction has taken place. However, no clues announce the onset of the reaction in which iron and oxygen combine to form rust. The only clue that iron has changed into a new substance is the visible presence of rust. Burning and rusting are chemical changes because new substances form.

Figure 17 When clear solutions of lead(II) nitrate and potassium iodide mix, a reaction takes place and a yellow solid, lead(II) iodide, appears. The yellow solid that is produced in the chemical reaction is called a precipitate.

Using chemical changes

One case where you might separate substances using a chemical change is in cleaning tarnished silver, such as jewelry. Tarnishing, a chemical reaction between silver metal and sulfur compounds in the air, results in silver sulfide. A chemical reaction in a warm water bath with baking soda and aluminum can change silver sulfide back into silver.

Separating substances using chemical changes is rarely done in the home, but it is commonly done in industrial and laboratory settings. For example, many metals are separated from their ores and then purified using chemical changes.

Weathering

The forces of nature continuously shape Earth's surface. Rocks split, deep canyons are carved, sand dunes shift, and limestone formations decorate caves. Do you think these changes, referred to as weathering, are physical or chemical? The answer is both. Geologists, who use the same criteria that you have learned in this chapter, say that some weathering changes are physical and some are chemical.

Get It?
Determine Is weathering a physical change or a chemical change?

Flowing water shaped and smoothed these rocks in a physical process.

Both chemical and physical changes shaped the famous White Cliffs of Dover, which line the English Channel.

Figure 18 Weathering can involve physical change and chemical change.

Physical weathering

Large rocks can split when water seeps into small cracks, freezes, and expands. Streams can smooth and sculpt hard rock, as shown in **Figure 18.** These are physical changes because the rock does not change into another substance.

Chemical weathering

In other cases, the change is chemical. For example, solid calcium carbonate, a compound found in limestone, reacts with water if it is slightly acidic, such as when it contains some dissolved carbon dioxide. The calcium carbonate reacts to form calcium bicarbonate. This change in limestone is a chemical change because the identity of the substances changes. This chemical change contributes to the weathering of the White Cliffs of Dover, shown in **Figure 18,** and also produces the icicle-shaped rock formations that are found in caves.

CCC CROSSCUTTING CONCEPTS

Energy and Matter Your friend says that chemical weathering makes limestone "disappear". Read about the law of conservation of mass on the next page. Then write a brief message to explain to your friend what really happens to limestone during chemical weathering.

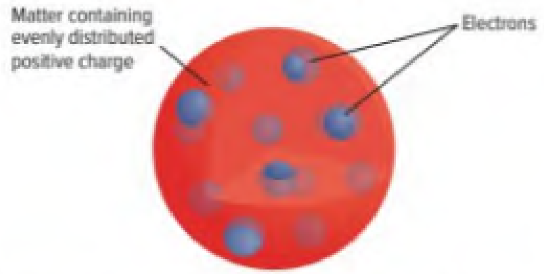
3	Compare and contrast between the atomic models that lead to the modern one (electron cloud model)	Textbook, figures 4, 5	402, 403

Figure 4 **Visualizing the Early Atomic Models**

The currently accepted model of the atom evolved from the ideas and the work of many scientists.

400 B.C. Democritus Model

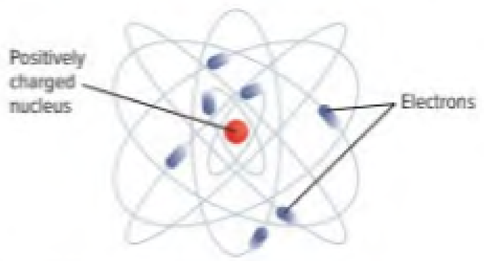
1904 Thomson Model



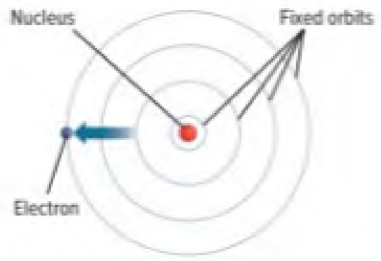
400 B.C. Democritus Model Democritus first proposed that elements consist of tiny, solid particles that cannot be subdivided. He called these particles *atomos*, meaning "uncuttable." Democritus's ideas were criticized by Aristotle, who believed that empty space could not exist. Because Aristotle was one of the most influential philosophers of his time, Democritus's atomic theory was rejected.

1904 Thomson Model English physicist Joseph John Thomson proposed a model that consisted of a spherical atom containing small, negatively charged particles. He thought these "electrons" (in blue) were evenly embedded throughout a positively charged sphere, much like chocolate chips in a ball of cookie dough.

1911 Rutherford Model



1913 Bohr Model



1911 Rutherford Model English physicist Ernest Rutherford proposed the idea that all the positive charge of an atom is concentrated in a central atomic nucleus that is surrounded by electrons.

1913 Bohr Model Danish physicist Niels Bohr hypothesized that electrons travel in fixed orbits. He suggested that electrons could jump between orbits as they absorb or release specific amounts of energy. The Bohr model worked very well for hydrogen, but did not work as well for atoms with many electrons.

The electron cloud model

By 1926, scientists developed the electron cloud model of the atom, which is the model that is accepted today. An **electron cloud** is the area around the nucleus of an atom, where electrons are most likely to be found. The electron cloud is 100,000 times larger in diameter than the nucleus of an atom. In contrast, each electron in the cloud is significantly smaller in mass than a single proton or single neutron.

Get It?
Explain the difference between the Bohr model and the electron cloud model.

Because an electron's mass is negligible compared to the nucleus and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom at any moment.

Picture the spokes on a moving bicycle wheel. The spokes are moving so quickly that you cannot pinpoint any single spoke in the wheel. All that you see is a blur that contains all the spokes somewhere within it. In a similar way, an electron cloud is a blur of activity containing all of an atom's electrons somewhere within it. **Figure 5** illustrates the location of the nucleus and the electron cloud in the electron cloud model of the atom.

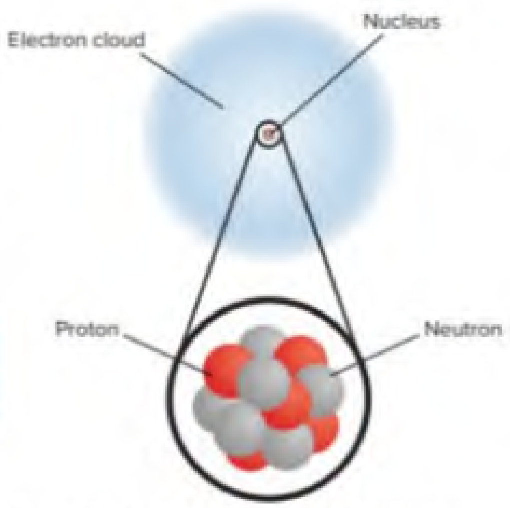


Figure 5 Most of an atom is empty space. The electron cloud represents the area in which the electrons are moving.

Check Your Progress

Summary

- Scientists use chemical symbols to abbreviate element names.
- Atoms are composed of protons, neutrons, and electrons.
- Scientists have confirmed the existence of six different quarks.
- The electron cloud model is the current atomic model.

Demonstrate Understanding

1. **Identify** the names, charges, and locations of three types of subatomic particles that make up an atom.
2. **Identify** the chemical symbols for the elements carbon, aluminum, hydrogen, oxygen, and sodium.
3. **Describe** how quarks were discovered.

Explain Your Thinking

4. **Describe** how a rotating electric fan could function as a model of the atom. Explain how the rotating fan is unlike an atom.
5. **MATH Connection** A proton's mass is estimated to be 1.6726×10^{-24} g, and the mass of an electron is estimated to be 9.1093×10^{-28} g. How many times greater is the mass of a proton compared to the mass of an electron?

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4	Compare between the properties of metals and nonmetals, Identify the nonmetal & metal part in different chemical compounds (ionic) using the periodic table of element, compare between the alkali metals & alkaline earth metals	textbook, periodic table fig 15, figures 4, 7, 10, 13,	415, 424, 427, 430, 433

Regions of the Periodic Table

The periodic table has areas with specific names. Recall that the horizontal rows of elements are called periods. The elements increase by one proton and one electron as you move from left to right across a period.

All the elements in the blue squares in **Figure 15** are metals. Iron, zinc, and copper are examples of a few common metals. Most metals occur as solids at room temperature. They are shiny, can be drawn into wires, can be pounded into sheets, and are good conductors of heat and electricity.

The elements on the right side of the periodic table, which appear in the yellow squares, are classified as nonmetals. Oxygen, bromine, and carbon are examples of nonmetals. Most nonmetals are gases or brittle solids at room temperature. They are poor conductors of heat and electricity. The elements in the green squares are metalloids. They exhibit properties of metals and nonmetals. Boron and silicon are examples of metalloids.

New elements

Scientists around the world continue their research into the synthesis of elements. In 1994, scientists at the GSI Helmholtz Center for Heavy Ion Research in Darmstadt, Germany, discovered element 111. The International Union of Pure and Applied Chemistry (IUPAC) confirmed the discovery in 2003. The name Roentgenium (Rg) was officially approved in 2004. Element number 112 was discovered at the same laboratory. Synthesis of the element was reported in 1996. IUPAC confirmed the discovery in 2009, and the element was officially named Copernicium (Cn) in 2010. These elements are produced in the laboratory by joining smaller atoms into a single, larger atom. Scientists have synthesized elements 113 through 118. The search for elements with higher atomic numbers continues.

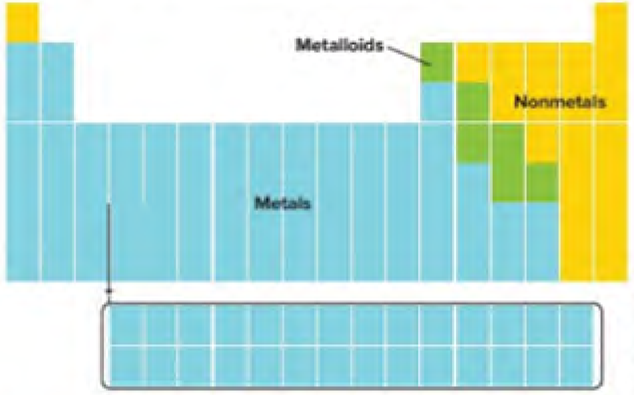


Figure 15 Metalloids are located along the green stair step line in the periodic table. Metals are located to the left of the metalloids and are shown in blue. Except for hydrogen, nonmetals are located to the right of the metalloids and are shown in yellow.

ACADEMIC VOCABULARY

occur
to be found; to come into existence
Many tornadoes occur in the central plains of the United States.

The Alkali Metals

The elements in group 1 of the periodic table are the alkali (AL kuh li) metals. Like other metals, alkali metals are shiny, malleable, ductile, and good conductors of heat and electricity. However, they are softer than most other metals and are the most reactive metals. They react rapidly and sometimes violently with oxygen and water, as shown in **Figure 4.** Because they are so reactive, alkali metals do not occur naturally in their elemental forms, and pure samples must be stored in oil to prevent reaction with oxygen and water in the air.

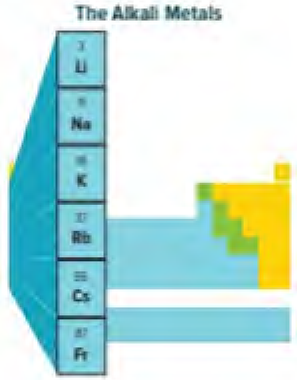
Get It?
Explain how knowledge of the properties of alkali metals is used to predict how they will react and determine how they should be stored.

Figure 4 Alkali metals are very reactive. For example, the vigorous reaction between potassium and water releases enough thermal energy to ignite the hydrogen gas that forms.

Atomic structure explains the reactive nature of alkali metals. Each atom of an alkali metal has one electron in its outer energy level. This electron is easily given up when an alkali metal combines with a nonmetal. As a result, the alkali metal atom becomes a positively charged ion in a compound such as sodium chloride ($NaCl$) or potassium bromide (KBr).

Get It?
Explain how interactions of electric charges at the atomic scale account for the reactivity of alkali metals.

Get It?
Explain how the location of alkali metals on the periodic table is related to the number of electrons in the outer energy level.



Lithium, sodium, and potassium

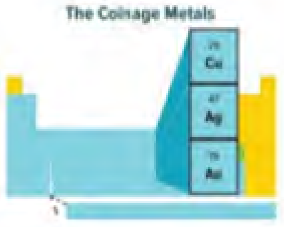
Look carefully at the nutritional information on a cereal box. You will notice that sodium and potassium are often listed. You and other living things need potassium and sodium compounds to stay healthy. Lithium can also benefit health. Lithium compounds are sometimes used to treat bipolar disorder. The lithium helps regulate chemical levels that are important to mental health.

Rubidium, cesium, and francium

The operation of some light-detecting sensors depends upon rubidium or cesium compounds. Cesium is used in atomic clocks because some of its isotopes are radioactive. A **radioactive element** is one in which the nucleus breaks down and gives off particles and energy. Francium is also radioactive and is extremely rare. Scientists estimate that Earth's crust contains less than 30 g of francium at one time.

Figure 7 Copper is often mixed with zinc or nickel to make modern coins. Gold, silver, and bronze—an alloy of copper and tin—are used to make athletic medals.

Copper, silver, and gold



You are probably familiar with copper, silver, and gold–three of the elements in group 11. Because they are so stable and malleable and can be found as free elements in nature, these metals were once used widely to make coins. For this reason, they are known as the coinage metals. Because they are so expensive, silver and gold are rarely used in coins anymore. The United States stopped making everyday coins with gold in 1933 and coins with silver in 1964. Most coins now are mixtures of nickel, zinc, and copper, as shown in **Figure 7.**

The coinage metals have a variety of other uses, such as in the athletic medals in **Figure 7.** Copper is often used in electrical wiring because of its superior ability to conduct electricity and its relatively low cost. The compounds silver iodide (AgI) and silver bromide ($AgBr$) are used to make photographic film and paper because they break down when they are exposed to light. Silver and gold are used in jewelry because of their attractive colors, relative softness, resistance to corrosion, and rarity.

Get It?
Explain why gold's relative softness makes it a good material for use in jewelry.

Zinc, cadmium, and mercury

Zinc, cadmium, and mercury are found in group 12 of the periodic table. Zinc combines with oxygen in the air to form a thin, protective coating of zinc oxide on its surface. Zinc and cadmium, which also forms a protective coating, are often used to coat metals such as iron. Cadmium also is used in rechargeable batteries.

Mercury is the only metal that is a liquid at room temperature. It is used in thermostats, switches, and batteries. Mercury is toxic and can accumulate in the body, so it is rarely used in modern thermometers. People have died from mercury poisoning due to repeatedly eating fish that lived in mercury-contaminated water.

التكمله في الصفحه الثانيه .

4	Compare between the properties of metals and nonmetals, Identify the nonmetal & metal part in different chemical compounds (ionic) using the periodic table of element, compare between the alkali metals & alkaline earth metals	textbook, periodic table fig 15, figures 4, 7, 10, 13,	415, 424, 427, 430, 433

LESSON 2

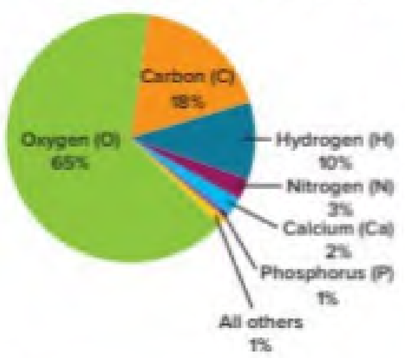
NONMETALS

FOCUS QUESTION

What are the properties of a typical nonmetal?

Properties of Nonmetals

Most of your body's mass is made of oxygen, carbon, hydrogen, and nitrogen, as shown in **Figure 10.** Calcium, phosphorus, sulfur, and chlorine are among the other elements found in your body. Except for the metal calcium, these elements are nonmetals. **Nonmetals** are elements that are usually gases or solids at room temperature. Solid nonmetals are not malleable or ductile, but are brittle or powdery. Nonmetals are poor conductors of heat and electricity because the electrons in nonmetals are not free to move as they do in metals.



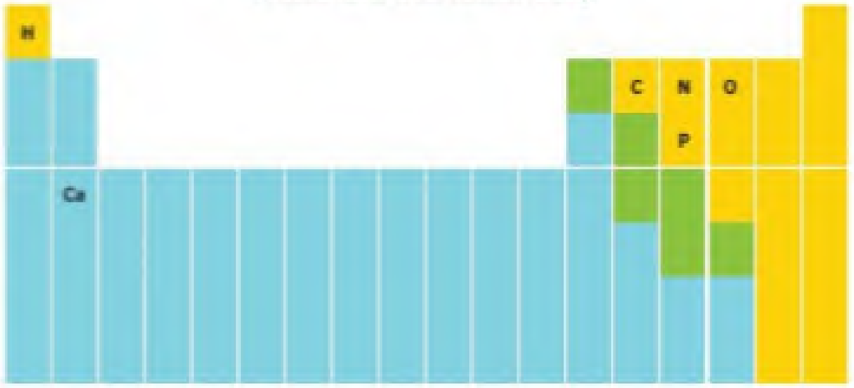


Figure 10 Humans are composed of mostly nonmetals. The pie chart breaks down the ratio of elements in the human body by mass (left). These elements mostly fall in the nonmetal portion of the periodic table (right).

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Quick Investigation: Identify Chlorine Compounds in Your Water

Carry out an investigation to determine the effect of adding silver nitrate to water.

Revisit the Encounter the Phenomenon Question

What information from this lesson can help you answer the Unit and Module questions?

Chlorine compounds are used to disinfect water in swimming pools.

Scientists use a bromine compound to stain DNA samples.

Iodine will sublime at room temperature.

Figure 13 Halogens have a wide variety of uses and properties.

Chlorine and bromine

The odor that you sometimes smell near a swimming pool is chlorine. Chlorine compounds, like those found in the tablet shown in **Figure 13**, disinfect water. Chlorine, the most abundant halogen, is obtained from seawater at ocean-salt recovery sites. Household and industrial bleaches that are used to whiten flour, clothing, and paper also contain chlorine compounds.

Bromine, the only nonmetal that is a liquid at room temperature, also is extracted from compounds in seawater. Some hot tubs use bromine compounds instead of chlorine compounds to disinfect water. Bromine compounds were once used in cosmetics and as flame retardants. But, due to health concerns, these compounds are being used less frequently.

Another bromine compound is used to study genetic material, such as DNA. The bromine compound binds to the DNA in certain areas and acts as a sort of tag. Under fluorescent light, the bromine compound absorbs the fluorescent light and emits a reddish visible light, as shown in **Figure 13.**

Get It?

Name some uses of chlorine and bromine compounds.

Iodine and astatine

Iodine, a shiny purple-gray solid at room temperature, is obtained from seawater. When heated, iodine sublimes to a purple vapor, as seen in **Figure 13.** Iodine is essential in your diet for production of the hormone thyroxin and to prevent goiter, an enlarging of the thyroid gland in the neck. Iodine compounds are also used as disinfectants.

Astatine is the last member of group 17. It is radioactive and rare but has many properties similar to those of the other halogens. Because it is so rare in nature, scientists usually make astatine for research purposes. Medical researchers are investigating the possibility of using astatine's radioactive properties to treat cancer.

5	Describe changes of state in terms of the attractive forces, and energy of particles, Analyze all feature on heating curves. & Predict the cooling curve features for the same matter	textbook, figure 7	358

Heating curves

A graph of temperature v. time for heating of 1.0 kg of water is shown in **Figure 7.** This type of graph is called a heating curve. It shows how temperature changes over time as thermal energy is continuously added. Notice the two areas on the graph where the temperature does not change. At 0°C, ice is melting. All of the energy put into the ice at this temperature is used to overcome the attractive forces between the particles. The flat line on the graph indicates that temperature remains constant during melting.

After the attractive forces between the particles of the solid are overcome, the particles move more freely, and their temperature increases. At 100°C, water is boiling, the temperature remains constant again, and the graph is flat. All of the energy that is put into the water goes to overcoming the remaining attractive forces between the particles. When all of the attractive forces between the particles of the liquid are overcome, the energy goes into increasing the temperature of the gas.

Get It?
Explain why the graph in Figure 7 is flat at b.

Plasma State

So far, you have learned about the three familiar states of matter—solids, liquids, and gases. However, there is a state of matter beyond the gas state. **Plasma** is matter that has enough energy to overcome not just the attractive forces between its particles but also the attractive forces within its atoms. The atoms that make up a plasma collide with such force that the electrons are stripped off the atoms. As a result, plasmas are made up of electrons and other charged particles.

You may be surprised to learn that most of the ordinary matter in the universe is in the plasma state. Every star that you can see in the sky, including the Sun, is composed of matter in the plasma state. Most of the matter between the stars and galaxies is also in the plasma state. The familiar states of matter—solid, liquid, and gas—are extremely rare in the universe.

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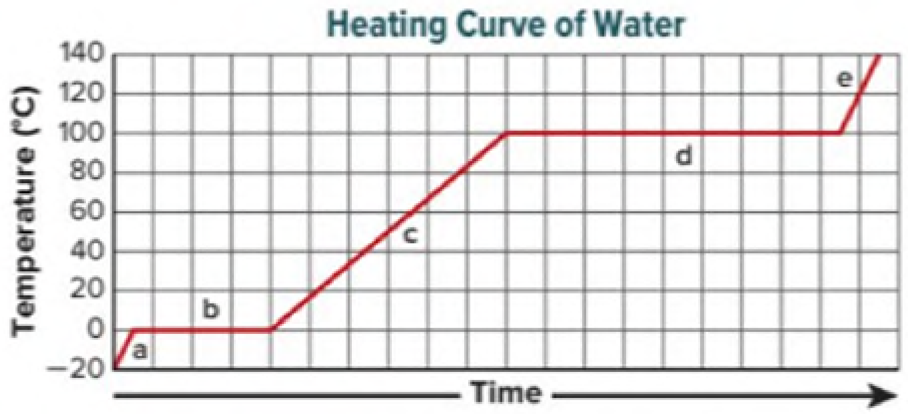

Figure 7 Although thermal energy is added at a constant rate, the temperature of the water increases only at *a*, *c*, and *e*. At *b* and *d*, the added energy is used to overcome the attractions between the particles.

Infer *how this graph would be different if 2.0 kg of water were being heated instead of 1.0 kg of water. How would this graph be different if 0.5 kg of water were being heated?*

6	Differentiate between constant, control, dependent & independent variables and assign them in a given example (scenario)	textbook, table 1, figure 13	7, 8, 19

Form a hypothesis

A **hypothesis** is a possible answer to a question or a possible solution to a problem based on what you know and what you observe. When trying to find a better material to protect the space shuttle, NASA scientists looked to other materials that were used in similar situations. Scientists knew that a ceramic coating had been found to solve the guided missile problem. They hypothesized that a ceramic material might work on the space shuttle also.

Figure 4 An astronaut aboard the International Space Station conducts an experiment session with the Capillary Flow Experiment (CFE). CFE observes the flow of fluid, in particular capillary phenomena, in microgravity.

Test a hypothesis

Some hypotheses can be tested by making observations. Others can be tested by building a model and relating it to real-life situations. One common way to test a hypothesis is to perform an experiment. An **experiment** tests the effect of one thing on another using a control.

Variables An experiment usually contains at least two variables. A **variable** is a quantity that can have more than a single value. **Table 1** summarizes the types of variables. For example, numerous experiments aboard space shuttles and the *International Space Station* (ISS) have studied the effects of microgravity on plants. Before these experiments could begin, scientists had to think of every factor that might affect plant growth. Each of these factors is a variable.

Independent and dependent variables In the microgravity experiment, plant growth is the **dependent variable** because its value changes according to the changes in the other variables. The variable that is changed to see how it will affect the dependent variable is called the **independent variable.** The microgravity is the independent variable. Scientists on the ISS are using microgravity as an independent variable in other experiments as well, as shown in **Figure 4.**

Constants To be sure they were testing to see how microgravity affects growth, mission specialists kept the other possible factors the same. A factor that does not change is called a **constant.** The microgravity experiments used the same soil and type of plant. Additionally, each plant was given the same amount of light and water and was kept at the same temperature. Type of soil, type of plant, amount of light, amount of water, and temperature were constants for this experiment.

Table 1 Types of Variables

Dependent Variable	changes according to the changes of the independent variable
Independent Variable	the variable that is changed to test the effect on the dependent variable
Constant	a factor that does not change when other variables change
Control	the standard by which the test results can be compared

Controls A **control** is the standard by which test results can be compared. After the mission specialists gathered their data on the plants grown in microgravity, they compared their results with the same types of plants grown on Earth's surface with the same constants. This comparison allowed them to analyze the data and form a conclusion about whether microgravity has an effect on plant growth.

Get It?
Identify What is the purpose of a control in an experiment?

Analyze the data

An important part of every investigation includes recording observations and organizing the test data into easy-to-read tables and graphs. Later in this module, you will study ways to display data. When you are making and recording observations, you should include all results, even unexpected ones. Many important discoveries have been made from unexpected results.

Scientific inferences are based on observations made using scientific methods. All possible scientific explanations must be considered. If the data are not organized in a logical manner, wrong conclusions can be drawn. When a scientist communicates and shares data, other scientists will examine that data, consider how it is analyzed, and compare it to the work of others. Scientists share their data through reports and conferences. In **Figure 5,** a scientist is presenting his data.

Draw conclusions

Based on the analysis of the data, the next step is to decide whether the hypothesis is supported. For the hypothesis to be considered valid and widely accepted, the experiment must result in the exact same data every time it is repeated. If the experiment does not support the hypothesis, the hypothesis must be reconsidered. Perhaps the hypothesis needs to be revised, or maybe the experiment's procedure needs to be refined.

Figure 5 An exciting and important part of an investigation is sharing your ideas with others.

ACADEMIC VOCABULARY
Infer
to come to a logical conclusion based on observations and evidence
After observing a trail of ants in his kitchen, Joe inferred that he had spilled some sugar.

COMMUNICATING WITH GRAPHS

FOCUS QUESTION
When would you use a bar graph instead of a line graph?

A Visual Display

Scientists often graph the results of their experiments to make it easier to detect patterns in the data. A **graph** is a visual display of information or data. **Figure 13** is a graph that shows the time and distance from home as a girl walked her dog. The horizontal axis, called the *x*-axis, measures time. Time is the independent variable, because as it changes, it affects the measure of another variable. The distance from home that the girl and the dog walk is the other variable. It is the dependent variable and is measured on the vertical axis, called the *y*-axis.

Graphs are useful for displaying numerical information in business, science, sports, advertising, and many everyday situations. Graphs make it easier to understand patterns by displaying data in a visual manner.

Scientists often graph their data to detect patterns that would not have been evident in a table. Businesspeople may graph sales dollars to determine trends. Different kinds of graphs—line, bar, and circle—are appropriate for displaying different types of information. Additional information on making and using graphs can be found in the Math Skill Handbook in the back of this book.

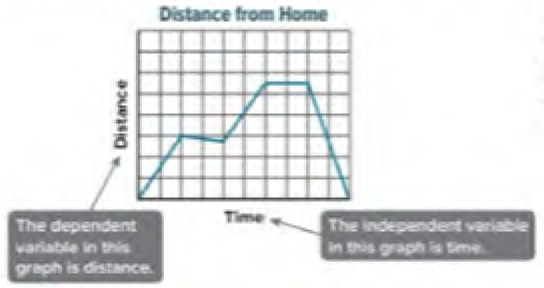

Figure 13 This graph tells the story of the motion that takes place when a girl takes her dog for a 10-minute walk. The dependent variable is on the *y*-axis, and the independent variable is on the *x*-axis.

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE
Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE
GO ONLINE to find these activities and more resources.

Lab: Who contributes carbon dioxide?
Carry out an investigation to calculate the quantity of carbon dioxide produced per person in different countries.

Teaching Activity: Reading Graphs
Analyze a graph to determine how they make it easier to understand and detect patterns within data.

7	Define peer review, bias & blind experiment, to evaluate the effect on the quality of them on problem solving & scientific method	textbook, figure 6	8, 9

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After observing a trail of ants in his kitchen, Joe inferred that he had spilled some sugar.

Figure 6 In order for medicine to be approved for use on humans, scientists have to run multiple trials to prove the results are objective.

Peer review

Before it is made public, science-based information is reviewed by scientists' peers—scientists who are in the same field of study. Peer review is a process by which the procedures and results of an experiment are evaluated by other scientists who are in the same field as those who are conducting similar research. Reviewing other scientists' work is a responsibility that many scientists have.

Being objective

Scientists also have a responsibility to minimize bias in their investigations. **Bias** occurs when a scientist's expectations change how the results are analyzed or conclusions are formed. Bias might cause a scientist to select a result from one trial over those from other trials. An example of bias would be presenting positive test results to promote a product and withholding unfavorable results.

Scientists can reduce bias by running as many trials as possible and by keeping accurate notes of each observation made. **Figure 6** shows a scientist who is researching a medication's effectiveness. One way to reduce bias in this case would be to conduct the experiment so that the researchers didn't know which group was the study group and which group was the control. This is called a blind experiment.

Valid experiments must also have data that are measurable. For example, a scientist performing a global warming study must base his or her data on accurate measures of global temperature. This allows others to compare the results to data they obtain from similar experiments. Most importantly, the experiment must be repeatable. Findings are supportable when other scientists around the world perform the same experiment and get the same results.

Get It?
Define What is bias in science?

8	Identify the SI base unit for different quantities (Time, length, mass, temperature, amount of a substance and electric current), and **convert** between these units using the prefixes	textbook, tables 2 & 3	13, 14

International System of Units

In 1960, an improved version of the metric system was devised. Known as the International System of Units, this system is often abbreviated **SI**, from the French *Le Systeme Internationale d'Unites.* All SI standards are universally accepted and understood by scientists throughout the world.

All of the units in SI are based on fundamental physical constants that are the same throughout the universe. For example, the standard meter equals the exact distance that light travels through a vacuum in 1/299,792,458 seconds.

Table 2 SI Base Units

Quantity Measured	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Intensity of light	candela	cd

A base unit in SI is one that is based on a universal physical constant. There are seven base units in SI. The names and symbols for the seven base units are shown in **Table 2.** All other SI units are derived from these seven units. The base unit of mass, the kilogram, was recently redefined to be based on a constant known as the Planck constant.

SI prefixes

The SI system is easy to use because it is based on multiples of ten. Prefixes are used with the names of the units to indicate what multiple of ten should be used with the units. For example, the prefix *kilo-* means "1000," which means that one kilometer equals 1000 meters. Likewise, one kilogram equals 1000 grams. Because *deci-* means "one-tenth," one decimeter equals one-tenth of a meter. A decigram equals one-tenth of a gram. The most frequently used prefixes are shown in **Table 3.**

Table 3 Common SI Prefixes

Prefix	Symbol	Multiplying Factor
Kilo-	k	1,000
Deci-	d	0.1
Centi-	c	0.01
Milli-	m	0.001
Micro-	μ	0.000 001
Nano-	n	0.000 000 001

Get It?
Calculate How many meters is 1 km? How many grams is 1 dg?

Converting between SI units

Sometimes quantities are measured using different units. A conversion factor is a ratio that is equal to 1. It is used to change one unit to another. For example, there are 1000 mL in 1 L, so 1000 mL = 1 L. If both sides in this equation are divided by 1 L, the equation becomes:

$$\frac{1000 \text{ mL}}{1 \text{ L}} = 1$$

To convert units, multiply by the appropriate conversion factor. For example, to convert 1.255 L to mL, multiply 1.255 L by a conversion factor. Use the conversion factor with new units (mL) in the numerator and the old units (L) in the denominator.

$$1.255 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1255 \text{ mL}$$

EXAMPLE Problem 1

CONVERT UNITS How long, in centimeters, is a 3075-mm rope?

Identify the Unknown: rope length in cm

List the Knowns: rope length in mm = 3075 mm
1 m = 100 cm = 1000 mm

Set Up the Problem: $\text{length in cm} = \text{length in mm} \times \frac{100 \text{ cm}}{1000 \text{ mm}}$

Solve the Problem: $\text{length in cm} = 3075 \text{ mm} \times \frac{100 \text{ cm}}{1000 \text{ mm}} = 307.5 \text{ cm}$

Check the Answer: Millimeters are smaller than centimeters, so make sure your answer in mm is greater than the measurement in cm. Because SI is based on tens, the answer in mm should differ from the length in cm by a factor of ten.

PRACTICE Problems ADDITIONAL PRACTICE

5. If your pencil is 11 cm long, how long is it in millimeters?

6. CHALLENGE Some birds migrate 20,000 miles. If 1 mile equals 1.6 kilometers, calculate the distance these birds fly in kilometers.

Measuring Length

The word *length* is used in many ways. For example, the length of a novel is the number of pages or words it contains. In scientific measurement, however, length is the distance between two points. That distance might be the diameter of a hair or the distance from Earth to the Moon. The SI base unit of length is the meter (m). A baseball bat is about 1 m long. Metric rulers and metersticks are used to measure length. **Figure 10** compares a meter and a yard.

Figure 10 One meter is slightly longer than 1 yard, and 100 m is slightly longer than a football field.
Predict *whether your time for a 100-m dash would be slightly more or less than your time for a 100-y dash.*

STEM CAREER Connection

Computer Systems Analyst

Computer systems analysts study an organization's current computer systems and procedures and design solutions to help the organization operate more efficiently and effectively.

9	State the features of water on the Celsius, Fahrenheit, and Kelvin temperature scales, and compare between them	textbook, figure 12	18,

Comparing Temperature Scales

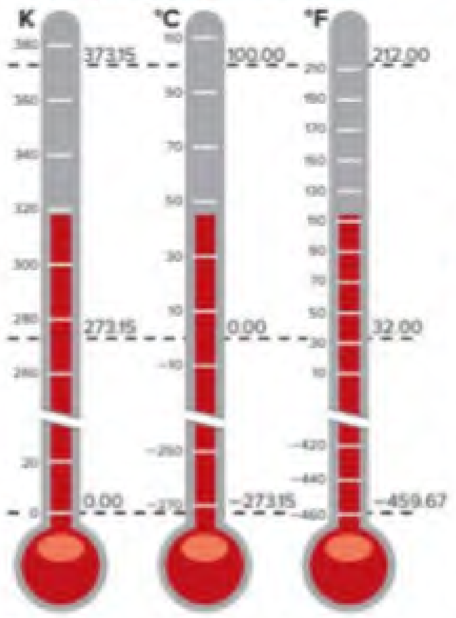

Figure 12 These three thermometers illustrate the three most common temperature scales. The dotted lines show absolute zero, the freezing point of water, and the boiling point of water.

State *the boiling point of water on the three scales.*

Celsius

Look at **Figure 12.** For much scientific work, temperature is measured on the Celsius (C) scale. On this scale, the freezing point of water is 0°C, and the boiling point of water is 100°C. Between these points, the scale is divided into 100 equal divisions. Each one represents 1°C. On the Celsius scale, average human body temperature is 37°C, and a typical room temperature is between 20°C and 25°C.

Kelvin and Fahrenheit

The SI unit of temperature is the kelvin (K). Zero on the Kelvin scale (0 K) is the coldest possible temperature, also known as absolute zero. Absolute zero is roughly equal to −273°C, which is 273°C below the freezing point of water.

Most laboratory thermometers are marked only with the Celsius scale. Because the divisions on the Celsius and Kelvin scales are the same size, the Kelvin temperature can be found by adding 273 to the Celsius reading. So, on the Kelvin scale, water freezes at 273 K and boils at 373 K. Notice that degree symbols are not used with the Kelvin scale.

The temperature measurement with which you are probably most familiar is the Fahrenheit scale. On the Fahrenheit scale, the freezing point of water is 32°F, and the boiling point is 212°F. A temperature difference of 1° on the Fahrenheit scale is 5/9° on the Celsius scale.

Check Your Progress

Summary

- The International System of Units, or SI, was established to provide a standard of measurement and to reduce confusion.
- Conversion factors are used to change one unit to another and involve using a ratio equal to 1.
- The size of an object determines which unit you will use to measure it.

Demonstrate Understanding

7. **Explain** why it is important to have exact standards of measurement.
8. **Make a Table** Organize the following measurements from smallest to largest and include the multiplying factor for each: kilometer, nanometer, centimeter, meter, and micrometer.

Explain Your Thinking

9. **Explain** why density is a derived unit.
10. **MATH Connection** Make the following conversions: 27°C to kelvins, 20 dg to milligrams, and 3 m to decimeters.
11. **MATH Connection** What is the density of an unknown metal that has a mass of 158 g and a volume of 20 mL? Use **Table 4** to identify this metal.

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10	Analyze and interpret data from given graphs	textbook, figures 15, 16, 17	21, 22, 23

Constructing line graphs

In addition to choosing a scale that makes a graph readable, other factors are involved in constructing useful graphs. The most important factor in making a line graph is always using the x-axis for the independent variable. The y-axis is always used for the dependent variable. Recall that the dependent variable changes in response to the changes that you make to the independent variable, and the independent variable is the variable that you change to see how it will affect the dependent variable.

Another factor in constructing a graph involves units of measurement. You must use consistent units when graphing data. For example, you might use a Celsius thermometer for one part of your experiment and a Fahrenheit thermometer for another. But you must first convert your temperature readings to the same unit of measurement before you make your graph.

Once the data is plotted as points, a straight line or a curve is drawn based on those points. This should not be done like a connect-the-dots game. Instead, a best-fit line or a most-probable smooth curve is placed among the data points, as shown in **Figure 15**.

In the past, graphs had to be made by hand, with each point plotted individually. Today, scientists, mathematicians, and students use a variety of tools, such as computer programs and graphing calculators, to help them draw and interpret graphs.

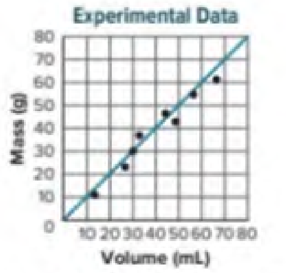

Figure 15 Generally, the line or curve that you draw will not intersect all of your data points.

APPLY SCIENCE

Make and Use Graphs

Line graphs are useful tools for showing the relationship between an independent and a dependent variable. In an experiment, you checked the air temperature at certain hours of the day and recorded it in the data table shown here.

Time	Temperature
8:00 A.M.	27°C
12:00 P.M.	32°C
4:00 P.M.	30°C

Identify the Problem

time = independent variable
temperature = dependent variable

Temperature is the dependent variable because it varies with time. Graph time on the x-axis and temperature on the y-axis. Mark equal increments on the graph and include all measurements. Plot each point on the graph by finding the time on the x-axis and moving up until you find the recorded temperature on the y-axis. Continue placing points on the graph. Then, connect the points from left to right.

Solve the Problem

1. Based on your graph, what was the temperature at 10:00 A.M.? What was the temperature at 2:00 P.M.?
2. What is the relationship between time and temperature?
3. Why is a line graph a useful tool for viewing this data?
4. For what other types of data might a line graph be useful?

Table 7 Classroom Size

Number of Students	Number of Classrooms
20	1
21	3
22	3
23	2
24	3
25	5
26	5
27	3

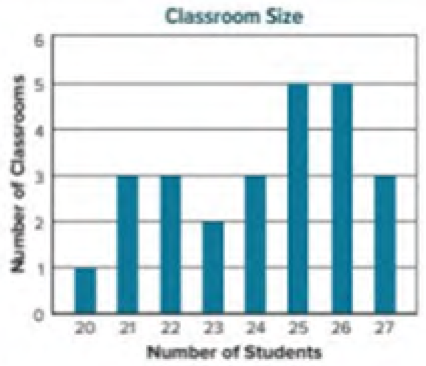

Figure 16 The height of each bar corresponds to the number of classrooms having a particular number of students.

Bar Graphs

A bar graph is useful for comparing information or displaying data that do not change continuously. Suppose you counted the number of students in every classroom in your school and organized your data in **Table 7**. You could show these data in a bar graph like the one in **Figure 16**. Notice you can easily determine which classrooms have the greatest and least numbers of students. You can also easily see that there are the same numbers of classrooms with 21 and 22 students and with 25 and 26 students.

Bar graphs can be used to compare oil or crop production, to compare costs of different products, or as data in promotional materials. Similar to a line graph, the independent variable is plotted on the x-axis, and the dependent variable is plotted on the y-axis.

Recall that you might need to place a break in the scale of the graph to better illustrate your results. For example, if your data set included the points 1002, 1010, 1030, and 1040 and the intervals on the scale were every 100 units, you might not be able to see the difference from one bar to another. If you had a break in the scale and started your data range at 1000 with intervals of ten units, you could make a more accurate comparison.

Get It?
Describe possible data for which using a bar graph would be better than using a line graph.

Circle Graphs

A circle graph, sometimes called a pie chart, is used to show how some fixed quantity is broken into parts. The circular pie represents the total. The slices represent the parts and usually are represented as percentages of the total.

Figure 17 illustrates how a circle graph could be used to show the percentage of buildings in a neighborhood using each of a variety of heating fuels. You easily can see that more buildings use gas heat than any other kind of system. What other information does the graph provide?

To create a circle graph, start with the total of what you are analyzing. Suppose the survey of heating fuels counted 72 buildings in the neighborhood. For each type of heating fuel, you divide the number of buildings using each type of fuel by the total (72). Then multiply that decimal by 360° to determine the angle that the decimal makes in the circle. For example, 18 buildings use steam. Therefore, $18 \div 72 = 0.25$, and $0.25 \times 360° = 90°$ on the circle graph. You then would measure 90° on the circle with your protractor. You can also calculate that if this graph shows 50 percent of the buildings use gas, then 36 of the buildings use gas ($0.50 \times 72 = 36$).

When you create a graph, think carefully about which type of graph you will use and how you will present your data. In addition, consider the conclusions you may draw from your graph. Make sure your conclusions are based on sound information and that you present your information clearly.

Figure 17 A circle graph shows the different parts of a whole quantity.

Check Your Progress

Summary

- Graphs are a visual representation of data.
- Scientists often graph their data to detect patterns.
- A line graph shows a relationship between an independent and a dependent variable.
- Bar graphs are best used to compare information collected by counting.
- A circle graph shows how a fixed quantity is broken down into parts.

Demonstrate Understanding

12. **Identify** the kind of graph that would best show the results of a survey of 144 people, of which 75 ride a bus, 45 drive cars, 15 carpool, and 9 walk to work.
13. **State** which type of variable is plotted on the x-axis and which type is plotted on the y-axis.
14. **Compare and Contrast** How are line, bar, and circle graphs similar? How are they different?

Explain Your Thinking

15. **Explain** why the points in a line graph can be connected.
16. MATH Connection In a survey, it was reported that 56 out of 245 people would rather drink orange juice than coffee in the morning. Calculate the percentage of a circle graph that orange-juice drinkers would occupy.

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11	List the assumptions of kinetic molecular theory as explanation of how the particles in gases behave	textbook	354

LESSON 1

MATTER AND THERMAL ENERGY

FOCUS QUESTION

How do changes in thermal energy affect the particles that make up matter?

Kinetic Theory

You encounter solids, liquids, and gases every day. Look at **Figure 1.** Can you identify the states of matter present? The tea is in the liquid state. The ice cubes dropped into the tea to cool it are in the solid state. Surrounding the glass, as part of the air, is water in the gas state. How do these states compare?

Gas state

To understand the states of matter, we must think about the particles that make up matter. Consider the air around you: it is composed of nitrogen, oxygen, and water, along with other gases. These atoms and molecules—the particles that make up the air—are constantly moving. The **kinetic theory**, also known as kinetic molecular theory, is an explanation of how the particles in gases behave. To explain the behavior of particles, it is necessary to make the following assumptions:

1. All matter is composed of tiny particles (atoms, molecules, and ions).
2. These particles are in constant, random motion.
3. The particles collide with each other and with the walls of any container in which they are held.
4. The amount of energy that the particles lose from these collisions is negligible.

Figure 1 Water is a substance that can exist in all three common states of matter at the same time.

Identify *the solid and liquid states of water in this photo.*

Figure 2, on the next page, illustrates the kinetic theory. Because the particles of a substance in the gas state are in constant motion, colliding with each other and with the walls of their container, gases do not have a fixed volume or shape. The particles that make up a gas spread out so that they fill whatever container they are in.

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE

Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE

GO ONLINE to find these activities and more resources.

Lab: Phase Changes

Carry out an investigation into the energy absorbed or released from a system when matter changes state.

Revisit the Encounter the Phenomenon Question

What information from this lesson can help you answer the Module question?

12	Differentiate between states of matter and describe the thermal energy associated with changing between these states	textbook	356, 357

Thermal energy is the total energy of a material's particles. Thermal energy is one of the ways energy manifests at the macroscopic scale. It includes both the kinetic energy of the particles as well as their potential energy. Energy from the motions of individual particles and energy from forces that act within or between particles are both forms of thermal energy. Energy from the motion of an object as a whole and energy from its interactions with its surroundings are not thermal energy.

Temperature

Temperature is the term used to explain how hot or cold an object is. Temperature represents the average kinetic energy of the particles that make up a substance. On average, molecules of water at 0°C have less kinetic energy than molecules of water at 100°C.

Changes of State

What happens to a solid when thermal energy is added to it? Think about the iced water in **Figure 4**. The particles that make up the water are moving fast and colliding with the particles that make up the ice cubes. Those collisions transfer energy from the water to the ice. The particles at the surface of an ice cube vibrate faster, transferring energy to other particles in the ice cube.

Melting and freezing

Soon, the particles that make up the ice have enough kinetic energy to overcome the attractive forces holding them in their crystalline structure. The ice melts. The **melting point** is the temperature at which a solid becomes a liquid. Energy is required for the particles to slip out of the ordered arrangement of a solid. The **heat of fusion** is the energy required to change a substance from solid to liquid at its melting point.

The transfer of energy between particles of liquid and particles of solid causes the ice to melt, but what happens to the particles of liquid after they collide with the solid? They slow down because they have less kinetic energy. As more of these collisions occur, the average kinetic energy of the particles of the liquid decreases, and the liquid cools.

Freezing is the reverse of melting. When a liquid's temperature is lowered, the average kinetic energy of the molecules decreases. When enough energy has been removed, the molecules become fixed into position. The freezing point is the temperature at which a liquid turns into a solid.

Figure 4 When ice is placed in water, energy from the particles of the liquid water is transferred to the particles of solid ice, melting the ice and cooling the water.

ACADEMIC VOCABULARY

definite
having distinct or certain limits
The teacher set definite standards for the students to meet.

CCC CROSSCUTTING CONCEPTS

Energy and Matter Energy cannot be created or destroyed. It moves between one place and another place, between objects and/or fields, or between systems. Create a graphic organizer that shows the movement of energy during different charges of state.

Vaporization and condensation

How does a liquid become a gas? Remember that the particles that make up a liquid are constantly moving. When particles move fast enough to escape the attractive forces of other particles, they enter the gas state. This process is called vaporization. Vaporization can occur in two ways: evaporation and boiling. The process in which a gas becomes a liquid is called condensation. Condensation is the reverse of vaporization.

Evaporation Evaporation occurs at the surface of a liquid and can happen at nearly any temperature. To evaporate, particles must be at the liquid's surface and have enough kinetic energy to escape the attractive forces of the liquid.

Boiling Shown in **Figure 5**, boiling is the second way that a liquid can vaporize. Unlike evaporation, boiling occurs throughout a liquid at a specific temperature, depending on the pressure on the surface of the liquid.

Figure 5 As temperature increases, the particles that make up a substance in its liquid state move faster. When their energy creates sufficient pressure to surpass the air pressure above the liquid, the liquid boils.

Infer *What is inside the bubbles of the boiling liquid?*

The **boiling point** of a liquid is the temperature at which the pressure of the vapor in the liquid is equal to the external pressure acting on the surface of the liquid. This external pressure pushes down on the liquid, keeping particles from escaping. Particles require energy to overcome this pressure. The **heat of vaporization** is the amount of energy required for the liquid at its boiling point to become a gas.

Sublimation At certain pressures, some substances can change directly from solids into gases without going through the liquid phase. **Sublimation** is the process of a solid changing directly to a gas without forming a liquid. **Figure 6** shows frozen carbon dioxide, also known as dry ice, which is a common substance that undergoes sublimation.

Figure 6 Carbon dioxide (CO_2) turns from a solid directly to a gas. Because this gas is very cold, it causes water in the air to condense, forming a white fog.

Explain, *at the molecular level, the behavior of CO_2 as it undergoes this phase transition.*

13	Differentiate between the principles that describe the behavior of fluids and relate them to daily life examples	textbook, figures 13, 14, 15, 16, 17, 18	362, 363, 365, 367, 368

LESSON 2

PROPERTIES OF FLUIDS

FOCUS QUESTION

What principles describe the behavior of fluids?

Archimedes' Principle and Buoyancy

Some ships are like floating cities. For example, aircraft carriers are large enough to allow airplanes to take off and land on their decks. Despite their weights, these ships float. There is a force pushing up on the ship that opposes the gravitational force pulling the ship down.

What is the force pushing up on the ship? It is called the buoyant force. If the buoyant force is equal to an object's weight, the object will float. If the buoyant force is less than an object's weight, the object will sink. **Buoyancy** is the ability of a fluid—a liquid or a gas—to exert an upward force on an object immersed in it.

Archimedes' principle

In the third century B.C., a Greek mathematician named Archimedes made a discovery about buoyancy. Archimedes found that the buoyant force on an object is equal to the weight of the fluid displaced by the object. For example, if you place a block of wood in water, it will push water out of the way as it begins to sink—but only until the weight of the water displaced equals the block's weight.

When the weight of water displaced—the buoyant force—becomes equal to the weight of the block, the block floats. If the weight of the water displaced is less than that of the block, the block sinks. **Figure 13** shows the forces that affect objects in fluids.

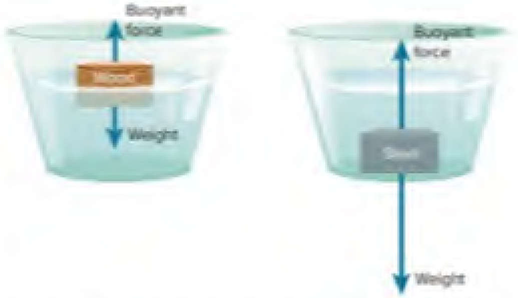

Figure 13 The steel block sinks because the buoyant force from the fluid is less than the gravitational force on the object. When the buoyant force is the same as or greater than the gravitational force—as with the wooden block—the object floats.

Compare *the volumes of the wood block and the steel block. How do the masses of the wood block and the steel block compare?*

Get It?
Infer why rocks sink and rubber balls float in water.

3D THINKING | DCI Disciplinary Core Ideas | CCC Crosscutting Concepts | SEP Science & Engineering Practices

COLLECT EVIDENCE
Use your Science Journal to record the evidence you collect as you complete the readings and activities in this lesson.

INVESTIGATE
GO ONLINE to find these activities and more resources.
Laboratory: Density of a Liquid
Analyze and interpret data to calculate and compare the densities of several liquids.
Identify Crosscutting Concepts
Create a table of the crosscutting concepts and fill in examples you find as you read.

Comparing buoyancy and weight

Look again at the wood and steel blocks in **Figure 13.** They both displace the same volume and weight of water when submerged. Therefore, the buoyant forces on the blocks are equal. Yet, the steel block sinks and the wood block floats. What is different?

The steel block weighs much more than the wood block. The gravitational force on the steel block is enough to make the steel block sink. The gravitational force on the wood block is not enough to make the wood block sink.

Density and buoyancy

One way to know whether an object will float or sink is to compare its density to the density of the fluid in which it is placed. An object floats if its density is less than that of the fluid. Remember that density is mass per unit volume. The density of the steel block is greater than the density of water. The wood block's density is less than that of water.

Suppose you formed the steel block into the shape of the hull of a ship filled with air, as shown in **Figure 14.** Now the same mass takes up a larger volume. The overall density of the steel boat and air is less than the density of water. The boat will now float.

Get It?
Explain why a steel block sinks but a steel ship floats.

Pascal's Principle and Pressure

Blaise Pascal (1623–1662), a French scientist, discovered that pressure applied to a fluid is transmitted throughout the fluid. This is why when you squeeze one end of a toothpaste tube, toothpaste emerges from the other end. The pressure has been transmitted through the toothpaste. In order to understand Pascal's principle, you must first understand pressure.

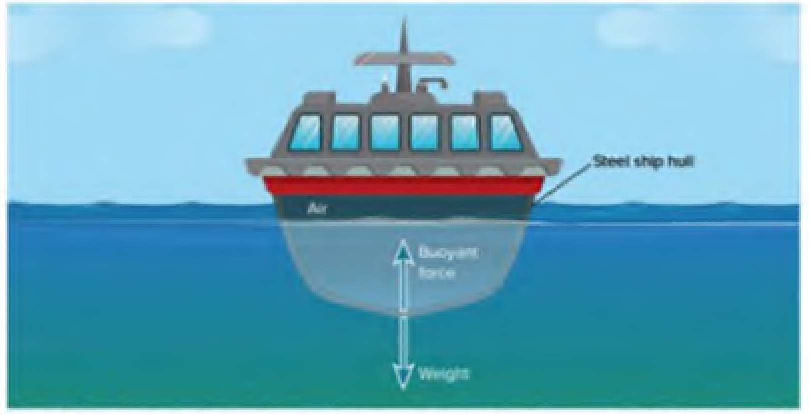

Figure 14 The overall density of a large ship is lower than the density of water because its empty hull contains mostly air.
Infer *why a boat cannot be made of solid steel.*

Pascal's principle

The idea that pressure is transferred through a fluid can be written as an equation: pressure in = pressure out. Since pressure is force over area, Pascal's principle can be written another way.

Pascal's Principle

$$\frac{\text{input force (N)}}{\text{input area (m}^2\text{)}} = \frac{\text{output force (N)}}{\text{output area (m}^2\text{)}}$$

$$\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$$

Hydraulic lifts Auto repair shops often make use of hydraulic lifts, which move heavy loads in accordance with Pascal's principle. A pipe that is filled with fluid connects small and large cylinders, as shown in **Figure 15.** Pressure applied to the small cylinder is transferred through the fluid and to the large cylinder. With a hydraulic lift, you could use your weight to lift something much heavier than you.

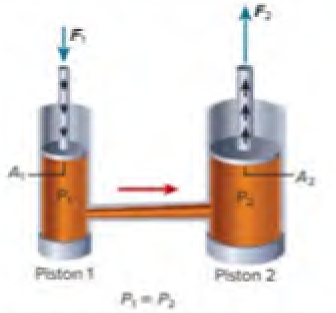

Figure 15 The pressure of the fluid on one side of a hydraulic lift is equal to the pressure on the other side.

EXAMPLE Problem 2

CALCULATE FORCES A hydraulic lift is used to lift a heavy machine that is pushing down on a 2.8-m^2 platform with a force of 3700 N. What force must be exerted on a 0.072-m^2 piston to lift the heavy machine?

List the Unknowns: force on piston: F_{in}

List the Knowns: force on platform: F_{out} = 3700 N
area of platform: A_{out} = 2.8 m^2
area of piston: A_{in} = 0.072 m^2

Set Up the Problem: $\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$

Solve the Problem: $F_{in} = \left(\frac{F_{out}}{A_{out}}\right)A_{in} = \left(\frac{3700\ N}{2.8\ m^2}\right) 0.072\ m^2 = 95\ N$

Check the Answer: The ratio of the forces should be the same as the ratio of the areas. The area of the platform is about 40 times the area of the piston. Therefore, the force on the platform should be about 40 times the force on the piston. 3700 N is about 40 times greater than 95 N, so the answer is reasonable.

PRACTICE Problems — ADDITIONAL PRACTICE

11. A car weighing 15,000 N is on a hydraulic lift platform measuring 10 m^2. What is the area of the smaller piston if a force of 1100 N is used to lift the car?
12. **CHALLENGE** A heavy crate applies a force of 1500 N on a 25-m^2 piston. The smaller piston is 1/30 the size of the larger one. What force is needed to lift the crate?

التكلمه في الصفحه الثانيه .

13	Differentiate between the principles that describe the behavior of fluids and relate them to daily life examples	textbook, figures 13, 14, 15, 16, 17, 18	362, 363, 365, 367, 368

Viscosity

Another property exhibited by a fluid is its tendency to flow. While all fluids flow, they vary in the rates at which they flow. **Viscosity** is the resistance of a fluid to flowing. For example, when you take syrup out of the refrigerator and pour it, as shown in **Figure 18**, the flow of syrup is slow. But if this syrup were heated, it would flow much faster. Water flows easily because it has low viscosity. Cold syrup flows slowly because it has high viscosity.

Figure 18 This maple syrup flows slowly because it has high viscosity.

Identify *other examples of liquids with high viscosities.*

What causes viscosity? When a container of liquid is tilted to allow flow to begin, the flowing portion of the liquid transfers energy to the portion of the liquid that is stationary. In effect, the flowing portion of the liquid is pulling the stationary portion of the liquid, causing it to flow, too.

If the flowing portion of the liquid does not effectively pull the other portions of the liquid into motion, then the liquid has a high viscosity, which is a high resistance to flow. If the flowing portion of the liquid pulls the other portions of the liquid into motion easily, then the liquid has low viscosity, or a low resistance to flow.

Check Your Progress

Summary

- If the buoyant force on an object is equal to or greater than the gravitational force on that object, the object will float. If the buoyant force on an object is less than the gravitational force on that object, the object will sink.
- Pascal's principle states that pressure applied to a fluid is transmitted throughout the fluid.
- Bernoulli's principle states that as the velocity of a fluid increases, the pressure exerted by the fluid decreases.
- The resistance to flow by a fluid is called viscosity.

Demonstrate Understanding

13. **Describe** how fluids exert forces on objects.
14. **Explain** why a steel boat floats on water, but a steel block does not.
15. **Explain** why squeezing a plastic mustard bottle forces mustard out the top.
16. **Describe,** using Bernoulli's principle, how tornadoes lift roofs off of buildings.

Explain Your Thinking

17. **Infer** If you blow up a balloon, tie it off, and release it, it will fall to the floor. Why does it fall instead of float? Explain what would happen if the balloon contained helium instead of air.
18. **MATH Connection** The density of water is 1.0 g/cm^3. How many kilograms of water does a submerged 120-cm^3 block displace? Recall that 1.0 kg weighs 9.8 N on Earth. What is the buoyant force on the block?
19. **MATH Connection** To lift an object weighing 21,000 N, how much force is needed on a piston with an area of 0.060 m^2 if the platform being lifted has an area of 3.0 m^2?

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LESSON 3
BEHAVIOR OF GASES

FOCUS QUESTION

How do gases respond to changes in pressure and temperature?

Boyle's Law—Volume and Pressure

Have you ever seen a weather balloon, like the one shown in **Figure 19**? They carry sensing instruments to very high altitudes to detect weather information. A weather balloon is inflated near Earth's surface with a low-density gas.

Recall that a gas completely fills its container. The balloon remains inflated because of collisions between the gas particles inside the balloon and the balloon itself. In other words, these collisions between gas particles and the container wall cause the gas to exert pressure on the container. As the balloon rises, the atmospheric pressure outside the balloon decreases. This decrease in pressure allows the balloon to expand, eventually reaching a volume between 30 and 200 times its original size. Boyle's law describes the relationship between gas pressure and volume that explains the behavior of weather balloons.

Get It?
Describe what happens to weather balloons as they rise.

Figure 19 A weather balloon expands as it rises due to decreased external pressure. Eventually, the balloon ruptures, and the instruments fall back to the ground.

3D THINKING DCI Disciplinary Core Ideas CCC Crosscutting Concepts SEP Science & Engineering Practices

COLLECT EVIDENCE
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INVESTIGATE
GO ONLINE to find these activities and more resources.

Laboratory: The Behavior of Gases
Carry out an investigation into the effects of changes in pressure and temperature on a sample of a gas.

Revisit the Encounter the Phenomenon Question
What information from this lesson can help you answer the Unit and Module questions?

14	Calculate pressure from force and area, and apply pascal's principle on hydraulic lifts to find force or area	Textbook, Example problems 1 &2, practice problems	364, 365

Pressure

Right now, pressure from the air is pushing on you from all sides, like the pressure you feel underwater in a swimming pool. **Pressure** is force exerted per unit area.

Pressure Equation

$$\text{Pressure (Pa)} = \frac{\text{force (N)}}{\text{area (m}^2\text{)}}$$

$$P = \frac{F}{A}$$

The SI unit of pressure is the pascal (Pa). Because pressure is the amount of force divided by area, one pascal is one newton per square meter (N/m^2). Most pressures are given in kilopascals (kPa) because 1 Pa is a very small amount of pressure.

EXAMPLE Problem 1

CALCULATE FORCE Atmospheric pressure at sea level is about 101 kPa. With how much total force does Earth's atmosphere push on an average human being at sea level? Assume that the surface area of an average human is 1.80 m^2.

List the Unknown: force: F

List the Knowns: pressure: $P = 101\text{ kPa} = 101{,}000\text{ Pa}$

area: $A = 1.80\text{ m}^2$

Set Up the Problem: $P = \frac{F}{A}$

Solve the Problem: $101{,}000\text{ Pa} = \frac{F}{1.80\text{ m}^2}$

$F = 101{,}000\text{ Pa} \times 1.80\text{ m}^2$

$= 182{,}000\text{ Pa} \cdot \text{m}^2 = 182{,}000\frac{\text{N}}{\text{m}^2} \cdot \text{m}^2 = 182{,}000\text{ N}$

Check the Answer: You've set up your equation correctly if the units are the same on both sides: units of pressure = Pa = N/m^2, and (units of force)/(units of area) = N/m^2. The units on both sides of the equation match. Now, just double-check the calculation.

PRACTICE Problems ADDITIONAL PRACTICE

8. A diver who is 10.0 m underwater experiences a pressure of 202 kPa. If the diver's surface area is 1.50 m^2, with how much total force does the water push on the diver?
9. A car weighs 15,000 N, and its tires are inflated to a pressure of 190 kPa. How large is the area of the car's tires that are in contact with the road?
10. **CHALLENGE** The atmospheric pressure at the surface of Venus is 91 times the pressure at sea level on Earth. With approximately how much total force would Venus's atmosphere push on an average human being at sea level? Assume that the surface area of an average human being is 1.8 m^2.

SCIENCE USAGE v. COMMON USAGE

pressure

Science usage: force per unit area

Increasing the pressure on a gas decreases its volume.

Common usage: the burden of physical or mental stress

Teachers often feel a lot of pressure to help their students do well in school.

Pascal's principle

The idea that pressure is transferred through a fluid can be written as an equation: pressure in = pressure out. Since pressure is force over area, Pascal's principle can be written another way.

Pascal's Principle

$$\frac{\text{input force (N)}}{\text{input area (m}^2\text{)}} = \frac{\text{output force (N)}}{\text{output area (m}^2\text{)}}$$

$$\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$$

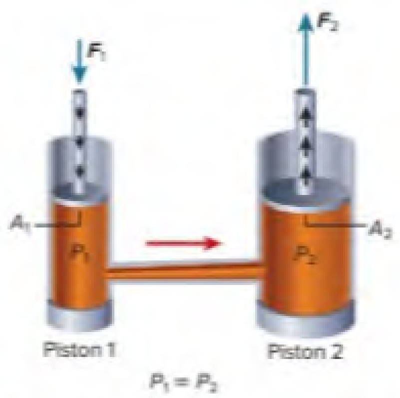

Figure 15 The pressure of the fluid on one side of a hydraulic lift is equal to the pressure on the other side.

Hydraulic lifts Auto repair shops often make use of hydraulic lifts, which move heavy loads in accordance with Pascal's principle. A pipe that is filled with fluid connects small and large cylinders, as shown in **Figure 15.** Pressure applied to the small cylinder is transferred through the fluid and to the large cylinder. With a hydraulic lift, you could use your weight to lift something much heavier than you.

EXAMPLE Problem 2

CALCULATE FORCES A hydraulic lift is used to lift a heavy machine that is pushing down on a 2.8-m^2 platform with a force of 3700 N. What force must be exerted on a 0.072-m^2 piston to lift the heavy machine?

List the Unknowns: force on piston: F_{in}

List the Knowns: force on platform: $F_{out} = 3700\text{ N}$

area of platform: $A_{out} = 2.8\text{ m}^2$

area of piston: $A_{in} = 0.072\text{ m}^2$

Set Up the Problem: $\frac{F_{in}}{A_{in}} = \frac{F_{out}}{A_{out}}$

Solve the Problem: $F_{in} = \left(\frac{F_{out}}{A_{out}}\right)A_{in} = \left(\frac{3700\text{ N}}{2.8\text{ m}^2}\right)0.072\text{ m}^2 = 95\text{ N}$

Check the Answer: The ratio of the forces should be the same as the ratio of the areas. The area of the platform is about 40 times the area of the piston. Therefore, the force on the platform should be about 40 times the force on the piston. 3700 N is about 40 times greater than 95 N, so the answer is reasonable.

PRACTICE Problems ADDITIONAL PRACTICE

11. A car weighing 15,000 N is on a hydraulic lift platform measuring 10 m^2. What is the area of the smaller piston if a force of 1100 N is used to lift the car?
12. **CHALLENGE** A heavy crate applies a force of 1500 N on a 25-m^2 piston. The smaller piston is 1/30 the size of the larger one. What force is needed to lift the crate?

15	Relate Boyles and Charles' laws to observations of gas behavior, and apply the laws to calculate final volume using pressure or tempreature for a system	textbook, figures 20& 21, Example problems 3 &4, practice problems	369, 370, 371, 372

Volume and pressure

Because a balloon is flexible, its volume can change. In the case of the weather balloon, the volume increases as the external pressure decreases. The volume of the gas inside the weather balloon continues to increase until the balloon can no longer contain it. At this point, the balloon ruptures, and the sensing instruments it was carrying fall to the ground.

From the weather balloon, we know what happens to volume when you decrease pressure. What happens to the pressure from a gas if you decrease its volume–for example, by decreasing the size of the container in which the gas is held? Think about the kinetic theory of matter. The pressure from a gas depends on how often its particles strike the walls of the container. If you squeeze gas into a smaller space, its particles will strike the walls more often, causing increased pressure. The opposite is also true. If you give the particles that make up the gas more space, increasing the volume, they will hit the walls less often, and the pressure from the gas will be reduced.

Get It?
Explain the relationship between pressure and volume.

Robert Boyle (1627–1691), a British scientist, described this property of gases. According to **Boyle's law**, if you decrease the volume of a container of gas and hold the temperature constant, the pressure from the gas will increase. An increase in the volume of the container causes the pressure to drop if the temperature remains constant. **Figure 20** shows this relationship as the volume of a gas is decreased from 10 L to 5 L to 2.5 L. Note the points on the graph that correspond to each of these volumes.

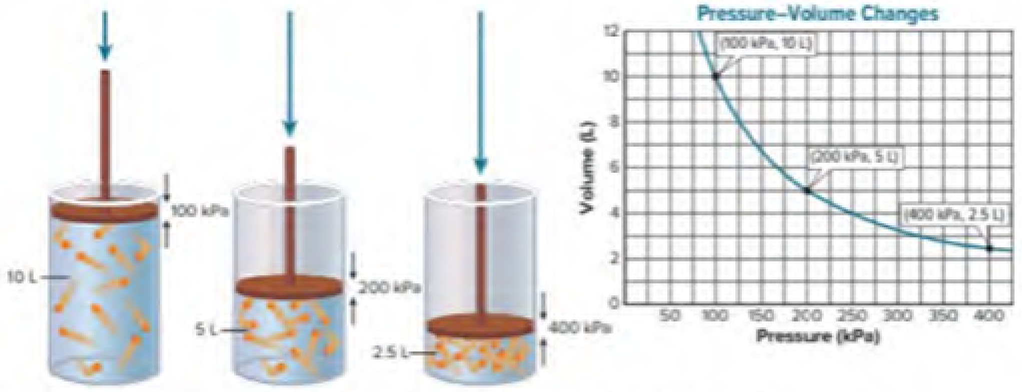

Figure 20 As volume is decreased, a gas exerts increased pressure on the walls of its container. The three canisters are depicted on the graph.

Interpret *What happens to the volume of a gas if the pressure on that gas is doubled?*

An equation for Boyle's law

Boyle's law can be expressed with a mathematical equation. When the temperature of a gas is constant, then the product of the pressure and volume of that gas does not change.

Boyle's Law Equation

initial pressure × initial volume = final pressure × final volume

$$P_iV_i = P_fV_f$$

The product of the initial pressure and volume–designated with the subscript *i*–is equal to the product of the final pressure and volume–designated with the subscript *f*. You can use this equation to find one unknown value when you have the other three. The equation will work with any units for either volume or pressure as long as you use the same pressure units for P_i and P_f and the same volume units for V_i and V_f.

Get It?
Show how to write the Boyle's law equation when it is solved for the final pressure of a gas.

EXAMPLE Problem 3

BOYLE'S LAW A weather balloon has a volume of 100.0 L when it is released from sea level, where the pressure is 101 kPa. What will be the balloon's volume when it reaches an altitude where the pressure is 43.0 kPa?

Identify the Unknown: final volume: V_f

List the Knowns:
initial pressure: P_i = 101 kPa
initial volume: V_i = 100.0 L
final pressure: P_f = 43.0 kPa

Set Up the Problem:
$$P_iV_i = P_fV_f$$
$$V_f = V_i\left(\frac{P_i}{P_f}\right)$$

Solve the Problem:
$$V_f = 100.0\ \text{L}\left(\frac{101\ \text{kPa}}{43.0\ \text{kPa}}\right)$$
$$= 235\ \text{L}$$

Check the Answer: You can do a quick estimate to check your answer. The pressure was slightly more than halved. Therefore, the volume should slightly more than double. The final volume of 235 L is slightly more than twice the initial volume of 100.0 L. Therefore, the answer seems reasonable.

PRACTICE Problems ADDITIONAL PRACTICE

20. A volume of helium occupies 11.0 L at a pressure of 98.0 kPa. What is the new volume if the pressure drops to 86.2 kPa?
21. **CHALLENGE** A weather balloon has a volume of 90.0 L when it is released from sea level. What is the atmospheric pressure on the balloon when it has grown to a size of 175.0 L?

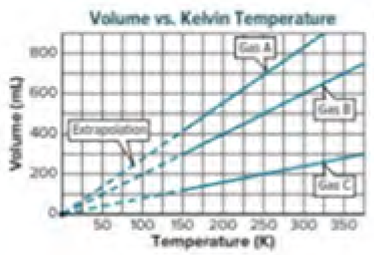

Figure 21 As the temperature of a sample of gas at constant pressure increases, the volume also increases. The dotted lines represent extrapolations of experimental data. Notice that all the extrapolated lines converge at 0 K.

Identify *which gas had the greatest volume change.*

Charles's Law—Temperature and Volume

If you've watched a hot-air balloon being inflated, you know that gases expand when they are heated. Jacques Charles (1746–1823), a French scientist, also noticed this. According to **Charles's law**, the volume of a gas increases with increasing temperature as long as the pressure on the gas does not change. As with Boyle's law, the reverse is also true. The volume of a gas shrinks with decreasing temperature, as shown in **Figure 21.**

Get It?
Explain the relationship between the temperature and volume of a gas.

The kinetic theory and Charles's law

Charles's law can be explained using the kinetic theory of matter. As a gas is heated, the particles that make up that gas move faster and faster. Because the particles that make up the gas move faster, they strike the walls of their container more often and with greater force. In the hot-air balloon, the walls have room to expand. So instead of pressure increasing, the volume increases.

Get It?
Describe How does the kinetic theory of matter explain Charles's law?

An equation for Charles's law

Like Boyle's law, Charles's law can be expressed mathematically. When the pressure on a gas is constant, then the ratio of the volume to the absolute temperature does not change. The absolute temperature is the temperature measured in kelvins.

Charles's Law Equation

$$\frac{\text{initial volume}}{\text{initial temperature (K)}} = \frac{\text{final volume}}{\text{final temperature (K)}}$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

This shows that the ratio of the initial volume to the initial temperature is equal to the ratio of the final volume to the final temperature. Remember that temperature must be in kelvins.

15	Relate Boyles and Charles' laws to observations of gas behavior, and apply the laws to calculate final volume using pressure or tempreature for a system	textbook, figures 20& 21, Example problems 3 &4, practice problems	369, 370, 371, 372

EXAMPLE Problem 4

USE CHARLES'S LAW A 2.0-L balloon at room temperature (20.0°C) is placed in a refrigerator at 3.0°C. What is the volume of the balloon after it cools in the refrigerator?

Identify the Unknown: final volume: V_f

List the Knowns:
initial volume: $V_i = 2.0$ L
initial temperature: $T_i = 20°C = 20.0°C + 273 = 293$ K
final temperature: $T_f = 3.0°C = 3.0°C + 273 = 276$ K

Set Up the Problem:
$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$
$$V_f = V_i\left(\frac{T_f}{T_i}\right)$$

Solve the Problem:
$$V_f = 2.0\ \text{L}\left(\frac{276\ \text{K}}{293\ \text{K}}\right) = 1.9\ \text{L}$$

Check the Answer: A good way to check your answer here is through experiment! If you place a balloon in a refrigerator, you will notice that the balloon shrinks, but not very much. This is consistent with our answer above.

PRACTICE Problems — ADDITIONAL PRACTICE

22. What would be the final size of the balloon in the example problem above if it were placed in a –18°C freezer?

23. CHALLENGE A gas is heated so that it expands from a volume of 1.0 L to a volume of 1.5 L. If the initial temperature of the gas was 5.0°C, then what is the final temperature of the gas?

Check Your Progress

Summary

- Boyle's law states that if the temperature is constant as the volume of a gas decreases, the pressure increases.
- Charles's law states that at constant pressure, the volume of a gas increases with increasing temperature.
- Both Boyle's law and Charles's law can be expressed as mathematical equations.

Demonstrate Understanding

24. **Describe** what would happen to the volume of a gas if the pressure on it were decreased and then the gas's temperature were increased.

25. **Predict,** using Boyle's law, what will happen to a balloon that an ocean diver takes to a pressure of 202 kPa.

Explain Your Thinking

26. **Predict** what would happen to the volume of a gas if the pressure on that gas were doubled and then the absolute temperature of the gas were doubled.

27. **MATH Connection** A helium balloon has a volume of 2.00 L at 101 kPa. As the balloon rises, the pressure drops to 97.0 kPa. What is the new volume?

28. **MATH Connection** If a 5.0-L balloon at 25°C were gently heated to 30°C, what would be the new volume?

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16	Diffrentiate between physical and chemical properties and list examples on them	Textbook, figures 13, 14,17	386, 387, 389

Behavior

Some physical properties describe the behavior of a material or a substance. As you might know, objects that contain iron, such as a safety pin, are attracted by a magnet. Attraction to a magnet is a physical property of iron.

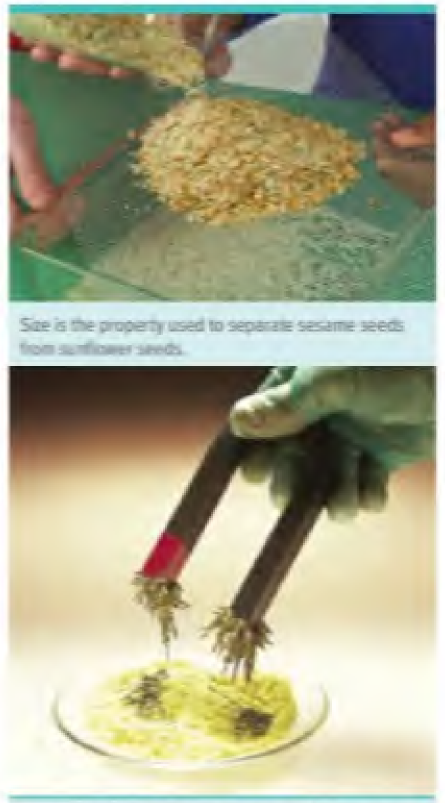
Every substance has a specific combination of physical properties that make it useful for certain tasks. Some metals, such as copper, can be drawn out into wires. Others, such as gold, can be pounded into sheets as thin as 0.1 micrometers (µm), about four-millionths of an inch. This property of gold makes it useful for decorating picture frames and other objects. Gold that has been beaten or flattened in this way is called gold leaf.

Think again about a soft drink in a cup. If you knock over the cup, the drink will spread over the table or floor. If you knock over a jar of molasses, however, it does not flow as easily. Viscosity, the resistance to flow, is a physical property of liquids.

Using physical properties to separate mixtures

Removing the seeds from a watermelon can be done easily based on the physical properties of the seeds compared to the rest of the fruit. **Figure 13** shows a mixture of sesame seeds and sunflower seeds. You can identify the two kinds of seeds by differences in color, shape, and size. By sifting the mixture, you can quickly separate the sesame seeds from the sunflower seeds because their sizes differ.

Now look at the mixture of iron filings and sand shown in **Figure 13.** You probably will not be able to sift out the iron filings because they are similar in size to the sand particles. What you can do is pass a magnet through the mixture. The magnet attracts only the iron filings and pulls them from the sand. This is an example of how a physical property, such as magnetic attraction, can be used to separate substances in a mixture. A similar method is used to separate iron from aluminum and other refuse for recycling. Strong magnets are used in scrapyards and landfills to remove iron for recycling and reuse in an effort to conserve natural resources.



Size is the property used to separate sesame seeds from sunflower seeds.

Magnetism easily separates iron from sand.

Figure 13 The best way to separate mixtures depends on their physical properties.

Get It?
Describe how you could use physical properties to separate sand from sugar.

ACADEMIC VOCABULARY

specific
characterized by precise formulation or accurate restriction
Some diseases have specific symptoms.

Physical Change

Physical properties can change while composition remains fixed. If you tear a piece of chewing gum, you change some of its physical properties—its size and shape. However, you have not changed the identity of the materials that make up the gum.

The identity remains the same

When a substance, such as water, freezes, boils, evaporates, or condenses, it undergoes a physical change. A change in size, shape, or state of matter in which the identity of the substance remains the same is called a **physical change**. These changes might involve energy changes, but the kind of substance—the identity of the element or compound—does not change. Because all substances have distinct properties, such as density, specific heat, and melting and boiling points, these properties can often be used to help identify a substance when a particular mixture contains more than one unknown material.

Get It?
Explain why the density of an unknown substance in a mixture can be used to identify the substance.

A substance can change states if it absorbs or releases enough energy. Iron, for example, will melt at high temperatures. Yet, whether in solid or liquid state, iron has physical properties that identify it as iron. Color changes are physical changes, too. For example, when iron is first heated, it glows red. Then, if it is heated to a higher temperature, it turns white, as shown in **Figure 14.**

Get It?
Infer Does a change in state mean that a new substance has formed? Explain.

Using physical changes

A cool drink of water is something most people take for granted; however, in some parts of the world, drinkable water is scarce. Not enough drinkable water can be obtained from wells. Many such areas that lie close to the sea obtain drinking water by using physical properties to separate salt from the water. One method, which uses the property of boiling point, is a type of distillation.

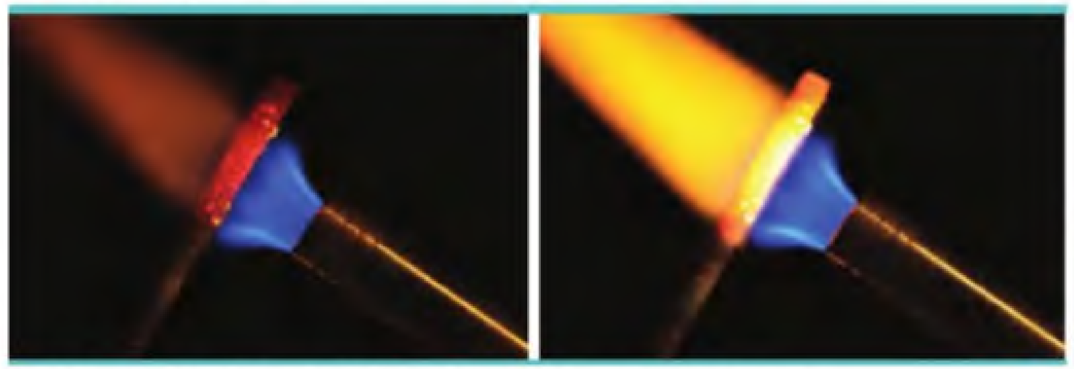


Figure 14 Heating iron raises its temperature and changes its color. These changes are physical changes because it is still iron.

Detecting Chemical Change

If you leave a pan of chili cooking unattended on the stove for too long, your nose soon tells you that something is wrong. Instead of a spicy aroma, you detect an unpleasant smell that alerts you that something is burning. This burnt odor is a clue that a new substance has formed.

The identity changes

The smell of rotten eggs and the formation of rust on bikes and car fenders are also signs that a chemical change has taken place. A change of one substance to another is a **chemical change**. Bubble formation produced by the foaming of an antacid tablet in a glass of water is a sign of new substances being produced. In some chemical changes, a rapid release of energy—detected as heat, light, and sound—is a clue that changes are occurring. A display of fireworks in the night sky is an example. **Figure 17** illustrates another visual clue—the formation of a solid precipitate. What is another example of a chemical change that produces a solid?

Get It?
Define What is a chemical change?

Heating, cooling, and the formation of bubbles or solids in a liquid are all indicators that a reaction is taking place. However, the only sure proof is that a new substance is produced. Consider the following examples. The heat, light, and sound produced when hydrogen gas combines with oxygen in a rocket engine are clear evidence that a chemical reaction has taken place. However, no clues announce the onset of the reaction in which iron and oxygen combine to form rust. The only clue that iron has changed into a new substance is the visible presence of rust. Burning and rusting are chemical changes because new substances form.

Figure 17 When clear solutions of lead(II) nitrate and potassium iodide mix, a reaction takes place and a yellow solid, lead(II) iodide, appears. The yellow solid that is produced in the chemical reaction is called a precipitate.

تعليم

17	State the law of conservation of mass and calculate the masses of the products and reactants of simple chemical reactions	textbook, fig.19, example problem 1, practice problem 7	391, 392

The Conservation of Mass

Wood burns, which means it undergoes combustion. Combustion is a chemical change. Suppose you burn a large log in a fireplace until nothing is left but a small pile of ashes. Smoke, heat, and light are given off, and the changes in the composition of the log confirm that a chemical change took place.

At first, you might think that matter was lost as the log burned because the pile of ashes looks much smaller than the log looked. In fact, the mass of the ashes is less than that of the log. However, suppose that you could collect all of the oxygen in the air that was combined with the log during the burning and all of the smoke and gases that escaped from the burning log and measure their masses too. You would find that no mass was lost after all.

Mass is not gained or lost during any chemical change. In fact, matter is neither created nor destroyed during a chemical change. According to the **law of conservation of mass**, the mass of all substances that are present before a chemical change, the reactants, equals the mass of all of the substances that remain after the change, which are called the products. The number and type of atoms do not change, they are just rearranged. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

The Law of Conservation of Mass

total mass of the reactants = total mass of the products

Figure 19 illustrates the law of conservation of mass. Solid sodium bicarbonate in the balloon reacts with liquid hydrochloric acid in the flask. A gas, carbon dioxide, is released and expands the balloon. Without the balloon in place, the gas would escape, and you might think that mass was not conserved. With the balloon to collect the gas, the mass on the scale remains the same. The mass of the reactants is the same as the mass of the products.

Figure 19 The reaction between sodium bicarbonate and hydrochloric acid produces carbon dioxide gas, which is collected in the balloon.

Describe How can you tell that matter was not created or destroyed in this reaction?

EXAMPLE Problem 1

CALCULATE TOTAL MASS OF PRODUCT When hydrogen reacts with chlorine, the only product is hydrochloric acid. If 18 g of hydrogen react completely with 633 g of chlorine, how many grams of hydrochloric acid are formed?

Identify the Unknown: mass of hydrochloric acid

List the Knowns: mass of hydrogen = 18 g
mass of chlorine = 633 g

Set Up the Problem: total mass of the product = total mass of the reactants
mass of hydrochloric acid = mass of hydrogen + mass of chlorine

Solve the Problem: mass of hydrochloric acid = 18 g + 633 g
The mass of hydrochloric acid is 651 g.

Check the Answer: The mass of reactants and products are equal because the equation was set up according to the law of conservation of mass.

PRACTICE Problems ADDITIONAL PRACTICE

7. When methane reacts with oxygen, the products are carbon dioxide and water. How many grams of water are formed if 24 g of methane react completely with 96 g of oxygen to form 66 g of carbon dioxide?
8. **CHALLENGE** Sulfur dioxide reacts with bromine and water to produce hydrogen bromide and sulfuric acid. If 64.1 g of sulfur dioxide react completely with 159.9 g of bromine and an unknown amount of water to form 161.9 g of hydrogen bromide and 98.1 g of sulfuric acid, then how many grams of water react?

Check Your Progress

Summary

- Physical properties can be used to distinguish and separate substances.
- A chemical change is sometimes indicated by cooling, heating, or formation of solids or bubbles.
- The law of conservation of mass states that matter is neither created nor destroyed in a chemical reaction.

Demonstrate Understanding

9. **Explain** why evaporation of water is a physical change and not a chemical change.
10. **Identify** four physical properties that describe a liquid. Identify a chemical property.
11. **Explain** how the law of conservation of mass applies to chemical changes.

Explain Your Thinking

12. **Determine** Does the law of conservation of mass apply to physical changes? How could you test this for melting ice? For the distillation of water?
13. **MATH Connection** Bismuth and fluorine react to form bismuth fluoride. If 417.96 g of bismuth reacts completely with 113.99 g of fluorine, how many grams of bismuth fluoride are formed?

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18	Use the relationship between the atomic number, and the mass number to find number of protons, electrons, and neutrons for a given element from the periodic table	Textbook, table 4	405

Table 4 Mass Numbers of Atoms

Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number
Boron	B	5	5	6	11
Carbon	C	6	6	6	12
Oxygen	O	8	8	8	16
Sodium	Na	11	11	12	23
Copper	Cu	29	29	34	63

Atomic number

Recall that an element is made of one type of atom. What determines the type of atom? In fact, the number of protons identifies the type of atom. For example, every carbon atom has six protons. Also, any atom with six protons is a carbon atom. Atoms of different elements have different numbers of protons. For example, atoms with eight protons are oxygen atoms.

Get It?
Describe what determines whether or not an atom is boron.

The number of protons in an atom's nucleus is equal to its **atomic number.** The atomic number of carbon is six. Oxygen's atomic number is eight, as shown in **Table 4.** Therefore, if you are given any one of the following–the name of an element, the number of protons for an element, or the atomic number of an element–you can identify the other two.

For example, if your teacher asked you to identify an atom with an atomic number of 11, you would know that the atom has eleven protons, and it is sodium, as indicated in **Table 4.**

Get It?
Interpret Table 4 to identify the name and the atomic number of the element with 29 protons.

Mass Number

The **mass number** of an atom is the sum of the number of protons and the number of neutrons in the nucleus of the atom.

Mass number = number of protons + number of neutrons

For example, you can calculate the mass number of the copper atom listed in **Table 4**: 29 protons plus 34 neutrons equals a mass number of 63.

Also, if you know the mass number and the atomic number of an atom, you can calculate the number of neutrons in the nucleus. The number of neutrons is equal to the mass number minus the atomic number. In fact, if you know two of the three numbers–mass number, atomic number, and number of neutrons–you can always calculate the third.

19	Explain how the isotopes of an element are alike and how they are different	textbook, figure 7	406, 407

Isotopes

Atoms of the same element can have different mass numbers. For example, some carbon atoms have a mass number of 12, while other carbon atoms have a mass number of 14. The number of protons for each element never changes. So, for an atom's mass number to differ, the number of neutrons must change. Atoms of the same element that have different numbers of neutrons are called **isotopes.**

Get It?
Identify What are isotopes?

To identify isotopes, scientists write the name of the element followed by the isotope's mass number. Carbon with a mass number of 12 is written as carbon-12. Carbon-12 has six protons and six neutrons. Carbon-14 has six protons and eight neutrons. Carbon-12 and carbon-14 are isotopes of the element carbon. Some properties of carbon-12 and carbon-14 are unique due to differences in the number of neutrons that each isotope contains. For example, carbon-14 is radioactive, but carbon-12 is not.

Get It?
Compare the following isotopes of chlorine in terms of mass number, number of protons, and number of neutrons: chlorine-35 and chlorine-37.

Suppose you have a sample of the element boron. Naturally occurring isotopes of boron have mass numbers of 10 or 11. How many neutrons does each isotope contain? Locate boron in **Table 4** on the previous page, and determine the number of protons in an atom of boron. You can then calculate that boron-10 has five neutrons and boron-11 has six neutrons.

APPLY SCIENCE

How can radioactive isotopes help tell time?

Some isotopes are radioactive, which means they decay over time. The time that it takes for half of a radioactive isotope to decay into another isotope is called its half-life. Scientists use the half-lives of radioactive isotopes to measure geologic time.

Identify the Problem

The table to the right shows the half-lives of some radioactive isotopes (parent isotopes) and the isotopes into which they decay (daughter isotopes). For example, it would take 5730 years for half of the carbon-14 atoms in a sample to change into atoms of nitrogen-14. After another 5730 years, half of the remaining carbon-14 atoms will change, and so on. Because the number of carbon-14 atoms changes, while the number of carbon-12 atoms does not, the ratio of the number of carbon-14 atoms to carbon-12 atoms can be used to determine the length of time that has passed.

Half-Lives of Radioactive Isotopes

Parent Isotope	Daughter Isotope	Half-Life
Uranium-238	Lead-206	4.47 billion years
Potassium-40	Argon-40, Calcium-40	1.26 billion years
Rubidium-87	Strontium-87	48.8 billion years
Carbon-14	Nitrogen-14	5730 years

Solve the Problem

1. How many years would it take for half of the rubidium-87 atoms in a piece of rock to change into strontium-87? How many years would it take for three-fourths of the atoms to change?
2. After a long period, only one-fourth of the parent uranium-238 atoms in a sample of rock remain. How many years old would you predict the rock to be?

Average atomic mass

How do scientists account for and represent the different atomic masses of isotopes? As an example, models of two naturally occurring isotopes of boron are shown in **Figure 7.** Because most elements, including boron, naturally occur as more than one isotope, each element can be described by an average atomic mass of the isotopes. The **average atomic mass** of an element is the weighted average mass of all naturally occurring isotopes of an element, measured in atomic mass units (amu), according to their natural abundances.

For example, 80 percent (four out of five) of boron atoms are boron-11, and 20 percent (one out of five) are boron-10. The following calculation gives the weighted average of these two masses.

$$\frac{4}{5}(11\text{ amu}) + \frac{1}{5}(10\text{ amu}) = 10.8\text{ amu}$$

The average atomic mass of the element boron is 10.8 amu. Note that the average atomic mass of boron is closer to the mass of its more abundant isotope, boron-11.

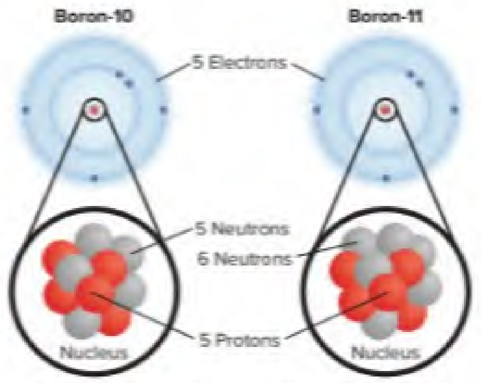

Figure 7 Boron-10 and boron-11 are two isotopes of boron. These two isotopes differ by one neutron. Most naturally occurring elements have more than one naturally occurring isotope.

Explain *why these atoms are isotopes.*

Get It?
Define average atomic mass, and explain how it is calculated.

Check Your Progress

Summary

- Protons and neutrons make up most of an atom's mass.
- Each element has a unique number of protons.
- Atoms of the same element with different numbers of neutrons are called isotopes.
- The average atomic mass of an element is the weighted average mass of all naturally occurring isotopes of that element.

Demonstrate Understanding

6. **Determine** the mass number and the atomic number of a chlorine atom that has 17 protons and 18 neutrons.
7. **Explain** how the isotopes of an element are alike and how they are different.
8. **Explain** why the atomic mass of an element is a weighted-average mass.
9. **Calculate** the number of neutrons in potassium-40.

Explain Your Thinking

10. **Explain** Chlorine has an average atomic mass of 35.45 amu. The two naturally occurring isotopes of chlorine are chlorine-35 and chlorine-37. Do most chlorine atoms contain 18 neutrons or 20 neutrons? Why?
11. **MATH Connection** Use the information in **Table 3** on page 404 to determine the mass in kilograms of each subatomic particle.

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20	Define row and group in periodic table of elements, explain common physical and chemical properties of elements within a group and/or a row, link the location of the element to the number of valency electrons and atomic number in order to explain why elements in the same group have similar properties.	textbook, fig. 11 & 13	412, 414

The Atom and the Periodic Table

The modern periodic table consists of boxes, each containing information such as element name, symbol, atomic number, and atomic mass. A typical box is shown in **Figure 10.** As you have learned, elements on the periodic table are organized based on similarities in their physical and chemical properties. The horizontal rows of elements in the periodic table are called **periods** and are numbered 1 through 7. The vertical columns in the periodic table are called **groups** (also called families), and they are numbered 1 through 18. Elements in each group share similar properties. For example, the elements in group 11—including copper, silver, and gold—are all similar. Each element is a shiny metal and a good conductor of heat and electricity. Why are these elements so similar?

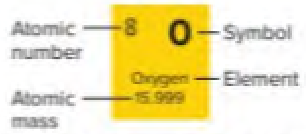


Figure 10 Each box on the periodic table contains the element's name, its atomic number, its chemical symbol, its atomic mass, and its state of matter.

Evaluate *What is the atomic mass of oxygen?*

Electron cloud structure

You have learned that each atom has a charged substructure consisting of a nucleus that is made of protons and neutrons. But where are the electrons? How many are there? Because an atom does not have an overall charge, the number of electrons is equal to the number of protons. Therefore, a carbon atom has six protons and six electrons. An oxygen atom has eight protons and eight electrons. Electrons surround the nucleus and are located in an area called the electron cloud.

Energy Levels Scientists have discovered that electrons within an electron cloud have different amounts of energy. Scientists model the energy differences between electrons by placing electrons in energy levels, as shown in **Figure 11.** Electrons located in energy levels close to the nucleus have less energy than electrons in energy levels farther away. Electrons occupy energy levels in a predictable pattern from the inner to the outer levels.

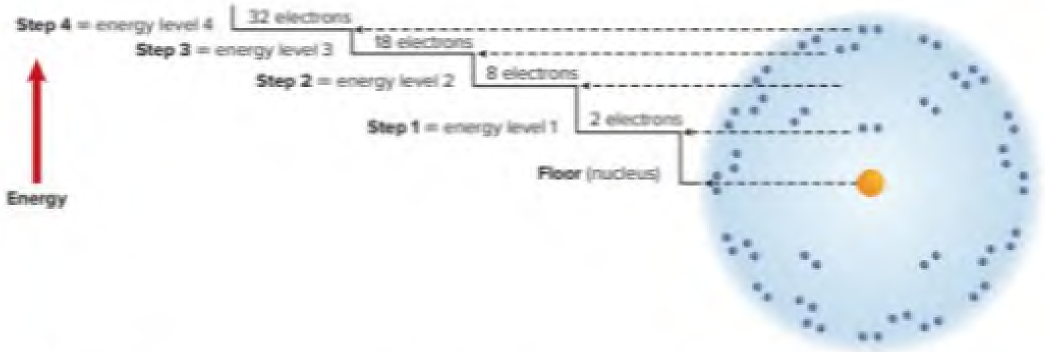


Figure 11 Energy levels in atoms can be represented by stairsteps. Each step away from the nucleus represents an increase in the amount of energy within the electrons. The higher energy levels can hold more electrons.

Filling higher rows The second row starts with lithium, which has three electrons—two in the first energy level and one in the second energy level. Lithium is followed by beryllium, with two outer electrons, boron, with three, and so on. Neon has a complete outermost energy level, with eight outer electrons. Electrons begin filling energy level 3 for elements in the third row. The row ends with argon, which has eight outer electrons.

Electron dot diagrams

Elements in the same group have the same number of electrons in their outermost energy levels. In fact, the repeating patterns in the table reflect these patterns of outer electron states. These electrons determine the chemical properties of an element. They are so significant that American chemist G. N. Lewis created a diagram to represent an element's outermost electrons. An **electron dot diagram** consists of the chemical symbol of an element surrounded by dots to represent the number of electrons in the outermost energy level. **Figure 13** shows the electron dot diagrams for the group 1 elements.

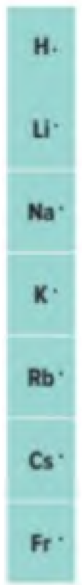


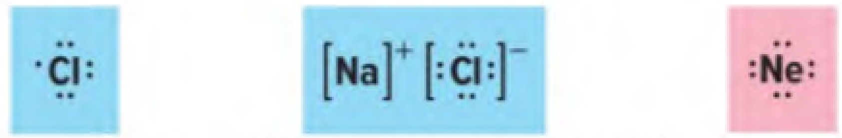
Figure 13 The elements in group 1 have one electron in their outermost energy levels.

Same group—similar properties

The electron dot diagrams for the elements in group 1 show that all members of a group have the same number of outermost electrons. Remember that the number of outermost electrons determines the chemical properties for each element.

A common chemical property of group 1 metals is the tendency to react with nonmetals in group 17. The nonmetals in group 17 have electron dot diagrams similar to chlorine, as shown in **Figure 14.** For example, the group 1 element sodium reacts easily with the group 17 element chlorine. The result is the formation of the compound sodium chloride (NaCl)—ordinary table salt.

Group 18 Not all elements will combine easily with other elements. The elements in group 18 have complete outermost energy levels, meaning that they cannot hold any more electrons. This special configuration makes many of the group 18 elements unreactive. **Figure 14** shows the electron dot diagram for neon, a member of group 18.



The electron dot diagram for group 17 consists of three sets of paired dots and one single dot.

Sodium combines with chlorine to give each element a complete outer energy level in the resulting compound.

Neon, a member of group 18, has a full outer energy level. Neon has eight electrons in its outer energy level, making it unreactive.

Figure 14 Electron dot diagrams show the electrons in an element's outermost energy level.

Relate *the properties of Na, Cl, and Ne atoms and their positions in the periodic table to the arrangement of their electrons.*

*	Questions might appear in a different order in the actual exam
*	قد تظهر الأسئلة بترتيب مختلف في الامتحان الفعلي
**	As it appears in the textbook (UAE Edition Grade 9 Inspire Student Edition) , LMS, and (Main_IP).
**	كما وردت في كتاب الطالب [كتاب الطالب الصف التاسع العام انسباير طبعة دولة الامارات العربية المتحدة] وLMS والخطة الفصلية .

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