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Scientific Explanations



TheBIG Idea

How can science provide answers to your questions about the world around you?



1.1 Understanding Science

- What is scientific inquiry?
- What are the results of scientific investigations?
- How can a scientist measure bias in a scientific investigation?



1.2 Measurement and Scientific Tools

- What is the difference between accuracy and precision?
- Why should you use significant digits?
- What are some tools used by life scientists?



1.3 Case Study

- How do independent and dependent variables affect?
- How is scientific inquiry used in a real-life scientific investigation?



Scientific Explanations

Answer these big questions to see how a scientist might be thinking about them. Which of the following do you think involves providing a scientific explanation?

Select the best response.

- A. hypothesis
- B. scientific theory
- C. scientific law
- D. hypothesis and scientific theory
- E. scientific theory and scientific law
- F. hypothesis, scientific theory, and scientific law
- G. None of the above. An explanation is something else.

Explain your thinking. Describe how explanations are used in science.

Chapter 1: Scientific Explanations 3

Scientific Explanations



TheBIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

- | | |
|--|--|
| <p>AL What are some things in nature or about technology that you wonder about?</p> | <p><i>Accept all reasonable responses. Guide students to brainstorm ideas and put them in question form. Some examples include: Why do dogs chase cats? Why are there so many of some species of birds? How does a switch turn on a light?</i></p> |
| <p>GL How could you find the answers to questions you have?</p> | <p><i>Students might propose that they read about it, look for answers on the Internet, experiment, or ask an expert.</i></p> |
| <p>SL How do you think scientists find answers to their questions?</p> | <p><i>Accept all reasonable responses.</i></p> |



Scientific Explanations

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

This Nature of Science chapter presents information about scientific inquiry, hypotheses, observation, measurement, and other scientific procedures. A case study, led by a team of Earth, life, and physical scientists, shows students how these same inquiry techniques are used in real-world science.

Throughout this book, students will apply nature of science and inquiry skills and processes while performing **Launch Labs**, **MiniLabs**, and **SkillPractice** activities, and chapters. As they read *Guides* titled **Science and Society**, **Careers in Science**, **How Things Work**, **How Nature Works**, **Women in Science**, analyze case studies, and apply scientific concepts to the world around them, they gain a better understanding of the importance of science. Completing online activities provides students with the opportunity to explore, research, and analyze the work of scientists who use these same skills and processes in their daily work.

Science Content Background

Lesson 1

Understanding Science

What is science? Science is the means by which we find out how nature works. It is a process of studying nature by collecting and analyzing the information resulting from that process.

Branches of Science There are three general fields of science: life science, Earth science, and physical science. Each branch of science includes many sub-branches.

Questions Scientists Ask Science has answered many questions about nature. In 2005, for its 125th anniversary, *Science* magazine listed 125 top questions that still await answers. They included: How does Earth's interior work? and What genetic changes make us uniquely human?

Scientific Inquiry answering questions about nature, scientists use skills called scientific methods. There is no single scientific method—rather, there is scientific inquiry. This process is shown in a graphic image for better understanding.

Research Free of Bias In conducting research, scientists must guard against being biased. To avoid bias, scientists use blind studies in which the identities of substances being tested are coded until results have been obtained. Researchers also repeat a test several times to be sure the outcome is always the same.

Scientific Theory and Scientific Law A theory in science is a detailed explanation of an event or phenomenon based on scientists' investigations. A law is a verbal or mathematical statement describing a pattern or event in nature that is always true. A theory might explain how and why an event occurs, but a law simply states that it will occur.

Results of Scientific Inquiry There are many possible outcomes to scientific inquiry, including new technology and new materials. Sometimes, however, it simply explains something that previously had not been understood, adding to the store of human knowledge.



Science Content Background

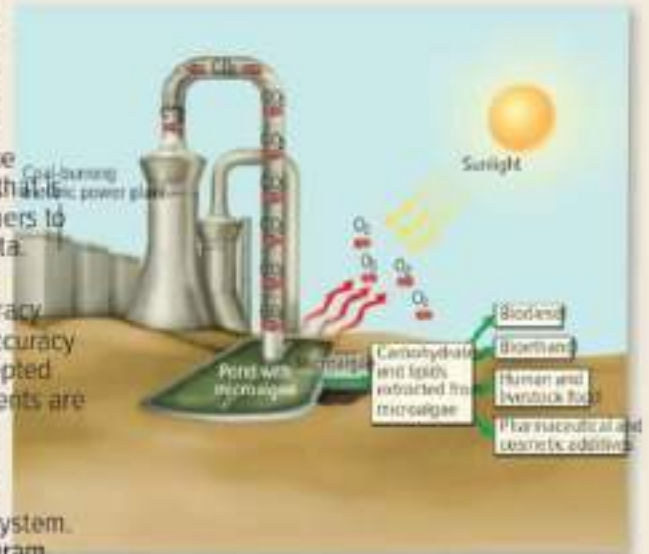
Lesson 2

Measurement and Scientific Tools

Description and Explanation In their investigations, scientists describe what they observe and then seek to explain it. The observation of nature requires a variety of tools. One tool that is used by scientists is the computer, which enables researchers to make models and record and analyze large amounts of data.

Accuracy and Precision Scientists seek to achieve both accuracy and precision in their observations and measurements. Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar measurements are to each other.

The International System of Units Scientists make their measurements with the International System Units, or SI system. All SI units are derived from seven base units: meter, kilogram, second, ampere, Kelvin, mole, and candela.



Lesson 3

Case Study: Biodiesel from Microalgae

The Biodiesel Revolution By-products of the combustion of fossil fuels contribute to air pollution and are a major cause of global warming. One solution could be biodiesel, diesel fuel made from plants. This would provide a limitless amount of fuel. Research seeks to obtain biodiesel from microalgae.

The Progress of Research In the 1970s, U.S. scientists experimented with species of microalgae that produce food and oils during photosynthesis. Researchers began growing microalgae in outdoor ponds and, later, in closed containers called bioreactors. They were looking to maximize the amount of light provided to the microalgae, to maximize its oil production.

Power Plant with Biodiesel Production Research on microalgae has led to the development of power plants connected to biodiesel production facilities. These power plants most often burn coal, a fossil fuel. Carbon dioxide emissions from the combustion of the fuel are piped to the biodiesel unit, where it is used by microalgae for photosynthesis. The microalgae produce biodiesel, which is harvested and used as fuel.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

* Interactions among the senses, nerves, and brain make possible the learning that enables human beings to predict, analyze, and respond to changes in their environment.

* Human beings use technology to match or exceed many of the abilities of other species.

* Written records and photographic and electronic devices enable human beings to share, compile, and use great amounts of information.

Lesson 1

Understanding Science



1 Scientific inquiry is a collection of skills that scientists use in different combinations to perform scientific investigations.

2 Scientific investigations often result in new technology, new materials, newly discovered objects or events, or answers to questions.

3 Scientists can help minimize bias in a scientific investigation by taking random samples, doing blind studies, repeating an experiment several times, and keeping accurate and honest records.



Lesson 2

Measurement and Scientific Tools



4 Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar or close measurements are to each other.

5 Significant digits communicate the precision of the tool used to make measurements.

6 Life scientists use many tools, such as science journals, microscopes, computers, magnifying lenses, slides, and dissecting tools.

Lesson 3

Case Study: Biodiesel from Microalgae



7 There are two main types of variables.

7a The independent variable is a factor in an experiment that is manipulated or changed by the investigator to observe how it affects a dependent variable.

7b The dependent variable is the factor measured or observed during an experiment.

8 Scientific inquiry is used to gain information and find solutions to real-life problems and questions.

Identifying Misconceptions

Scientific Inquiry

Find Out What Students Think

Students may think that...

... all experiments follow exactly the same method. Some students may not understand that a collection of skills is part of scientific inquiry, but that scientists may use different scientific methods or steps in their efforts to understand events or predict what might happen if certain conditions exist.

Discussion

Write the following sequence on the board or chart paper with arrows between each step: **Ask Questions** → **Hypothesize** → **Predict** → **Test Hypothesis** → **Analyze Results** → **Draw Conclusions** → **Communicate Results**. Write *scientific inquiry* over the sequence.

Ask Why is it important to first ask questions? **Asking what, when, where, who, why, and how helps the scientist focus on what he or she wants to know.** What is a hypothesis? **A possible explanation about an observation that can be tested by scientific investigation.**

Continue to help students understand the collection of skills in scientific inquiry. Switch two steps in the sequence. **Ask** Would it be possible to predict a result before I create a hypothesis? **It might be possible, but it also might be difficult because I would not know what I was trying to predict.** draw conclusions before I analyze results? **It's possible, but your conclusions could be faulty.** Explain that skills that are part of scientific inquiry involve different methods, and can change depending on the experiment, the methods, and/or sequence of steps. How a scientist decides to analyze results, for example, depends on the type of data obtained. **Ask** What are examples of how data can be analyzed? **Compare and contrast, observing patterns, determining relationships.** Emphasize that it is essential to understand the skills that are part of scientific inquiry.

Promote Understanding

Activity Prior to the activity, place pieces of paper with different topics written on them, such as *spiders*, *plants*, *ants*, *school lunch*, *favorite color*, and *time spent playing video games* in a container. Divide the class into five groups. Each group needs chart paper and markers.

1. Explain that each group will design an experiment using scientific inquiry.
2. Have each group choose a topic by selecting a piece of paper at random from the container.
3. Each group should write several questions about the topic and decide on one question to use for designing an experiment. Remind students that they will not be conducting the experiment, so they are not limited by time, materials, or equipment.
4. Have each group share its experiment and explain how scientific inquiry was used in the experiment's design.

Controlled Experiments

Find Out What Students Think

Students may think that...

... in a controlled experiment, the scientist controls the results. Students may not understand that in an experiment a scientist establishes constants and manipulates an independent variable to determine effects on the dependent variable.

Discussion

Define *independent* and *dependent* with the students. Provide examples of something dependent on an independent factor, such as getting to school on time. Have students suggest examples of *constants*, things that do not change in regard to getting to school on time. Draw the following graphic organizer on the board or chart paper.



Explain that in a controlled experiment, the scientist determines *constants*, or factors in the experiment that remain the same. The independent variable is changed by the scientist, who then measures and observes what happens to the dependent variable. **Ask** Explain why you want to determine if adding fertilizer to soil affects the growth of a bean plant. **What dependent variable will I measure?** **height of a bean plant** **What independent variable will I manipulate or change?** **added to the plants** **What constants should I establish?** **bean seeds, same soil, same growing conditions for both plants** **Which plant is the control?** **plant with no fertilizer added**

Promote Understanding

Activity Divide students into groups. Explain that students will design a controlled experiment to determine if offering free popcorn at football games increases attendance. Provide chart paper and markers for each group.

1. Have students in each group determine the independent variable, dependent variable, and constants. Students should create a chart noting the variables and constants.
2. Each group should brainstorm ways the experiment could be designed, discuss any difficulties with constants in the experiment, and other factors that might affect the outcome.
3. Have groups share their ideas and discuss why in experiments, many trials are needed to draw valid conclusions.

1.1 Understanding Science

Essential Questions

- What is scientific inquiry?
- What are the results of scientific investigations?
- How can a scientist minimize bias in a scientific investigation?

Vocabulary

science
observation
inference
hypothesis
prediction
technology
scientific theory
scientific law
critical thinking

What is science?

The last time that you watched squirrels play in a park or in your yard, did you realize that you were practicing science? Every time you observe the natural world, you are practicing science. **Science** is the investigation and explanation of nature's events and of the new information that results from these investigations.

When you observe the natural world, you might form questions about what you see. While you are exploring those questions, you probably use reasoning, creativity, and skepticism to help you find answers to your questions. People use these behaviors in their study to solve problems, such as how to keep a squirrel from eating bird seed in a **chiganaft**.

Similarly, scientists use these behaviors in their work. Scientists use a reliable set of skills and methods in different ways to find answers to questions. After reading this chapter, you will have a better understanding of how science works, the limitations of science, and scientific ways of thinking. In addition, you will recognize that when you practice science's abilities in the classroom, you use scientific methods to answer questions just as scientists do.



Figure 1.1.1 Scientists use reasoning and creativity to design experiments that address questions about the natural world. Some scientists use critical thinking to solve problems.

Branches of Science

No one person can study all the natural world. Therefore, people tend to focus their efforts on one of the three fields of science: life science, Earth science, or physical science, as described below. Then people or scientists can work answers to specific problems within one field of science.

Life Science

Biology, or life science, is the study of all living things. This aquatic ecologist, a life scientist, who studies interactions in aquatic ecosystems, is sampling invertebrates in the water.

- How do plants produce their own food?
- Why do some animals give birth to live young and others lay eggs?
- How are reptiles and birds related?

Earth Science

The study of Earth, including its landforms, rocks, soil, and forces that shape Earth's surface, is Earth science. These Earth scientists are collecting soil samples. Earth scientists ask questions such as:

- How do rocks form?
- What causes earthquakes?
- What substances are in soil?

Physical Science

The study of chemistry and physics is physical science. Physical scientists study the interactions of matter and energy. This chemist is preparing antibiotic solutions. Physical scientists ask questions such as:

- How do substances react and form new substances?
- How does a liquid change to a solid?
- How do forces and motion interact?

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Discussing a Common Misperception

- Write the terms *observation* and *hypothesis* on the board.
- Ask:** What do you think of when you hear the words *observation* and *hypothesis*? *Student responses will vary. Many students will connect these words to science. They may believe that making observations and hypotheses is something limited to scientists during experiments.*
- Tell students that, in reality, we all do and experience science every day. Discuss examples of everyday science, observations, and hypotheses, such as:
 - Cookies are burned.
 - Copper is tarnished.
 - Hail forms and falls down to Earth.
 - Ice is slippery.

- Have students build class definitions for *observation* and *hypothesis*. Students should record these definitions in their Science Journals.

Branches of Science

There are three main fields of science: life science, Earth science, and physical science.

Life Science

Life science is the study of all living things. Use the questions below to see what students already know about this field.

Guiding Questions

- EL** What is another name for life science? *It is also called biology.*
- OL** What kind of interactions might this aquatic ecologist be studying? *Students should conclude that the scientist is studying the interactions of the invertebrates with other aquatic organisms and the environment.*
- BL** What are examples of living things? *Students should understand that animals, plants, and microscopic organisms all are living things.*

Earth Science

Earth scientists study our planet's landforms, rocks, soils, and interior. Astronomy is also part of Earth science.

Guiding Questions

- OL** What natural Earth science topic might these scientists be studying? *They might be studying soil content.*
- BL** What other parts of Earth can you think of that would logically be part of Earth science? *The oceans and atmosphere are part of Earth, so they are also part of Earth science.*

Physical Science

The two main fields of physical science are physics and chemistry.

Guiding Questions

- OL** In general terms, what do physicists and chemists study? *They study the interactions of matter and energy.*
- BL** The chemist in the photo is preparing antibiotic solutions. How do chemistry and other sciences work together in the development of antibiotics? *Biology, the study of life, is key to understanding how antibiotics are processed by the body. Biochemists work with biology and chemistry.*

Word Origin

biology

Read aloud the derivation of the word biology and then ask the following question.

Ask: What are some other sciences with names that end in -ology?

Accept all reasonable responses. Answers may include: zoology, geology, anthropology, entomology, archaeology, meteorology, and psychology.

Teacher Notes



Scientific Inquiry

As scientists study the natural world, they often ask questions about what they observe. To find the answers to these questions, they usually use a process called **scientific inquiry**. The **Figure 2** shows that plants need plenty of water and have a source of the skills that a scientist might use in an investigation. However, it is important to know that, sometimes, not all observations are performed in an investigation. **Inference** is a logical conclusion drawn from an observation that is drawn from scientific inquiry—a process that uses a set of skills and tools to answer questions or to test ideas about the natural world.

Hypothesize

Ask Questions

Like a scientist, you use scientific inquiry to investigate why some vegetables are growing faster than others. A possible explanation about vegetable growth is that some plants are growing taller and faster because they are getting more water and sunlight. On your hypothesis, you predict that plants that get the fertilizer suggested by the scientist will grow more quickly. If your prediction is confirmed, it supports your hypothesis. If not, your hypothesis might need revision.

After making observations and inferences, you are ready to develop a hypothesis and test it. For example, you hypothesize that plants that get the fertilizer suggested by the scientist will grow more quickly. If your prediction is confirmed, it supports your hypothesis. If not, your hypothesis might need revision.

Predict

After you state a hypothesis, you might make a prediction to help you test your hypothesis. **Prediction** is a statement of what you expect to happen based on your hypothesis. For instance, based on your hypothesis, you might predict that if some plants receive more water, sunlight, or fertilizer, then they will grow taller and more quickly.

Test your Hypothesis

When you test a hypothesis, you often design an experiment to test your hypothesis. For example, you design an experiment to test your hypothesis about the fertilizer. You set up several groups of plants in which you plant seeds and water them in only one of them. You predict your hypothesis is that the plants that get the fertilizer suggested by the scientist will grow more quickly. If your prediction is confirmed, it supports your hypothesis. If not, your hypothesis might need revision.

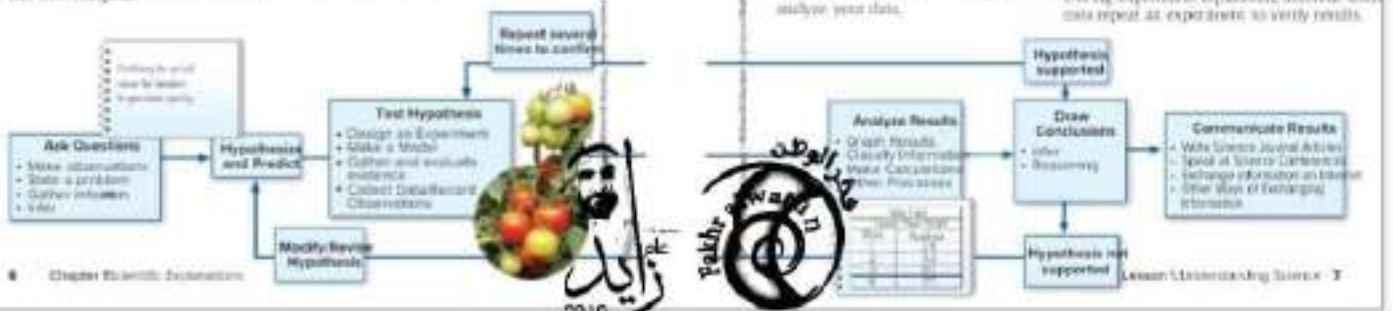
Analyze Results

As you are testing your hypothesis, you probably collecting data about the plants' rates of growth and how much fertilizer each plant receives. Usually, it might be difficult to measure patterns and relationships in data. Your next step might be to organize and analyze your data.

Communicate Results

Scientists communicate new information to others by writing a report, giving a presentation, or exchanging information. Other scientists can use this new information in their own work. This is also how other scientists learn about experiments that need to be repeated. During experiment replication, different scientists repeat an experiment to verify results.

Figure 2 The flow chart shows steps you can use during a scientific inquiry.



Scientific Inquiry

Point out to students that there is no single scientific method. Rather, there is scientific inquiry. Scientists ask questions about nature and decide on methods that will help them find answers to each one.

Ask Questions Hypothesize

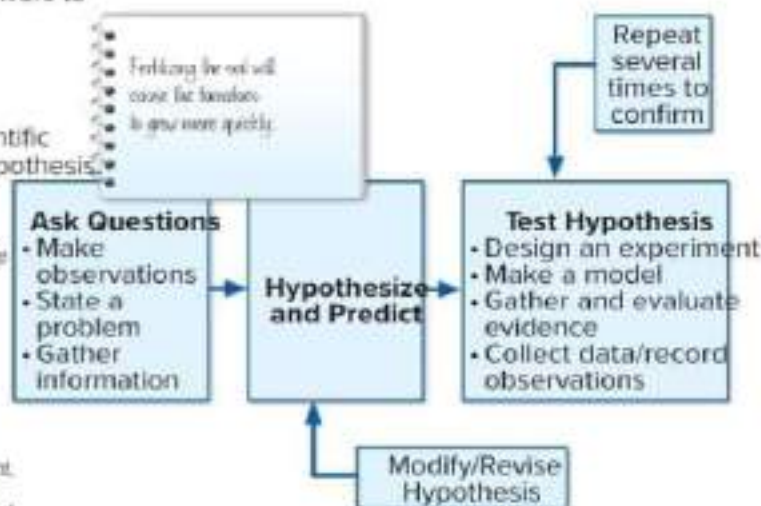
A properly framed question is one of the first steps in scientific inquiry. The next step in an inquiry is the formation of a hypothesis.

Guiding Questions

- OL** What is scientific inquiry? Scientific inquiry is a process that uses a set of skills and methods to answer questions or to test ideas about the natural world.
- OL** What is a hypothesis? It is a possible explanation about an observation that can be tested by scientific investigation.
- OL** How might a hypothesis be tested? Designing and completing an experiment, making a model, gathering and evaluating evidence, collecting data, and recording observations.

Visual Literacy: Figure 2

Have students study the flowchart in Figure 2. Figure 2 shows a possible sequence of steps involved in formulating and testing a hypothesis.



Ask: What happens if a hypothesis is not supported? modify your hypothesis and repeat the scientific inquiry process.

Design an Experiment and Make a Prediction Differentiated Instruction

Share with students that, after developing a hypothesis, they can design an experiment and make a prediction. The outcome of the experiment will either support the hypothesis or cast doubts on its validity.

Guiding Questions

- AL** How does a prediction differ from a hypothesis?
A hypothesis is a possible explanation about an observation that can be tested. Whereas, a prediction is a statement about what will happen next in a sequence of events.
- OL** How might the results of a scientific investigation be analyzed?
Results might be analyzed by graphing the results, classifying information, making calculations, and other processes.

The Research Hypothesis

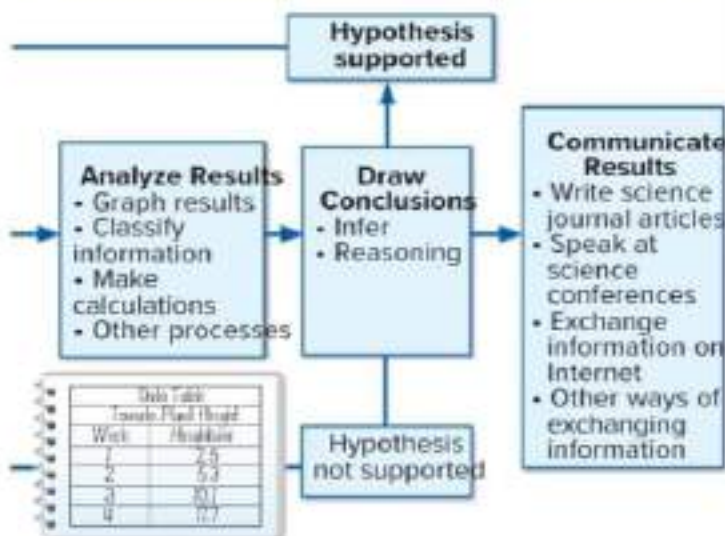
A research hypothesis can help students design an experiment and make a prediction. **Ask:** What should be included in a research hypothesis?
The original hypothesis, a method for testing it, and a prediction that supports the hypothesis.

Analyze Results / Draw Conclusions / Communicate Results

Discuss with students that, after testing the hypothesis, a scientist analyzes the data from the inquiries. From that analysis, a scientist draws conclusions about the validity of the original hypothesis. Scientists then communicate their results with others.

Guiding Questions

- OL** If a scientist's hypothesis predicts a certain outcome of a test and that outcome does not occur, what should the scientist do?
The scientist might revise the hypothesis, continue researching, or repeat the scientific inquiry process.
- OL** What is an inference?
An inference is a logical conclusion based on available information or evidence.
- BL** What are some examples of how a scientist can communicate results?
Science conferences, exchange information, confer with colleagues



OL On Level **AL** Approaching Level **BL** Beyond Level

Writing Hypotheses

Ask students to look for clues about what factors can affect plant growth. Have them write down all the possible factors: water, weeding, fertilizer. Then, write hypotheses by incorporating each factor into an *if-then* statement. For example, "If I give a plant more water, then it will grow taller."

The Flow of Scientific Inquiry

Have groups create illustrations of methods of scientific inquiry to include headings from the lesson. Then, give this scenario into a room and try to turn on the lights. They don't come on. Have students draw and label beneath each heading how they try to solve this problem.

Teacher Tools

Teacher Demo

Observation or Inference? Review with students the definition of observation as "the act of watching something and recording what occurs." Inference is defined as "a logical conclusion based on available information or evidence." Display a whole red apple to the class. Ask students to classify these statements as observations or inferences.

1. The apple's covering is red.

2. The apple is edible.

3. There are seeds inside the apple.

Statement 1 is an observation—it can be seen. Statements 2 and 3 are inferences made from prior knowledge of apples. Could statement 3 become an observation? Cut the apple open.

Reading Strategy

Scientific Inquiry In their Science Journals, ask students to write down a difficult problem that they have recently tried to solve in everyday life. Have students compare and contrast the process of a scientific investigation with the process they used to try to solve the problem. Students should ask themselves:

- Did I narrow down my problem to a question, making observations and gathering information? (Ask Questions)
- Did I think of a possible solution and predict an outcome? (Hypothesize and Predict)
- Did I try the solution? (Test Hypothesis)
- Did the solution work? (Analyze Results)
- Did I figure out why the solution worked or failed? (Draw Conclusions)
- Did I let others know that the problem was solved or not? (Communicate Results)

Scientific Theory and Scientific Laws

Scientific investigations can lead to the formulation of theories and laws. Use the questions below to help students contrast theories and laws.

Guiding Questions

- OL** What is a scientific theory? *It is an explanation of observations or events based on knowledge gained from many observations and investigations.*
- OL** What is one example of a scientific theory? *Accept all reasonable responses. The cell theory states that all living things are made of cells.*
- BL** Do you think it's possible to prove a scientific theory is true? *No, a scientific theory can't be proved beyond all doubt, but it can be disproved. However, if a tested theory adequately explains observations or events and is not disproved, it is accepted as correct.*
- OL** What does a scientific law do? *It describes a pattern or event in nature that is always true.*
- OL** What is one example of a scientific law? *Sample answers include: Law of conservation of mass or the commonly understood law that the Sun will rise again tomorrow.*
- OL** How do scientific theories and scientific laws compare? *A theory explains how and why a particular event occurs. A law simply says that it will occur.*

Visual Literacy: Comparing Scientific Theories and Scientific Law

Have students revisit **Table 1** then determine how well they have assimilated the information presented by discussing the following questions.

Table 1: Comparing Scientific Theory and Scientific Law

Scientific Theory	Scientific Law
A scientific theory is based on repeated observations and scientific investigations.	Scientific laws are observations of similar events that have been observed repeatedly.
If new information does not support a scientific theory, the theory will be modified or rejected.	If new observations do not follow the law, the law is rejected.
A scientific theory attempts to explain why something happens.	A scientific law states that something will happen.
A scientific theory usually is more complex than a scientific law and might contain many well-supported hypotheses.	A scientific law is based on one well-supported hypothesis that states that an event will occur.

Say: Compare and contrast how scientific theories and scientific laws are connected to observations. A scientific theory is based on observations. A scientific law is an observation.

Say: Compare and contrast how scientific theories and laws might be rejected. A scientific theory might be rejected if new information doesn't support it. A scientific law might be rejected if new information doesn't follow it.

Say: Compare and contrast the complexity of scientific theory to scientific law. A theory is usually more complex than a law. This is because most theories contain many hypotheses, while laws usually contain one hypothesis.

Differentiated Instruction

OL Retracing the Steps Have student partners write each step of the scientific inquiry process on a separate index card. Have them form a sequence using all of the cards. Next, have them form a new sequence using some or all of the cards. Ask students to describe each sequence in their own words.

BL Application of Scientific Inquiry Have student groups make poster reports on a technological advance or a new material that resulted from scientific inquiry. In their reports, students should identify the practical question researchers were trying to answer. They should include any relevant steps of scientific inquiry. Have them present their findings to the class.

Teacher Tools

Teacher Demo

Cell Theory Evidence Demonstrate how evidence can be gathered to prove the cell theory.

1. Scrape a toothpick against the inside of your cheek, then spread the material across a clean microscope slide.
 2. Add a drop of stain to the slide. Place a cover slip on top of the slide and put the slide on the microscope stage. Use the microscope to allow students to observe the cells. Project the image for the class.
- Explain that samples taken from every human would contain cells. This is the basis of the cell theory.

Real-World Science

Thinking Like a Scientist Encourage students to pose questions about the world they see—for example, "How do birds fly?" Student questions have probably already been answered. However, they will be thinking like scientists by asking questions. Have students brainstorm questions and design basic investigations to determine answers.

2. Show that a bounded sequence has a convergent subsequence.

1 Sampling

A method of data collection that involves studying small amounts of something in order to learn about the larger whole is sampling. A sample should be a random, representative part of the whole.

2. Bias. It is important to realize that during scientific investigations, bias is intentional or unintentional prejudice toward a specific outcome. Sources of bias in an investigation can include equipment choices, questionnaire limitations, and prior knowledge. Suppose you were a parent of a kindergarten kid. If you were a parent of a kindergartener, you might think that the child requires one teacher. The fact, this is a bias.

Critical thinking—improving what you already know with the information you are given in order to decide whether you agree with it. Identifying and minimizing bias also is important when conducting scientific inquiry. To minimize bias is an ongoing task; sampling, repetition, and blind studies can be helpful, as discussed below.

3. Eldest Study

4 Repetition
If you get different results when you repeat an investigation, then the original investigation probably was flawed. Repetition of experiments takes more time.



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Safety in Science

Scientists follow safety procedures when they conduct experiments. You must develop follow safety procedures when you are experimenting. You should wear appropriate safety measures and listen to your teacher's instructions. Also, you should be able to recognize personal hazard and to know the meaning of safety symbols. Read here about science laboratory safety in the Science Skill Handbook at the back of this book.

Ethics are especially important when using living things during investigations. Animals should be treated properly, and this also should tell research participants about the possible risks and benefits of the research. Anyone can refuse to participate in scientific research.

Major Milestones

Keywords: Treatment; Series; Experiment; Orders of conditions; Typical participants; Partials

10 Effective 8

Lesson 5, Understanding Science 89

Science cannot answer all questions. Safety in Science

Guiding Questions

It is comparing what you already know about something with new information and then deciding whether you agree with the new information.

A blind study will help to prevent bias. Factors that contribute to bias include: poor formation of hypothesis, lack of prior knowledge about the study, researcher expectations of conclusions and de-emphasis of results that do not support that conclusion.

Academic Vocabulary

Use caution when discussing ethical treatment of animals as students may feel strongly, giving rise to debate and possible hurt feelings.

Guiding Questions

Q When are ethical guidelines most often required?

They are most often required in research involving animals or human subjects.

BL Why are questions about personal opinions, values, beliefs, and feelings beyond science? *They are personal opinion. For instance, science cannot determine which color is prettier. Color preference is subjective.*

1.1 Review

Understanding Science

Visualize It!



A scientific theory is an explanation of observations or events based on knowledge gained from many observations and investigations.



Scientific inquiry sometimes leads to new materials.

Summarize It!

1. What is scientific inquiry?

2. What are the results of scientific investigations?

3. How can a scientific revolution result in a scientific investigation?

Use Vocabulary

1. Explain the relationship between observations and hypotheses.
2. Use the terms testing, scientific law, and scientific theory in complete sentences.
3. Contrast inference and prediction.
4. Compare and contrast critical thinking and inference.

Understand Key Concepts

5. Which should NOT be part of scientific inquiry?
A. bias C. hypothesis
B. analysis D. testing
6. Describe and list examples of the results of scientific investigations.
7. Explain how a scientist can notice a scientific investigation.

Interpret Graphics

8. Draw a graphic organizer like the one below. In each oval, list an example of how to test a hypothesis using scientific inquiry.



Critical Thinking

9. Suggest why do you think people believe some theories even if they are not supported by credible evidence?
10. Evaluate a magazine you read that has two scientific investigations attempted to answer the same question. However, the two teams of scientists came to opposite conclusions. How do you decide which investigation was valid?

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. To which key concept does each image relate?

Summarize It!

Answer may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Branches of Science
- Scientific Inquiry
- Results of Scientific Inquiry
- Scientific Theory and Scientific Laws

Use Vocabulary

1. An observation in nature often leads to a testable hypothesis that explains how or why the observation occurred.
2. Sample answer: The new video game has the latest, most amazing technology. The change of season is an example of scientific law in action. One basic scientific theory is that all living things are made up of cells.

3. An inference is a logical conclusion based on available information or evidence. A prediction is a statement of what will happen next in a sequence of events.

4. Both are decision-making skills. An inference is a logical conclusion based on available information or evidence. Critical thinking is comparing what you know to be true with new information and determining if the new information is true.

Understand Key Concepts

5. Sample answers: artificial limbs, vaccines, pharmaceutical drugs, airplanes, spacecraft, synthetic textiles, and the discovery of all the planets and their moons.
7. A scientist can use a blind study, sampling, and repetition and not allow prior knowledge to influence the interpretation of test results.

Interpret Graphics

8. design an experiment, make a model, gather and evaluate evidence, and collect data/ record observations

Critical Thinking

9. Sample answers might include: People might not understand the process of scientific inquiry; they might think a common theory is supported by valid evidence, even though in reality it is not. They also might believe common theories because, for personal reasons, they want to believe in what the theory is saying. **DOK 3**
10. Sample answers might include: ~~ide~~ **E**ide which investigation is valid, you use critical thinking skills to examine the information you are given. ~~ea~~ **S**hould be skeptical of investigations that show signs of ~~bias~~ **b**ias. ~~sh~~ **S**hould examine the investigations for correct use of the skills of scientific inquiry and laboratory procedure. **DOK 3**

Teacher Tools

Teacher Demo

Classroom Blind Study Conduct your own blind study. Use three varieties of a common item, such as pudding, popcorn, colored pencils, or tissues. Have students appropriately test the samples without knowing the name and price of each one. Then repeat the study with new samples whose identities are known to the students. Compare the outcome of the two tests. Did bias play a role in students' selections? Try repeating this test with a product with the brand names and prices switched around in the non-blind part of the test. Will students say they prefer one of the cheaper brands if they think it's actually the premium brand?

Reading Strategy

Learning Journals Have students use learning journals. Ask students to divide each page into three columns. In the left column, record headings from the text. In the middle column, include summary notes. In the right column, have them include page numbers of text and illustrations that helped them understand a concept. Continue the journal throughout the course.



1.2 Measurement and Scientific Tools

Essential Questions

- What is the difference between accuracy and precision?
- Why should you use significant digits?
- What are some tools used by the scientists?

Vocabulary

- description
- explanation
- International System of Units (SI)
- accuracy
- precision
- significant digits

Description and Explanation

How would you describe the squirrel's activity?

A **description** is a spoken or written summary of observations. Your description might include information such as the squirrel hopped five acorns near a large tree. A qualitative description tells your senses such as sight, sound, smell, touch, and taste to describe an observation. A **quantitative** description uses numbers to describe the observation. A **large tree** is a qualitative description. However, a quantitative description uses numbers to describe the observation. The **acorns** is a quantitative description. You can use measuring tools, such as a ruler, a balance, or a thermometer, to make quantitative descriptions.

How would you explain the squirrel's activity?

An **explanation** is an interpretation of observations. You might explain that the squirrel is storing acorns for food at a later time. When you describe something, you report what you observe. But when you explain something, you try to interpret your observations. This can lead to a hypothesis.



Figure 8: description and an explanation of a squirrel's activity contain different information.

The International System of Units

Suppose you observed a squirrel searching for food. You recorded that it traveled about 200 ft from its nest. Scientists who measure distances in meters might not understand you or the squirrel traveled. The scientific community solved this problem in 1960. It adopted an internationally accepted system of measurement called the **International System of Units (SI)**.

SI Base Units and Prefixes

Like sciences and many other around the world, you probably use the SI units in your classroom. All SI units are derived from seven base units, as in **Table 2**. For example, the base unit for length is the meter. However, you have probably made measurements in kilometers or millimeters before. Where do these units come from?

A prefix can be added to a base unit's name to indicate either a fraction or a multiple of that base unit. The prefixes are based on powers of ten, such as 100 and 1000, as in **Table 3**. For example, one centimeter (1 cm) is one one-hundredth of a meter and a kilometer (1 km) is 1000 meters.

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)
Substance amount	mole (mol)
Light intensity	candela (cd)

Table 3 Prefixes

Prefix	Meaning
Mega- (M)	1,000,000 (10 ⁶)
Kilo- (k)	1,000 (10 ³)
Hecto- (h)	100 (10 ²)
Deca- (da)	10 (10 ¹)
Deci- (d)	0.1 (10 ⁻¹)
Centi- (c)	0.01 (10 ⁻²)
Milli- (m)	0.001 (10 ⁻³)
Micro- (μ)	0.000 001 (10 ⁻⁶)

Conversion

It is easy to convert between SI units. You often multiply or divide by a power of ten. For this use, we provide a table to help you convert. For example, a biologist measures an Earthworm's mass in the field. The biologist knows that the worm has a mass of 2.5 g. The biologist wants to calculate how many kilograms the worm weighs.

$$\begin{aligned} & 2.5 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} \\ &= 2.5 \times 10^{-3} \text{ kg} \\ &= 0.0025 \text{ kg} \end{aligned}$$

Notice that the answer has the correct units.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Using Word Origins

- Write **accuracy** and **precision** on the board or chart paper. Toss a wad of paper at a wastebasket. Explain that if you hit the wastebasket, your toss will be accurate. Toss a second wad of paper at the wastebasket. Explain that if both papers fell next to each other on the floor the tosses would be precise, though not accurate, because the wads of paper are close to each other. If both fell in the wastebasket, the tosses would have both precision and accuracy.

- Ask:** Why are scientists concerned about accuracy? *need repeated results that are on target* How can the results of an experiment be precise but not accurate? *Results can be precise but not accurate when they are consistent, but not "on target."*

- In this chapter students will learn about methods and tools scientists use to measure accurately and precisely.

Description and Explanation

Present the vocabulary words **description** and **explanation**. Direct student attention to **Figure 8** and read the caption emphasizing the two vocabulary words. Have students read the two paragraphs.

The International System of Units

Explain the term **international**. Then have students read the paragraph. Guide their understanding by asking the following questions.

Guiding Questions

What is SI?

How does having an international system of units help scientists communicate worldwide?

an accepted international system for measurement

They all use the same type of measurement, which makes sharing scientific information easier.

SI Base Units and Prefixes

Discuss the value of having an international system of units.

Guiding Questions

- AL** What term is used to describe the scientific measurement of length? *meter*
- CL** What do the seven base units measure? *distance, time, and the physical properties of objects and substances*
- BL** How do prefixes change the value of a base unit? *they consistently show a multiple or a fraction of a base unit.*

Visual Literacy Tables 2 and 3

Have students read the first paragraph, then direct them to Table 2. Read through the list and comment on how each of these units is used by scientists internationally. Provide scientific tools used to measure each property—metric ruler, meterstick, triple-beam or electronic balance, stopwatch or clock with second hand, ammeter, thermometers, equation 6.02×10^{23} , light meter and standard candle.

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)
Substance amount	mole (mol)
Light intensity	candela (cd)



Some students may not have had experience with base units that have prefixes added to them. Write the following terms on the board: meter, kilometer, hectometer, millimeter, micrometer. Redirect students' attention to Table 3.

Table 3 Prefixes	
Prefix	Meaning
Mega- (M)	1,000,000
Kilo- (k)	1,000
Hecto- (h)	100
Deka- (da)	10
Base unit	1
Deci- (d)	0.1 (1/10)
Centi- (c)	0.01 (1/100)
Milli- (m)	0.001 (1/1,000)
Micro- (μ)	0.000,001 (1/1,000,000)

Ask: Suppose you are investigating how sunlight and heat affect photosynthesis in a plant. What SI base units might you use to measure this? *Kelvin and candela*

Ask: Suppose you are comparing elephants and hippos. What base units might you use to make measurements? *meters and kilograms*

Ask: Suppose you are observing the speed of a mouse moving across a table. What SI base unit might you use to measure this? *seconds*

Measurement and Uncertainty

Look at a clock and make a general statement about time, such as *the bell will ring soon*. Discuss when the bell will ring based on what you said. Discuss whether the time you mentioned, *soon*, can be measured. Have students provide suggestions for measuring time with more certainty.

Guiding Questions

- AL** Why is it important for your watch *too I can get to places on time* to have the accurate time?
- OL** Why is it important for a tool that measures to be calibrated to be precise and accurate? *so its measurement is precise and accurate*
- BL** How can a clock be precise, but not accurate? *clock that runs fast or slow gives consistently incorrect time, so is precise, but because the time is incorrect, it is not accurate.*

Science Use v. Common Use

Digital

Ask: Do you prefer to use a digital clock or an analog clock? *will vary.*

Ask: How many digits do you have on one foot or one hand? *digits on each*

Significant Digits

Remind students that the word *significant* means *important* or *essential*. Direct attention to **Figure 10** and read the caption. Have students estimate the distance from one wall to another in the room. Discuss the difference between an estimate and precision. Ask which would be best when ordering new carpet.

Direct attention to Table 5, read through the rules for determining significant digits, and discuss the questions.

Guiding Questions

- OL** Why should you use significant digits? *to communicate the precision of the tool used to make a measurement*
- OL** How many significant digits does the number 4.01 have? *all nonzero numbers are significant and zeros between nonzero digits are significant*
- BL** Why is it important to consider all four rules when determining significant digits? *to be as accurate as possible*

Math Skill

Significant Digits

Explain to students that they will be determining significant digits.

Practice

Ask students to complete the practice task. The answers are: 2.02—3 significant digits; 0.0057—2 significant digits; 1,500—2 significant digits; 0.500—3 significant digits

Differentiated Instruction

AL Precision and Accuracy Working in small groups, use tape to construct a target on the floor. Be creative. Have students toss 5 wads of paper onto the target from a distance away. Chart each student's precision, accuracy and both accuracy and precision.

BL Significant Digits Give students the following examples: a school with a student population of 1500; with a population of 150,000; a country with a population of 15,000,000. Ask them to determine the number of significant digits in each example and to state which rule they used to make their determinations. (two; rules 1 and 2) Ask them to explain how each of these numbers can have the same number of significant digits, yet represent very different quantities. (The numbers reflect the degree of precision with which you can measure each population. For example, the population of a city might be known to the nearest thousand, while the population of a country might be known only to the nearest million.)

Teacher Tools

Math Activity

Significant Digits Use the following activity to help students gain a better understanding of significant digits.

1. Prepare the following numerals on the board or chart paper: 4.05, 770.032, .0025. Discuss which numbers are significant.
2. Prepare a series of numerals written on chart paper.
3. Underline each number that is a significant digit.
4. Cover each numeral with a sticky note containing the same numeral without the underlines.
5. Ask students to read the digits and determine which numerals are significant. Remove note to check answers.
6. Ask students to write three numerals each containing a decimal point. Students should design an answer key to identify the significant digits for each numeral. Check understanding and correct application. Students might exchange numerals for added practice.

Scientific Tools

Scientific inquiry often requires the use of tools. Scientists, including life scientists, might use the tools listed on this page and the next page. You might use one or more of them during a scientific inquiry, too. For more information about the proper use of these tools, see the Science Skill Handbook at the back of this book.

Science Journal

In a science journal, you can record descriptions, explanations, plans, and steps used in a scientific inquiry. A science journal can be a spiral-bound notebook or a loose-leaf binder. It is important to keep your science journal organized so you can find information when you need it. Make sure you keep thorough and accurate records.



Balances

You can use a triple-beam balance or an electronic balance to measure mass. Mass usually is measured in kilograms (kg) or grams (g). When using a balance, do not let objects drop directly onto the balance. Gently remove an object after you record its mass.



Thermometer

A thermometer measures the temperature of substances. The Celsius (°C) is the SI unit for temperature in the science community; you measure temperature in degrees Celsius (°C). When you place a thermometer into a hot substance so that it does not burn yourself. Handle glass thermometers gently so they do not break. If a thermometer does break, tell your teacher immediately. Do not touch the broken glass or the thermometer's bulb. Never use a thermometer to stir anything.



Glassware

Laboratory glassware is used to hold, pour, heat, and measure liquids. Many labs have many types of glassware. For example, flasks, beakers, petri dishes, and test tubes. Specimen jars are used as containers. To measure volume of a liquid, you use a graduated cylinder. The unit of measure for liquid volume is the liter (L) or milliliter (mL).



Compound Microscope

Microscopes enable you to observe small objects that you cannot observe with your naked eyes. Usually, two types of microscopes are in science classrooms: dissecting microscopes and compound light microscopes, such as the one shown to the left. The scientist is looking into the eyepiece light microscope to observe a magnified image of a small object in question, placed on a microscopic slide. However, some microscopes have only one eyepiece. Microscopes can be damaged easily. It is important to follow your teacher's instructions when carrying and using a microscope.

Computers—Hardware and Software

Computers process information. In science, you can use computers to compile, retrieve, and analyze data reports. You also can use them to create reports and other documents and information to others, and to research information.

The physical components of computers, such as monitors and keyboards, are called hardware. The programs you run on computers are called software. These programs include word processing, spreadsheets, and presentation programs. When scientists use computers, they use word processing, spreadsheets, and presentation programs to create and analyze data. Presentation programs can be used to create information to others.



Scientific Tools

Science Journal/Balances

Have students read each paragraph. Use the following questions to help students understand the purpose and use of each tool.

Guiding Questions

- AL** What is the purpose of a science journal? *to record data, observations, and other important information*
- OL** Why is it important to keep a science journal? *to have a neat, organized, clearly written, accurate, and thorough record of your procedures, questions, and results*
- AL** What is the purpose of a balance? *to measure the mass of objects*
- OL** Why is it important to carefully place objects on a balance? *the object is not dropped onto the pan, possibly damaging the precision and accuracy of the balance*

Thermometer

After discussing the following questions, brainstorm with students to find situations when they might use thermometers.

Guiding Questions

- AL** What does a thermometer measure? *The temperature of substances.*
- OL** Why should a thermometer never be used as a stirring rod? *it might break. It might give an inaccurate reading.*
- OL** What safety precautions should you take when handling a glass thermometer? *handle it carefully and do not let it roll off the table; lower it into hot substances with care so you don't get burned; report to the teacher if the thermometer breaks*

Glassware

Show students examples of glassware, such as flasks, beakers, petri dishes, test tubes, and graduated cylinders. Discuss the following questions.

Guiding Questions

- AL** What are graduated cylinders used to measure?
the volume of liquids
- OL** What unit is used for measuring volume?
usually liters and milliliters
- OL** What is the purpose of laboratory glassware?
to hold, pour, heat, and measure liquids
- BL** Why is a beaker not considered an accurate tool of measurement?
Because of their wide base, measurements can not be as accurate as with a slender graduated cylinder.

Compound Microscope

Use the Science Handbook in the back of this book to identify the parts of a compound microscope and demonstrate how to use it.

Guiding Questions

- AL** Why is a microscope used?
to see small objects that cannot be seen with an unaided eye
- OL** What precautions should be followed when moving a microscope?
Carry it carefully by holding the arm of the microscope with one hand and supporting the base with the other hand.
- BL** What is something that could be viewed with a microscope?
Accept all reasonable responses. Encourage students to think of interesting things to view that cannot be seen by using a microscope. Possible answer: bacteria, cells, dust.

Computers—Hardware and Software

Many students are familiar with computers, but some students may not be aware of the vast and varied amount of data that computers can analyze. Have students read the two paragraphs. Discuss with them the guided questions. Have them suggest examples of how computers can help a scientist study an organism.

Guiding Questions

- AL** What is the difference between computer hardware and computer software?
hardware—the main components of the computer; software—the computer programs
- BL** How do computers help scientists interpret information and data?
Possible answer: Scientists can use computers to compare and analyze data, research information, and communicate with fellow scientists.

Differentiated Instruction

AL Safety First Divide the class into student pairs. Using paper and markers, have students determine one safety rule for one scientific tool. Students should use their rule to create a Safety First! cartoon. Display the cartoons around the room.

BL Scientific Tools Pair up students and have them write a game using index cards. Divide the class into small groups. Have each group design a card game, in which the name of the tool is written on one card, its purpose on a second card, and its unit on a third card. Have students shuffle the cards and deal cards to each player. The object would be to create matching sets. Students may ask an opponent if he or she has a particular card or may draw from the deck to look for matches. The winner could be the first student to make a set, or the student who makes the most sets.

Teacher Tools

Teacher Demo Scientific Tools

1. Gather the scientific tools described on the two pages.
2. Demonstrate proper use of each tool.
3. Discuss the safety measures needed for use with each tool.
4. Provide opportunities for student to use the scientific tools to familiarize themselves with them.

Reading Strategy

Taking Notes Write the name of one of the scientific tools on the board or chart paper. Redirect students to the paragraph explaining the scientific tool in the lesson. Have students reread the information about the scientific tool and identify the main points. Create a bulleted list under the name of the tool as students identify each main point. Have students practice this note taking technique using the paragraphs describing other scientific tools. If you want to divide the class into groups, have them complete this for an assigned tool, and then share their bulleted lists.

1.2 Review

Tools Used by Life Scientists

Magnifying Lens

A magnifying lens is a hand-held lens that magnifies, or enlarges, an image of an object. It is not as powerful as a microscope and is used when great magnification is not needed. Magnifying lenses are easily used outside the lab where microscopes might not be available.



Slide

To observe items using a compound light microscope, you must place them on a thin, rectangular piece of glass called a slide. You must handle slides gently to avoid breaking them.

Dissecting Tools

Scientists use dissecting tools, such as scalpels and scissors, to examine tissues, organs, or prepared organisms. Dissecting tools are sharp, so always use extreme caution when handling them.



Pipette

A pipette is similar to an eyedropper. It is a small glass or plastic tube used to draw up and transfer liquids.

Key Concept Check

1. What are some tools used by the scientists?

Visualize It!



How can scientific tools help with scientific inquiry?



An explanation is an interpretation of observations. Grouping observations may lead to a hypothesis.

Summarize It!

1. What is the difference between accuracy and precision?

2. Why should you use significant digits?

3. What are some tools used by the scientists?

Tools Used by Life Scientists

Magnifying Lens, Slide, Dissecting, Pipette

Discuss the information in each paragraph as each one is read. Direct students to the images of the different tools as you discuss the type of tools used by life scientists. If possible, show and demonstrate use of each tool.

Guiding Questions

- Q1** What is the purpose of a magnifying lens? *to enlarge the image of an object*
- Q2** Why must slides be carefully handled? *because they are made of glass, easily broken, and could cut you*

Key Concept Check What are some tools used by life scientists? *Accept all reasonable responses.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Which Key Concept does each image relate to?**

Summarize It!

Answer may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Description and Explanation
- The International System of Units
- Measurement and Uncertainty
- Significant Digits
- Scientific Tools

Measurement and Scientific Tools



My Notes

Use Vocabulary

1. Define **description** and **explanation** in your own words.

2. Use the **International System of Units (SI)** in a sentence.

Understand Key Concepts

3. Which tool would a scientist use to view a tiny organism?

A. compass C. test tube
B. compound light microscope D. triple beam balance

4. Describe the difference between accuracy and precision.

5. Explain why scientists use significant digits.

Interpret Graphics

6. Draw a graphic organizer like the one below. Write the name of an SI base unit in each circle. Add additional circles to the graphic organizer as needed.



Critical Thinking

7. Recommend ways that computers can assist life scientists in their work.

Math Skill

8. Suppose you measure the mass of a book and it is 420.10990 g. How many significant digits are in that measurement?



Use Vocabulary

1. Sample answer: A description is a summary of observations and an explanation is an interpretation of those observations **DOK 1**
2. Sample answer: The *International System of Units* is a system for measurement that is used and accepted by scientists worldwide **DOK 2**

Understand Key Concepts

3. B. compound microscope **DOK 1**
4. Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar or close measurements are to each other **DOK 1**
5. Scientists use significant digits to communicate the precision of their measurements to others **DOK 1**

Interpret Graphics

6. The graphic organizer should have seven circles around the center circle. The center circle should say, SI Base Units. The following terms should be in the individual circles, in any order, surrounding the center circle: length, mass, time, electric current, temperature, substance amount, light **DOK 2**

Critical Thinking

7. Answers should recommend ways in which computers can assist life scientists in their work. Sample answer: Life scientists use a computerized spreadsheet to keep track of their data, research information, graph data, and exchange ideas with scientific peers **DOK 3**

Math Skill

8. 7 significant digits **DOK 1**



LABManager

How can you build your own scientific instruments? Answers can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

1.3 Case Study

Essential Questions

- How do independent and dependent variables differ?
- How is scientific inquiry used in a real-life scientific investigation?

Vocabulary

- variable
- dependent variable
- independent variable
- constants

Biodiesel from Microalgae

For the last few centuries, fossil fuels have been the main source of energy for industry and transportation. But, scientists have shown that burning fossil fuels negatively affects the environment. Also, some people are concerned about eventually using up the world's reserves of fossil fuels.

During the past few decades, scientists have explored using proteins to produce biodiesel. Biodiesel is a fuel made primarily from living organisms. For this case study, the **Figure 5.1** is a group of microscopic organisms that usually live in water or moist soil environments. Some of these proteins are plastic-like because they make their own food using a process called photosynthesis. Microalgae are plastic-like proteins.

Designing a Controlled Experiment

The scientists in this case study used scientific inquiry to investigate the use of proteins to make biodiesel. They designed controlled experiments to test their hypotheses. In the margins, this lesson are examples of how scientists in the study designed inquiry and the skills you read about in Lesson 1. The notebook pages contain information that a scientist might have written in a science journal.

A controlled experiment is a scientific investigation that tests one variable affects another. **variable** and factor is an experiment that can have more than one value. In controlled experiments, there are two types of variables: **dependent variable**—factor measured or observed during an experiment; **independent variable**—the factor that you want to test. It is changed by the investigator to observe how it affects a dependent variable. **Constants** are the factors in an experiment that remain the same.

A controlled experiment has two groups: an experimental group and a control group. The experimental group is the study have a change in the independent variable; the control group is the dependent variable. The control group remains the same as the experimental group, but the independent variable is not changed. Without a control, it is difficult to know which experimental observations result from the variable you are testing, and which result from other factors.

Biodiesel

The idea of engines running on fuel made from plants or plastic-like sources is not strictly new. Rudolph Diesel, shown in **Figure 5.1**, designed the diesel engine. He used petroleum to demonstrate how his engine worked. However, when petroleum was burned as a diesel fuel source, it was polluted over ground oil because it was cheap.

Oil-rich food crops, such as soybeans, can be used as a source of biodiesel. However, some people are concerned that crops grown for fuel sources will replace crops grown for food. If farmers grow crops for fuel, then the amount of food available worldwide will be reduced. Because of food shortages in many parts of the world, replacing food crops with fuel crops is not a good solution.



Figure 5.1 Diesel designed the first diesel engine in the early 1900s.

Aquatic Species Program

In the late 1970s, the U.S. Department of Energy began funding its Aquatic Species Program (ASP) to investigate ways to reduce pollution. Coal-fueled power plants produce carbon dioxide (CO_2) pollution, as a by-product. In the beginning, the study examined all aquatic organisms that grow during photosynthesis, their food-making process. These included large plants, corn, mostly known as seaweeds, plants that grow partially underwater, and microalgae. It was hoped these organisms might remove CO_2 from the atmosphere. During the study, however, the project leaders noticed that microalgae produced large amounts of oxygen. The project leaders began to use microalgae to produce oils that could be used to make biodiesel.

Scientific investigations often begin when someone observes an event in nature and wonders why or how it occurs.

A hypothesis is a tentative explanation that can be tested by scientific investigations. A prediction is a statement of what someone expects to happen next in a sequence of events.

Question 1

What factors would you consider if they would affect the growth of microalgae?

Hypothesis

Some microalgae species can be used as a source of biodiesel fuel because the microalgae produce a large amount of oil.

Prediction

If the correct species is found and the growing conditions are optimal, then large amounts of oil will be collected.

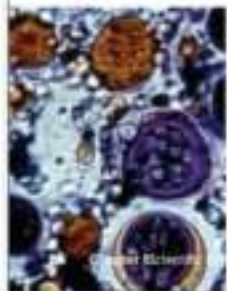


Figure 5.1 Microalgae are microscopic organisms that usually live in water or moist soil environments.

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Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Connect to Prior Knowledge

Have students use their prior knowledge to understand the words **variable**, **dependent variable**, **independent variable**, and **constants**.

- Ask:** What is the definition of **variable**? **variables** vary a noun (a thing) or a verb (an action)? **a verb**
- Ask:** What is the noun version of vary? variable; something that can be changed in an experiment
- Have students contrast the words **dependent** and **independent**. A dependent variable is the factor measured or observed during an experiment. The independent variable is a factor that is changed to observe how it affects the dependent variable.
- Ask:** What is the definition of the adjective **constant**? means "always the same, not changing." The noun version means "a thing that is always the same."

Biodiesel from Microalgae

To prepare students to recognize the value of creating biodiesel from algae, use the scaffolded questions below.

Guiding Questions

- AL** What have people used for several centuries as the main source of energy for industry and transportation? **They will be depleted and will no longer exist.**
- CL** What will likely happen to fossil fuels if they continue to be used at a great rate? **They will be depleted and will no longer exist.**
- SL** What are some negative effects of the use of fossil fuels? **Students should be aware of effects such as global warming, pollution, cost, or safety.**

Designing a Controlled Experiment

Use the scaffolded questions below to guide students in recognizing components of a controlled experiment.

Guiding Questions

- BL** What are constants? *Constants are the factors in an experiment that remain the same.*
- OL** How do dependent and independent variables differ? *A dependent variable is a factor measured or observed during an experiment. An independent variable is changed by the investigator, and the dependent variable responds to the change in the independent variable.*

Biodiesel

The scaffolded questions below will guide students in recognizing the beginnings of biodiesel, as well as concerns relevant to utilizing crops grown for fuel.

Guiding Questions

- AL** Name an oil-rich crop. *soybeans*
- BL** What did Rudolph Diesel use as fuel? *peanut oil*
- OL** Some people are concerned that crops grown for fuel will replace crops grown for food. Do you think their concerns are valid? Explain. *Have certain students support their opinions with evidence from the text and their own background knowledge.*

Aquatic Species Program

Students have discussed biodiesel as an energy source. Use the scaffolded questions below as you continue to deepen their knowledge of sources in nature that have been examined as positive contributors to energy resources.

Guiding Questions

- OL** What was the purpose of the ASP? *to investigate ways to remove air pollutants naturally using aquatic organisms*
- OL** What significant observations were made about microalgae during the original ASP project? *Some of the microalgae produced large amounts of oil.*
- BL** How has the purpose of the ASP program changed? *The focus of the project shifted to microalgae producing oils for biodiesel.*
- BL** How are biodiesel and the ASP related? *They are both ways to utilize items grown naturally—to aid in the energy crisis.*

Teacher Notes



One way to test a hypothesis is to design an experiment, collect data, and test predictions.

Design an Experiment and Collect Data
The ASP scientists designed a rapid-screening test to identify which microalgae species produced the most oil.
Independent Variable
Amount of nitrogen available
Dependent Variable
Amount of oil produced
Controls
The growing conditions of each bioreactor were exactly the same as the others, except for the amount of nitrogen.

During an investigation, observations, hypotheses, and predictions are often revised when new information is discovered.

Hypothesis 1
Based on previous research, shallow ponds containing algae would produce a large amount of oil.

Hypothesis 2
Microalgae grown with abundant amounts of nitrogen will have greater biomass and produce more oil.

Prediction 1
If microalgae grown with abundant amounts of nitrogen have the oil production goal of 100%.

Figure 10: Green microalgae and diatoms showed the most promise during testing for biofuel production.



Which Microalgae?

Microalgae are microscopic organisms that live in marine (salty) or freshwater environments. Like many plants and other plantlike organisms, they use photosynthesis and make sugar. The process requires light energy. Microalgae make more sugar than they can use as food. They convert excess sugar to oil. Scientists focused on these microalgae because even if they could be processed into biofuel.

The scientists began their research by collecting and identifying promising microalgae species. The search focused on green algae in shallow, inland, saltwater ponds. Scientists predicted that these microalgae were more resistant to changes in temperature and salt content in the water.

By 1980, a law was in place for identifying microalgae with high oil content. Two years later, 1,000 microalgae species had been collected. Scientists checked these samples for tolerance to salinity, salt levels, and temperature and selected 500 species. Of these 500 species, green microalgae and diatoms, as shown in Figure 10, showed the most promise. However, it was obvious that neither species was going to be perfect for all climates and water types.

Oil Production in Microalgae

Scientists also began researching how microalgae produce oil. Some studies suggested that starving microalgae of nutrients such as nitrogen could increase the amount of oil they produced. However, starving microalgae also caused them to be smaller, resulting in no overall increase in oil production.

Outdoor Testing v. Bioreactors

By the 1970s, the ASP scientists were growing microalgae in outdoor ponds in New Mexico. However, outdoor conditions were very different from those in the laboratory. Cooler temperatures in the outdoor ponds resulted in smaller microalgae. Native algae species also invaded the ponds, limiting use of the high oil-producing laboratory microalgae species.

The scientists continued to focus on growing microalgae in open ponds, such as the one in Figure 15. They scientists still believe that these open ponds are better for producing large quantities of biofuel from microalgae. But, some researchers are now growing microalgae in closed glass containers called bioreactors, also shown in Figure 15. Inside these bioreactors, organisms live and grow under controlled conditions. This method avoids many of the problems associated with open ponds. However, bioreactors are more expensive than open ponds.

A biotech company in the western United States has been experimenting with a low-cost bioreactor. A scientist at the company explained that they examined the ASP program and hypothesized that they could use long plastic bags as closed glass containers. However, microalgae grown in plastic bags are very expensive to harvest.

Figure 15: Three methods of growing microalgae are shown: open ponds, bioreactors, and plastic bags. Each method has its own advantages and disadvantages.



Which Microalgae?

Use the scaffolded questions below, focusing on algae, as you read. Students have studied the value of algae in oil production. Use the scaffolded questions below to guide them in recognizing some of the problems scientists have encountered as they have worked to increase algae oil production.

Guiding Questions

- OL** What is photosynthesis? *Photosynthesis is the process used by many plants and plantlike organisms to make food, such as sugars and oils.*
- OL** Why have scientists focused on microalgae in their biodiesel research? *Microalgae produce oils during photosynthesis—oils that easily can be converted into biodiesel.*
- SL** Why do you think scientists predicted that algae from shallow ponds were more resistant to changes in temperature and salt content in the water? *Students will likely recognize that algae in shallow ponds are exposed to more changes in temperature and salt content than their deep-water counterparts—so they are better acclimated to these conditions.*

Oil Production in Algae

Students have studied the value of algae in oil production. Use the scaffolded questions below to guide them in recognizing some of the problems scientists have encountered as they have worked to increase algae oil production.

Guiding Questions

- OL** Why did scientists propose to starve the microalgae? *They hoped the algae would produce more oil.*
- OL** What was the negative result of nitrogen starvation? *The negative result was a decrease in size.*
- SL** What do you think scientists should have tried when they discovered that the same deprivation leading to the increase in oil production led to decrease in size? *Use this question to launch a discussion about variables, such as deprivation of a different nutrient that scientists might have tried.*

Outdoor Ponds v. Bioreactors

Use the scaffolded questions below to guide students in understanding, comparing and contrasting three methods of growing algae. Encourage students to discuss the value of the hypotheses and controlled experiments in finding a profitable, feasible method.

Guiding Questions

- OL** What are bioreactors? *closed containers used for growing algae*
- OL** As ASP scientists grew algae in outdoor ponds in New Mexico in the 1980s, what was the result of the experiment? *smaller plants and invasion of native algae forcing out high-oil-producing microalgae species*

Visual Literacy: Figure 11

Ask students to study the photographs and caption. **Figure 11** you draw the diagram below on the board. Encourage students to provide additional information from the main text.

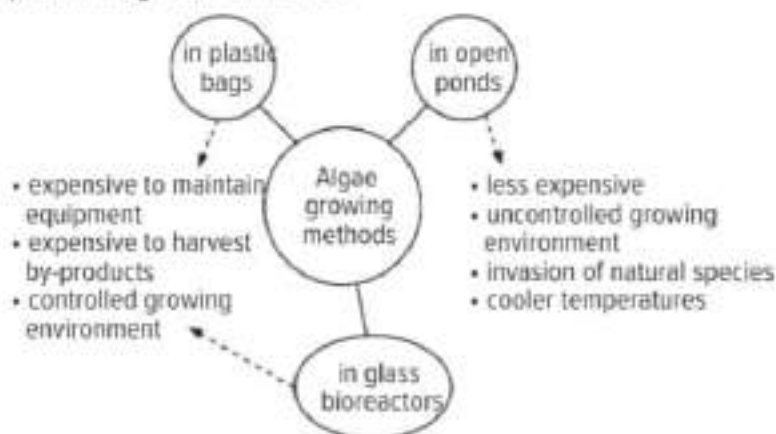
Ask: Why are open ponds used to grow algae? *They are less expensive than bioreactors. What is a problem with this method? Uncontrolled outdoor temperatures result in small microalgae. Also, native outdoor algae species can invade the ponds.*

Ask: What is the main problem with using bioreactors when growing algae? *It is expensive.*

Ask: What is a problem with using plastic bags to grow algae? *very expensive to collect the by-products.*

Ask: How are open ponds, plastic bags, and glass bioreactors alike? *They are examples of different hypotheses that scientists test for growing high-oil-producing microalgae in controlled experiments.*

Ask: What are some possible hypotheses that scientists might test using these three environments for growing the algae? *reasonable responses. Hypotheses might include: If we grow the algae in open ponds in a natural setting, then the algae will produce larger amounts of oil. If we grow the algae in plastic bags in a controlled setting, then the algae will produce larger amounts of oil. If we grow the algae in glass bioreactors in a controlled setting, then the algae will produce larger amounts of oil.*



Differentiated Instruction

OL Growth Methods Have pairs divide a large paper into three columns and label the top of the columns: *Open Ponds, Plastic Bags, Glass Bioreactors*. Have students draw an illustration, write a caption, and list advantages and disadvantages for each method.

BL Growth Plan Ask students to think of another method that might work for growing algae. Have them create a diagram with captions and callouts to explain why the method might work.

Teacher Tools

Teacher Demo

Method Video Obtain videos depicting some or all of the methods: open ponds, plastic bags, glass bioreactors. After viewing the videos, discuss how bioreactors could provide enough essential fuel to fill human needs.

Real-World Science

Growing Algae in Mines In November of 2009, scientists at the Missouri University of Science and Technology made plans to grow algae in abandoned mines. Their plans included use of LEDs, light-emitting diodes. The LEDs emit the red and blue parts of the light spectrum needed by algae to produce oils and oxygen. Discuss with students why scientists would possibly be interested in growing algae in mines.

Reading Strategy

Clarifying Questions Have students write five questions they would ask the scientists doing research at the facility shown in Figure 11.

Why So Many Hypotheses?

According to Dr. Richard Sayre, a Nobel laureate, all the ASP research was based on forming hypotheses. Dr. Sayre says, "It was hypothesis-driven. You just don't go in and say 'Well, I have a feeling this is the right way to do it.' You propose a hypothesis. Then you test it."

Dr. Sayre added, "Biologists have been trained over and over again to develop research strategies based on hypothesis. It's sort of ingrained into our culture. You don't get research support by saying, 'You going to put together a system, and it's going to be wonderful.' You have to come up with a question. You propose some strategies for answering the question. What are your objectives? What outcomes do you expect for each objective?"

Increasing Oil Yield

Scientists from a biotech company in Washington State thought of another way to increase oil production. Researchers knew microalgae use light energy, water, and carbon dioxide and make sugar. The microalgae eventually convert sugar into oil. The scientists wondered if they could increase microalgae oil production by distributing light to all microalgae. The experiment was set up to test this idea.



Figure 12 Acrylic rods distribute light to microalgae below the water's surface. If microalgae receive light, they can photosynthesize and eventually produce oils. Without light, microalgae are not productive.

Bringing Light to Microalgae

Normally microalgae grow near the surface of a pond. Any microalgae about 1 cm below the pond's surface will grow less. Why is this? First, water blocks light from reaching deeper into a pond. Second, microalgae at the top of a pond block light from reaching microalgae below them. Only the top part of a pond is productive.

Experimental Group

Researchers decided to simulate a natural experiment to design a light distribution system. Light rods distribute artificial light to microalgae in a biosensor. The biosensor simulates the environmental conditions that affect how the microalgae grow. These conditions include temperature, nutrient levels, carbon dioxide level, airflow, and light.

Data from their experiments showed that this new microalgae growth environment grew comparable to how microalgae grow in natural environments. Using solar data from various parts of the country, the scientists concluded that the light rods would significantly increase microalgae growth and oil production in outdoor ponds. These scientists plan to use the light-rod growing method in outdoor ponds.

Field Testing

Scientists plan to take light to microalgae instead of moving microalgae to light. Dr. Leanne is chief microalgae scientist at a biotech company, he said, "What we are proposing to do is to take the light from the surface of a pond and distribute it throughout the depth of the pond instead of only the top 5 cm. The whole pond becomes productive."

Scientists tested their hypothesis, collected data, analyzed the data, and drew conclusions.

Ask: Read:
The experiment results showed that microalgae could produce more oil using a light rod system than by using just sunlight.
Ask: Conclude:
The researchers are excited that the light rod system greatly increased microalgae oil production.

Researchers study and simulate in the field only on variables the methods and scientific inquiry to make affect the problem. When a scientific investigation is conducted, many hypotheses are tested. Some hypotheses are supported, and other hypotheses are not. However, information is gathered and lessons are learned. Hypotheses are tested and tested many times. This process of scientific inquiry results in a better understanding of the problem and possible solutions.

Ask: Read:
Is the experimental group, which variables are controlled in the biosensor?

Ask: Read:
What is the benefit of the light distribution system?

Why so many hypotheses?

As students study science and scientific principles, they often form hypotheses. Use the Guiding Questions below to help them recognize they are utilizing the same types of skills utilized by seasoned scientists. Guide students in recognizing that their skills with forming hypotheses should improve as they practice.

Guiding Questions

- AL** What does a scientist do after proposing a hypothesis? After proposing a hypothesis, the scientist tests it.
- Reading Check** Why is it important for a scientific researcher to develop a precise hypothesis that is testable by fellow scientists? Scientific research is funded by organizations that need understandable and practical information, hypotheses, and examples.
- EL** Do you think scientists grow more skilled at proposing a new hypothesis after testing many hypotheses? Explain. Use this question to launch a class discussion that illustrates recognition of improving skills through repeatedly using them.

Increasing Oil Yield

Visual Literacy: Figure 12

Have students read the caption and study the photograph in Figure 12. Discuss the photo using the following questions.

- Ask:** What kind of energy do algae use to convert water and carbon dioxide into food? Light energy.
- Ask:** What was the purpose of the acrylic rods shown in Figure 12? What was the purpose of the experiment? The purpose of the rods was to distribute more light below the water's surface. Scientists thought they might be able to increase algae yields by distributing the light deeper into the water to reach more algae.
- Ask:** Suppose there was a malfunction in the rods shown in Figure 12 resulting in the lights going out. What would be the impact? Explain. Without light, algae are not productive, so the algae would not be able to photosynthesize and produce oil.

Bringing Light to Microalgae Experimental Group

Students are continuing to learn about scientific hypotheses and the tests of these hypotheses. Use the scaffolded questions below to establish continuity from the earlier lesson content and emphasize the importance of scientific methods and scientific inquiry to solve real-life problems.

Guiding Questions

- AL** Where do scientists plan to use the outdoor ponds light-rod growing method?

Reading Check the experimental group, what variables are controlled in the bioreactor? *temperature, nutrient levels, carbon dioxide level, and airflow. The variables are controlled to help insure the only factor that changes is the independent variable which causes the effects on the dependent variable—oil production.*

- BL** Do you think it is a good idea for scientists to combine methods they have been working with? Support your reasoning.

Students should support their comments with evidence from the text and their own background. They should recognize that scientists have hypothesized, tested their hypotheses, collected data, analyzed the data, and drawn conclusions—and then used these conclusions to create new hypotheses. Students should be aware that this is an integral part of scientific research.

Field Testing

Use the Guiding Questions below to deepen students' knowledge of scientists' work with algae.

Guiding Questions

- AL** Why do the scientists plan to change the level of light during field testing?

Because the light is only able to penetrate a few centimeters into the pond, the algae that is below the surface cannot receive the light to make food and oils. Scientists are working to take more light down to the algae in the hopes of producing more oil.

Reading Check What is the benefit of the light-distribution system? *Light is distributed throughout the depth of the pond so the whole pond—not just the top 5 cm—will be more productive.*

- BL** What is the advantage of many scientists spending time on real-life scientific inquiry?

It allows for many hypotheses to be tested. Much information is gathered and allows for a thorough understanding of the problem studied and its possible solutions.

Differentiated Instruction

AL Illustrating Acrylic Rods Have students create an informative illustration that shows how acrylic rods distribute light below the surface of the water. Call outs should include: sunlight, pond surface microalgae populations, deep-water algae, light rods, and oil production.

BL Field Testing Have students create graphic stories with at least six frames to illustrate different hypotheses for testing light rods in algae ponds. In each frame, have students diagram a pond cross section. In frame one, students could show the light system at 5 cm. Successive frames could show the light system placed at different depths. Students may list controlled variables, including temperature, nutrients, carbon dioxide, and airflow.

Teacher Tools

Teacher Demo

Grow Algae Demonstrate the effect light energy has on microalgae by modeling it. Obtain algae from a science supply company. Divide the algae into two samples. Place one of the samples under a plant light that is constantly on. Place the other sample in a closet. Have the class compare the results in a week.

Real-World Science

Vehicles Powered by Algae Biodiesel A documentary film about biodiesel fuels was featured at the Sundance Film Festival. Cars powered by algae biodiesel were also available for public viewing.

Reading Strategy

Flowchart Have student pairs create flowcharts showing the steps researchers used to develop a "biodiesel from microalgae" process. Have students start with the Aquatic Species Program. The flowcharts can be continued and completed as students work through **Lesson 3**.



Key Concept Task

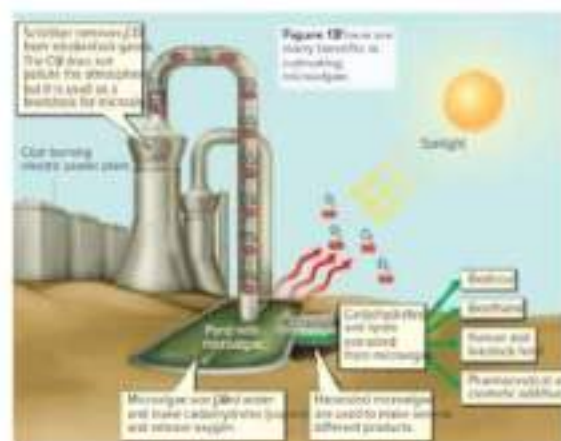
1. Describe three ways in which scientists regularly use models in this case study.

Another Way to Bring Light to Microalgae

Light rods are not the only way to bring light to microalgae. Paddlewheels can be used to keep the microalgae's location changing. Paddlewheels continuously move microalgae to the surface. This exposes the organisms to more light.

Why Grow Microalgae?

While the focus of this case study is microalgae growth for biofuel production, there are other benefits of growing microalgae, as shown in Figure 13. Lower plants that have small roots release carbon dioxide into the atmosphere. Evidence indicates that this contributes to global warming. During photosynthesis, microalgae use carbon dioxide and water, release oxygen, and produce sugar, which they convert to oil. Not only do microalgae produce a valuable fuel, they also remove pollutants from and add oxygen to the atmosphere.



30 Chapter 10: Scientific Endeavors

Are microalgae the future?

The United Arab Emirates (UAE) coast is home to a unique species of Marine algae known as *Nannochloris*. It is considered an extremely rare species. The UAE government is trying to genetically produce clean energy and biofuel from this unique resource by the year 2021. Scientists from the Abu Dhabi 'Masdar City' have been working consistently for five years until this moment in time to test and develop the technology that could be created from the algae through *Nannochloris* growth and reproduction.

The United Arab Emirates is planning to be a pioneer in this field. The production of energy from seaweed does not have any environmental disadvantages. It is a clean energy produced from low cost materials and resources. The algae industry does not need to be cultivated in water. It can be grown in non-habitable land. The United Arab Emirates where they can grow easily. Furthermore, a seaweed culture facility, that is well constructed, have no impact on the marine ecosystem of the Arabian Gulf.

The algae on the UAE coast are considered one of the highest quality. They can withstand wide thermal and humidity variations, and can break and survive in highly saline environments. According to scientific studies, the benefits of algae are not limited to the production of biofuel as they can also provide nutritional products such as cosmetics and food supplements.

Scientists in Masdar in Abu Dhabi are still working on more research to produce new types of fuel that can be used by more specialized needs, such as aviation fuel. Figure 14

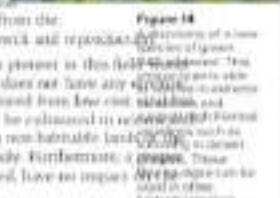


Figure 14
A photograph of a new species of algae, *Nannochloris*. The algae are extremely rare and are considered an extremely rare species. The UAE government is trying to genetically produce clean energy and biofuel from this unique resource by the year 2021. Scientists from the Abu Dhabi 'Masdar City' have been working consistently for five years until this moment in time to test and develop the technology that could be created from the algae through *Nannochloris* growth and reproduction.

My Note

Blank lined area for notes.

Lesson 10 Case Study 31

Another Way to Bring Light to Microalgae

Discuss how paddlewheels distribute microalgae to the water surface.

Guiding Questions

- Describe how the use of paddlewheels bring the algae from deep to the surface allowing more microalgae to reach the sunlight.

Key Concept Challenge Describe three ways scientific inquiry was used in this case study. Accept all reasonable responses. Scientists generated testable hypotheses, tested their hypotheses, refined their hypotheses, and tested them again.

Why Grow Microalgae?

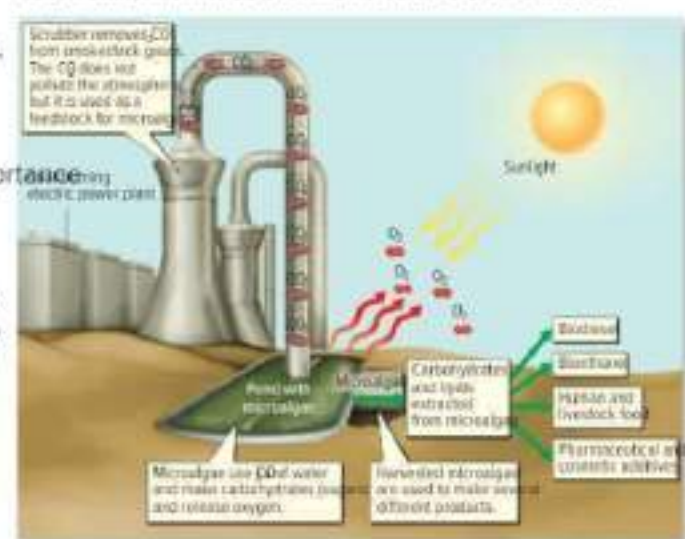
Discuss the scaffolded question below to reinforce the importance of algae growth for biodiesel production.

Guiding Questions

- How is burning fossil fuels a problem? How can tiny algae be a part of the solution? Lower plants release carbon dioxide into the atmosphere. Algae use photosynthesis to produce their food and oxygen. Sugars produced are converted to oil. Algae use carbon dioxide in the process of photosynthesis, converting it to food and oxygen.

Visual Literacy: Figure 14

Have students study the diagram. **Ask:** Explain why a community should establish methods to move forward with algae cultivation. **Sample answer:** The CO₂ in the process is used as feedstock for microalgae instead of polluting the air. Algae harvested from the process can be used to make several different products, including biodiesel, bioethanol, human and livestock food, and pharmaceutical and cosmetic additives.



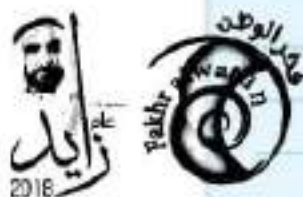
Are microalgae the future?

Use the scaffolded questions below to guide students in considering the future of algae-based biodiesel.

Guiding Questions

- BL** How have scientists designed a partnership between a coal-powered electrical plant and a microalgae bioreactor? *The power plant produces carbon dioxide, which is captured and then used by the microalgae to produce oil. This less expensive fuel can then be used in the production of electricity, saving fossil fuels, and helping to eliminate pollution and carbon dioxide in the atmosphere.*
- OL** Why is algae-based biodiesel currently unable to compete with petroleum-based biodiesel? *Algae-based biodiesel is too expensive to compete with less expensive petroleum-based biodiesel at this time.*

Teacher Notes



1.3 Review

Visualize It!



Physical scientists study the interactions of matter and energy.



Scientists test hypotheses in experiments under controlled conditions.

Summarize It!

1. How do independent and dependent variables differ?

2. How is scientific inquiry used in a real-life scientific investigation?

LAWManager

Case Study

Use Vocabulary

1. **Define** in your own words.

2. **Contrast** terms dependent variable, independent variable, and constants.

Understand Key Concepts

3. Which factor does the investigator change during an investigation?

- A. constant
- B. dependent variable
- C. independent variable
- D. variable

4. Give an example of scientific inquiry used in a real-life scientific investigation that is not mentioned in this chapter.

Interpret Graphics

5. **Organize** information and fill in a graphic organizer like the one below with information about the three types of oil production discussed in the study.



Critical Thinking

6. **Hypothesize** methods to either increase the oil content of microalgae or to grow greater amounts of microalgae for biodiesel production.

7. **Evaluate** research efforts to increase the oil content of microalgae and to grow microalgae more quickly. What would you do differently?

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. Which Key Concept does each image relate to?

Summarize It!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- The Biodiesel Revolution
- Designing a Controlled Experiment
- Biodiesel
- Aquatic Species Program
- Which Microalgae?
- Oil Production in Algae
- Outdoor vs. Bioreactors
- Why so many hypotheses?
- Increasing Oil Yield
- Bringing Light to Microalgae
- Why Grow Microalgae?

Use Vocabulary

1. **Sample answer:** A variable is a factor measured or observed during an experiment. **DOK 1**
2. An independent variable is the factor that you manipulate in an investigation. However, a dependent variable is a factor that responds to a change in the independent variable. The constants are all the factors in an experiment that are not allowed to change. **DOK 1**

Understand Key Concepts

3. **Independent variable**. **DOK 1**

4. **Sample answer:** Scientists use scientific inquiry when they test new medicines before these medicines are released to the public. **DOK 3**

Interpret Graphics

5. open ponds, plastic bags, glass tubes (in an open pond). **DOK 1**

Critical Thinking

6. Accept all reasonable answers. **Sample answer:** If specific growing conditions were used in a pond with a top over it to control variables, then the algae growth and oil production should increase. **DOK 2**

7. Accept all reasonable responses. Sample answer: We could conduct the studies in a less expensive way, so that we could use the technology and reduce our dependency on petroleum production. **DOK 1**



LABManager

How can you design a bioreactor? Lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Teacher Notes



CHAPTER 1 Study Guide

1 TheBIGidea
 The process of scientific inquiry and performing scientific investigations can provide answers to questions about your world.

Key Concepts Summary

1.1 Understanding Science

- Scientific inquiry, also known as scientific methods, is a collection of scientific skills used by different communities to perform scientific investigations.
- Scientific investigations often result in **technology**, newly discovered objects or methods, or answers to questions.
- A scientific hypothesis eventually leads to a scientific investigation by testing various methods, using valid studies, repeating an experiment several times, and keeping accurate and honest records.

1.2 Measurement and Scientific Tools

- Precision** is a description of how similar or close measurements are to each other.
- Accuracy** is a description of how close a measurement is to an accepted value.
- Significant digits** communicate the precision of the tool used to make measurements.
- Like scientific tools, many have, such as scientific journals, microscopes, and measuring tapes, rulers, and measuring tools.

1.3 Case Study: Biodiesel from Microalgae

- The **independent variable** is a factor in an experiment that is manipulated by the investigator to observe how it affects a dependent variable.
- The **dependent variable** is a factor that is measured or observed during an experiment.
- Scientific inquiry is used to gain information and find answers to real-life problems and questions.

Vocabulary

science
observation
inference
hypothesis
prediction
technology
scientific theory
scientific law
critical thinking

description
explanation
International System of Units (SI)
precision
accuracy
significant digits

independent variable
dependent variable
constants

CHAPTER 1 Review

Use Vocabulary

Explain the relationships between each set of terms.

- scientific law, scientific theory
- observation, explanation
- hypothesis, scientific theory
- description, explanation
- International System of Units (SI), significant digits
- variable, constant

Understand Key Concepts

- Which is a quantitative observation?
 - 15.46 long
 - red color
 - rough texture
 - strong odor
- Which is one way scientists indicate how precise and accurate their experimental measurements are?
 - They keep accurate, honest records.
 - They make sure their experiments can be repeated.
 - They use significant figures in their measurements.
 - They record small samples of data.
- Which is NOT a source of bias?
 - accurate records
 - equipment choice
 - testing source
 - hypothesis formation

Critical Thinking

10. **Explain** what would be the next step in the scientific inquiry process below?

Ask Questions → Hypothesize → ?

11. **Select** science career that uses technology. Explain how that career would be different if the technology had not been invented.

12. **Identify** experimental group, the control group, and controls in the following example. Explain your decision.

A scientist tests a new cough medicine by giving it to a group who have colds. The scientist gives another group with colds a liquid and tells them it is cough medicine. The people in both groups are women between the ages of 20 and 30 who normally are in good health.

Writing to Learn

13. **Write** five-sentence paragraph that includes examples of how bias can be intentional or unintentional and how scientists can reduce bias. Be sure to include topic and concluding sentences in your paragraph.

Key Concepts Summary

Study Strategy: Self-Assessment

Self-assessment helps students increase their awareness of their understanding.

- Ask students to create a chart similar to the one below.
- Have students list the Key Concept questions found on the first page of each lesson in the first column.
- Have students write their own answer to each Key Concept question in the second column. Prompt them to use complete sentences.
- Then have them read the Key Concept Summaries. Prompt students to self-assess their answers in the third column.

Example:

Lesson Key Concept Questions	My Answers	My Self-Assessment
What is scientific inquiry?	Scientific inquiry is using different skills to do investigations in science.	I could have included it is also called the scientific method.

Use Vocabulary

- Answers will vary. Sample answer: A scientific theory might contain many well-supported hypotheses that explain why something happens. A scientific law usually contains one well-supported hypothesis that states that something will happen.
- Answers will vary. Sample answer: An observation is the act of watching something and recording what occurs. An explanation is an interpretation of observations.
- Answers will vary. Sample answer: A hypothesis is a possible explanation about an observation that can be tested by scientific investigations. A scientific theory is an explanation based on repeated observations and scientific investigations. It might contain many well-supported hypotheses.
- Answers will vary. Sample answer: A description is a spoken or written summary of observations. An explanation is an interpretation of observations.
- Answers will vary. Sample answer: The International System of Units is the internationally accepted system for

measurement. Significant digits are the number of digits in a measurement that are with a certain degree of reliability.

- 6 Answers will vary. Sample answer: A variable is any factor in an experiment that can have more than one value. A constant is a factor in an experiment that remains the same. There can be many constants in an experiment.

Understand Key Concepts

- 7 A. 15 m long
8 C. They use significant figures in their measurements.
9 A. accurate records

Critical Thinking

- 10 Test hypothesis, which includes design an experiment, make a model, gather and evaluate evidence, and collect data/record observations.
11 Accept all reasonable answers. Sample answer: A computer programmer uses technology and writes programs to make technology usable and available to more people. If computers did not exist, computer programmers would not exist. All processes and systems that use computers would not exist or would be manual processes.
12 The experimental group is the one that got the real cough medicine because they got the medicine that was being tested. The people that got the inert liquid were the control group because they were given a liquid that did not have active ingredients in it. Constants were that all participants were women ages 20–30 and normally healthy.

Writing In Science

- 13 Students' paragraphs should contain facts from the chapter and they should include a topic sentence and a concluding sentence.

Teacher Notes



Chapter Review

TheBIGidea

14. What process do scientists use to perform scientific investigations? List a possible sequence of steps in a scientific inquiry and explain your reasoning.
15. What next step of scientific methods might these marine biologists perform?



Math Skill

Significant Digits

16. How many significant figures are in 2.00440, 0.7, and 13.0401?

My Notes

TheBIGidea

- 14 Scientists use a process called the scientific method. Steps include: gather information, hypothesize and predict, test hypothesis, analyze results, draw conclusions, communicate results.
- 15 The biologists might continue to collect more data or might begin to organize and analyze their data.

Math Skill

Significant Digits

16 3; 3; 5

Motion, Forces, and Newton's Laws



TheBIG Idea

In what ways do forces affect an object's motion?



2.1 Describing Motion

- What information do you need to describe the motion of an object?
- How are speed, velocity, and acceleration related?
- How can a graph help you understand the motion of an object?



2.2 Forces

- How do different types of forces affect objects?
- What factors affect the way gravity acts on objects?
- How do balanced and unbalanced forces differ?



2.3 Newton's Laws of Motion

- How do unbalanced forces affect an object's motion?
- How are the acceleration, the net force, and the mass of an object related?
- What happens to an object when another object exerts a force on it?



Beach Ball

When does gravitational force act on a beach ball? Check off all the descriptions that are examples of gravity acting on a beach ball.

- ☐ A. Beach ball tossed up into the air, moving upward
- ☐ B. Beach ball falling downward after it is tossed into the air
- ☐ C. Beach ball floating in a swimming pool
- ☐ D. Person holding a beach ball
- ☐ E. Beach ball resting on the ground, not moving

Explain your thinking. What rule or reasoning did you use to decide when gravity acts on a beach ball?



Chapter 2 Motion, Forces, and Newton's Laws

Motion, Forces, and Newton's Laws



TheBIG Idea

There are no right or wrong answers to these questions. Write student generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

- AL** Describe an object that is moving. *Students may describe how an object travels from one location to another or its speed as an example of an object in motion. This question encourages students to reflect on ways to observe movement.*
- GL** How can you tell when something is in motion? *Students may explain that an object in motion can often be observed as it moves, such as a car that drives past. Or you can tell that an object has moved because it started in one location and is now in another, such as the hand of a clock.*
- BL** Describe one way to set an object in motion. Describe one way to stop a moving object. *Students may describe a push or pull that sets an object in motion, such as a push to open a door, and a push or pull that stops a moving object, such as catching a frisbee or a ball.*



Beach Ball

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about motion, forces, and Newton's laws. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

- You must use a reference point to describe an object's motion.**

Agree. A reference point is the position that is used to describe the motion of an object.

- An object that is accelerating must be speeding up.**

Disagree. An object accelerates when it changes velocity, which can include change in speed, a change in direction, or both.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

* Things change in steady, repetitive, or irregular ways—or sometimes in more than one way at the same time.

* Changes in speed or direction of motion are caused by forces.

* How fast things move differs greatly.

* Earth's gravity pulls any object on or near Earth toward it without touching it.

* The greater the force is, the greater the change in motion will be.

* An unbalanced force acting on an object changes its speed or direction of motion, or both.

Lesson 1 Describing Motion



1 An object's motion depends on how it changes position. Motion can be described using speed, velocity, or acceleration.

3 A graph can show you how either the distance or the speed of an object changes over time.

2 Speed is how fast an object moves. Velocity describes an object's speed and the direction it moves. Acceleration describes the rate at which an object's velocity changes.



Lesson 2 Forces



4 A force is a push or pull on an object. Contact and noncontact forces can change the motion of an object.

5 Gravity is a force of attraction between any two objects. Gravitational force increases as the masses of the objects increase and decreases as the distance between the objects increases.

6 Balanced forces acting on an object cause no change in the motion of the object. When unbalanced forces act on an object, the sum of the forces is not equal to zero.

Lesson 3 Newton's Laws of Motion



7 An unbalanced force on an object will cause the object to accelerate.

8 Newton's second law of motion states that the acceleration of an object increases as the force acting on it increases and decreases as the mass of the object increases.

9 Newton's third law of motion states that for every action force, there is an equal but opposite reaction force. The action-reaction forces are called a force pair.

Identifying Misconceptions

Changes in Velocity

Find Out What Students Think

Students may think that...

... speed and velocity mean exactly the same thing. They may not realize that velocity also includes the direction of a moving object. They may believe that changing the direction of an object does not affect its velocity.

Discussion

Remind students that speed and velocity have different meanings. Speed is simply how fast an object is traveling. Velocity is how fast an object is traveling as well as the direction in which it is moving. The velocity of a moving object changes when its speed changes. The velocity of a moving object also changes when its direction changes. This is true even if its speed remains the same. **Ask** Picture a roller coaster traveling 50 kilometers per hour in a straight line. It curves around a loop without slowing down. Does the speed of the roller coaster change? **No, it is still traveling 50 kilometers an hour.**

Ask Does the direction of the roller coaster change? **Yes, it changes from a straight line to a curving loop.** Does the velocity of the roller coaster change? Why or why not? **Yes, the velocity changes because the direction changes.**

Promote Understanding

Activity Use visuals to check and correct students' understanding:

1. Have students find a photograph of an amusement park ride, such as a roller coaster, Ferris wheel, chair swing ride, or water slide, from a magazine, newspaper, or the Internet.
2. Have them use the photo to create a poster advertising the ride.
3. Their posters should describe the changes in velocity that a rider will experience on the ride. One of these changes should describe a change in direction; the speed remains constant.
4. Ask students to include arrows with the photo to indicate how the ride can change direction. If students need help with this, refer them to the three diagrams in **Figure 5 in Lesson 1.**



Newton's First Law

Find Out What Students Think

Students may think that...

... force is needed to keep an object in motion. They may think that an object in motion will naturally come to a stop when the object that set it in motion is no longer applied. They may not realize that another unbalanced force must act on the object before it will stop.

Discussion

Remind students that Newton's first law of motion states that if the net force on an object is zero, an object at rest will remain at rest and an object in motion will remain in motion. A moving object will only come to a stop if an unbalanced force acts on it. **Ask** students predict what will happen when you slide a book across the floor. **Ask** When I slide this book across the floor will it keep moving or will it eventually come to a stop?

The book will eventually come to a stop. Have them observe as you slide the book across the floor of the classroom.

Ask Why did the book come to a stop? **Friction acted on the book and caused it to stop moving.** Without friction or some other outside force, would the book have kept moving? **Yes.** A force is not required to keep the book in motion. It is the action of another unbalanced force (in this case, friction) that brings the book to rest.

Promote Understanding

Activity In this activity, students will engage with the contact and noncontact forces that put a ball in motion and then stop it.

1. Have students work in pairs with a rubber ball. Have them predict what will happen when they hold out the rubber ball and drop it.
2. Then have them take turns dropping the ball and observe as it bounces on the floor and eventually comes to a stop.
3. Ask them to explain why the ball came to a stop. The floor exerted a force on the ball, the ball reacted, and that, along with friction, eventually caused it to stop.
4. Ask them to create a diagram that shows how unbalanced forces caused the moving ball to stop moving.

Anticipation Set for Lesson 2

- 3. Objects must be in contact with one another to exert a force.**

Disagree. Noncontact forces include electricity, magnetism, and gravity.

- 4. Gravity is a force that depends on the masses of two objects and the distance between them.**

Agree. Gravity is a noncontact force of attraction between two objects. It is dependent upon mass and distance.

Anticipation Set for Lesson 3

- 5. All forces change the motion of objects.**

Disagree. Only unbalanced forces change an object's motion.

- 6. The net force on an object is equal to the mass of the object times the acceleration of the object.**

Agree. Net force equals mass times acceleration. It is expressed in units known as Newtons.

Options for Pre-Assessment

- 1. What do you think?** Use the exercise on this page to determine your students' existing knowledge.

- 2. Concept Mapping** Have students complete the concept map in the Chapter Study Guide. Use the result to determine students' existing knowledge and areas of need.



Teacher Notes

2.1 Describing Motion

INQUIRY

Where is the white ball? In an arcade, many games involve something moving. Objects speed up, slow down, and change direction. How would you describe the position of the white ball in this game at any moment in time? How is its motion different from the motion of the other balls? What words could you use to describe the motion of the ball?

Write your answer in your science notebook.



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Explore Activity

How can you describe motion?

You see things move in many ways each day. You might see a train moving along a track or raindrops falling to the ground. What information do you need to describe an object's motion?

Procedure

1. Read the procedure and identify the variables before work begins.
2. Choose **small objects** such as a ball or a pencil. Move the object in some way.
3. Have a partner write a short description of the movement in the Science Journal.
4. Exchange **verb** and descriptions with several other pairs of students. Each time, use the descriptions to try to duplicate the original motion.

Think About This

1. **Contrast** Why were some descriptions more useful than others when you tried to duplicate the motion?

2. **Key Concept** What information do you think you need to accurately describe an object's motion?

Essential Questions

- What information do you need to describe the motion of an object?
- How are speed, velocity, and acceleration related?
- How can a graph help you understand the motion of an object?

Vocabulary

motion
reference point
distance
displacement
speed
velocity
acceleration

INQUIRY

About the Phow Where is the white ball? Carnival games are often found at arcades, movie theaters, amusement parks, and other locations. In this game, a player tosses a ball and tries to get it to bounce or land in a cup. If the ball successfully lands in a cup the player gets a prize. The ball begins moving upward and horizontally because the player exerts a force on it. The ball moves downward due to gravity and will eventually stop when it comes into contact with another object, such as the cup.

Guiding Questions

- Describe the motion of the white ball.** *Sample answer: The ball moves up, down, and away from the thrower.*
- What sets the white ball in motion?** *Sample answer: The player exerts a force on the ball, moving it in the direction of the toss.*
- Describe the position of the white ball.** *Sample answer: The white ball is in front of the other balls and closer to the top of the cups.*

LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Create Motion Trading Cards

1. Have each student create a set of three trading cards related to motion. The front of each card should include an illustration or diagram that shows an example of motion, such as a person riding a bike, an airplane taking off, an athlete throwing a ball, and so on. The back of the card should remain blank.
2. After students complete the lesson, ask them to write a sentence on the back of each of their trading cards to describe the illustration or diagram that appears on the front. Each sentence should include one of the vocabulary terms from the lesson. For example, a student could use the term reference point to describe an airplane traveling down a runway, or velocity to describe the speed and direction of a ball thrown during a baseball game.
3. After students complete their sentences, ask them to share or exchange their cards with other members of the class.

ExploreActivity

How can you describe motion?

Prep 5 min Class 15 min

Purpose

To explore what information is needed to accurately describe motion.

Materials

Student Pair small object, such as a marble, pencil, or a wooden block

Before You Begin

Distribute one object to each student pair and establish a place where they will work. One student will need a place to freely move a small object; the other will need a place to write.

Guide the Investigation

Avoid leading students by telling them how to describe the motion of the object. For example, do not tell students that they need to say where the object starts or how fast it moves. Part of the learning process is having students discover how many of these details are needed. Ask them to create a simple chart in their Science Journal with all the objects they move.

Object	Description of Motion
Marble	Flicked marble with forefingers from corner of carpet to directly in front of class door
Wooden block	
Pencil	



Think About This

- Sample answer:** Descriptions that told where an object began and how fast it moved were more useful than those that didn't provide this information.
- Key Concept:** Accept any reasonable answer. **Sample answer:** An accurate description of an object's motion includes details about where the object started, how fast it moved, which direction it moved, any changes in its speed and direction, and where it stopped.

Teacher Notes

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned



Figure 1 A description of the motion of the puck depends on the reference point you choose.



Motion

Suppose you have been playing a chess game at an arcade. You decide to try something new, so you walk to a racing game. As you walk to the new game, your position is the same. Change **position** the position of changing position. If the games are 5 m apart, you could say that your position changed by 5 m.

Motion and Reference Points

You could say that you walked 5 m away from the chess game. Or you could say that you moved 5 m toward the racing game. The starting point you use to describe the motion of an object is called **reference point**. Position is described differently depending on the reference point you choose. You can choose any point from the room as a reference point. Both the racing game and the chess game can be reference points.

In addition to using a reference point to describe motion, you also need a direction. For example, the puck is moving away from the girl. **Figure 1** Other descriptions of direction might include east or west, or up or down.

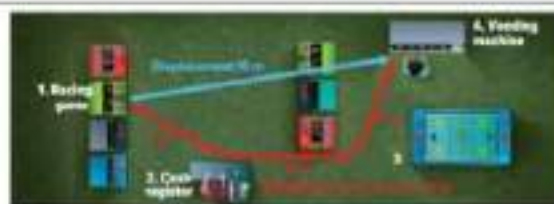


Figure 2 The distance traveled and the displacement take the game to the vending machine differ.

Distance and Displacement

Suppose you finish playing the racing game. Suppose you run out of tokens and leave the arcade. Walking slowly, it takes a long time to get to the end of the block. When you make it to the end of the block, you need to meet a friend at the library in 15 minutes. You start to run. When running, you travel the distance of the next block in a matter of time. How does your motion differ in the two blocks? Since you traveled the second block faster than the first, your speed was greater. **Speed** is the distance an object moves per unit of time. Displacement is represented by a straight arrow extending from the starting point to the ending point. The displacement between the racing game where you started and the vending machine where you ended is shown by the blue arrow in **Figure 2**. Your displacement is 10 m. To give a complete description of your motion, you must include a reference point, your displacement, and your direction from the reference point.

Speed can be constant or changing. Look at **Figure 3**. The runner moves every second for 4 seconds. In the first 4 seconds, the runner moves with constant, or unchanging, speed because he travels the same distance during each second. After the runner starts running, the distance he travels each second gets larger and larger. The runner's speed changes.

Constant and Changing Speed

Figure 3 The runner's speed changes between seconds 4 and 5.



Figure 3 The runner's speed changes between seconds 4 and 5.

Motion

Have students read the paragraph and **Figure 1**. Ask them to describe the objects in motion in the photo. Have them brainstorm games they might see in an arcade, such as video games, air hockey, or bumper cars.

Motion and Reference Points

Have students read the paragraphs. Ask a volunteer to raise her hand and describe how the position of the hand changed using a reference point. Then ask the following questions to their comprehension.

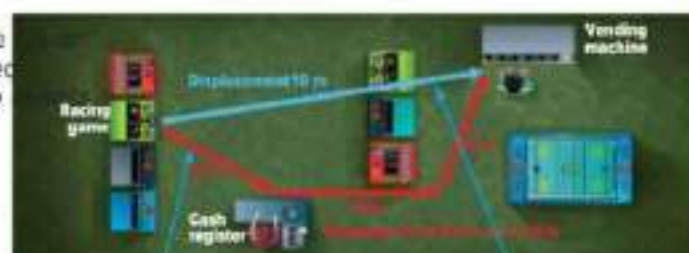
Guiding Questions

- AL** What is a reference point?
A reference point is the position you use to describe the motion of an object.
- OL** Describe your motion as you walk from your desk to the door. Use a reference point and a direction.
Answers will vary, but should include a reference point, a distance, and a direction.
- OL** Name three different reference points you could choose in order to describe the motion of the puck.
Sample answers include the person's hand, the dotted line, the edge of the table, and so on.

Distance and Displacement

Encourage students to think critically about using reference points to describe the motion of an object. Have students read the paragraphs and **Figure 2**. Then ask the questions below.

Visual Literacy: Figure 2



Ask: What is the difference between the distance and the displacement as you move from the racing game to the cash register to the vending machine?
2 meters

Ask: If you traveled back to the racing game, what would your displacement be? 0 meters

Ask: What information do you need to describe an object's motion?
You need a reference point, a direction, and a distance.

Speed

Ask students to discuss their experiences with the Launch Lab. Have them explain some of the ways they described the motion of the small objects they used in the lab. Have students examine the diagram of the runner in Figure 3 as they read this paragraph.

Constant and Changing Speed

Students may think that words describing motion involve only action verbs, such as run, reach, stretch, and throw. Explain that knowing the speed of an object can be helpful. Give the common example of speed limit signs on streets and highways.

Guiding Questions

- AL** What is speed? *Speed is the distance an object moves in a unit of time.*
- OL** Figure 3 shows changing speed. How would the illustration change if it showed constant speed for all seven seconds? *The runner's speed would remain the same. To show this, the runner would continue to look as if he were walking from seconds 4 to 7, and the distance between the illustrations of the runner would remain the same, as in seconds 1 to 4.*
- BL** How does the distance an object moves per unit of time change as its speed changes? *The distance increases as the object speeds up or decreases as the object slows down.*

Average Speed

Have students read the paragraph. Explain that average speed does not describe the speed an object moves from one place to the next or how the speed changes over the distance traveled. Instead, it gives the average speed traveled along the course of the whole trip. Then ask the following scaffolded questions to informally assess their understanding of this concept.

Guiding Questions

- AL** Name one unit of distance and one unit of time that could be used to describe average speed. *Sample answers include meters, kilometers, miles and seconds, minutes, hours, and so on.*
- OL** Which is greater, your average speed when you ride a bike or your average speed when you walk? *The average speed when you ride a bike is much greater.*

Velocity

Remind students that speed includes distance and time. However, it does not include direction, which is also used to describe motion. When you measure the speed of an object, you do not need to know if it is traveling east or west, left or right, and so on. The measurement 40 km/h only tells you how far and how fast a vehicle can travel in an hour's time, not which way it is moving.

Word Origin

velocity

Have students compare the Latin origin of velocity to the scientific definition of the term.

Ask: What element does the scientific definition of velocity include that the Latin origin does not?

Ask: How would you explain velocity in your own words?

Answer: Velocity is the speed and direction that an object moves.

AL Approaching Level **OL** OnLevel **BL** Beyond Level **LA** Language Acquisition

Differentiated Instruction

AL Motion, May I? Divide students into groups to play a game of "Motion, May I?" that reviews the terms they learned in the **Motion** section of this lesson: reference point, distance, and displacement. Draw a velocity board on the front of the classroom. Call on students and give a statement such as "I walked 9 meters from the cash register to the vending machine." Ask students to reply with the answer, "That is distance," and ask "May I?" If they are correct, allow them to move one step forward. The first group to advance to the front of the classroom wins.

BL Calculate Average Speed Equations Have students reread the section entitled **Average Speed**. Ask them to create three average speed problems. For example, what is the average speed in kilometers per hour, if it took 30 minutes to bike 8 kilometers? *16 km/h* Have students exchange their problems with another student's to solve.

LA Make a Map Put students in a group and ask them to make a map of the classroom with several different locations, such as the teacher's desk, board, door, and closet. Then have them locate three points on their map and use a tape measure to find the difference between distance when walking around items to get from one to the other and the displacement. Ask them to annotate their map and present the difference between distance and displacement to the class.

Teacher Toolbox

Reading Strategy

Summarize Have students reread the sections about **Speed**. Ask them to write a short summary to explain what the term *speed* means and the difference between constant and changing speed. Remind students that summaries should primarily include the main ideas of a topic and a few supporting details.

Teacher Demo

Longitude and Latitude Use a projector to display a map of the emirate. Have students help you find the location of several towns or attractions in the area. Write the latitude and longitude for each place on chart paper or the board. Explain that latitude and longitude are used to describe location using reference points that most people know and understand.

FOLDABLES

Write a horizontal three-leaf constant velocity foldable (as shown) that is negative your velocity when you fold the bottom.



Word Origin

Velocity from Latin *velocitas*, means "swiftness or speed"

Reading Lens

2. Draw like your teacher as you look from your desk to the door. Use a reference point and a direction.

Average Speed

Suppose you walk to figure out how fast you ran from the arcade to the library. As you ran, your speed probably changed from second to second. Therefore, in order to describe the speed you traveled, you describe the average speed of the entire trip. Average speed is the ratio of the distance an object moves to the time it takes for the object to move that distance. If it takes you 15 minutes, or 0.25 h, to run the 1 km to the library, your average speed was 4 km/0.25 h, or 4 km/h.

Velocity

If you tell your friend that you traveled along at 4 km/h, you are describing your speed. You could give your friend a better description of your motion if you also told him or her the direction in which you are moving. The speed and direction of an object's motion.

Often, velocity is shown by using an arrow, as shown in Figure 4. The length of the arrow represents the speed of an object, while the direction in which the arrow points represents the direction in which the object is moving.

Constant Velocity

Velocity is constant, or does not change, when an object's speed and direction of movement do not change. If you use an arrow to describe velocity, you can divide the arrow into segments to show whether velocity is constant. Look at the skateboarder's arrow in Figure 4. Each segment of the arrow shows the distance and the direction you move at a given unit of time. Because each segment is the same length, you are moving the same distance and in the same direction during each interval of time. Because both your speed and direction of movement are constant, you are moving at a constant velocity.



Figure 4 Our understanding of velocity is greater from your walking velocity. Both velocities are constant because they represent a constant speed in a constant direction.



Figure 5 The velocity of an object changes if the speed changes, the direction changes, or both the speed and the direction change.

Changing Velocity

Velocity can change even if the speed of an object remains constant. Recall that velocity includes both an object's speed and its direction of travel. Figure 5 shows several examples of changing velocity.

In the first panel, the ball drops toward the ground in a straight line in constant direction. The increased length of each arrow shows that the speed of the ball increases as it falls. As speed changes, velocity changes.

In the second panel, each arrow is the same length. This tells you that the balls wheel can move around a circle at a constant speed. However, each arrow points in a different direction. This tells you that the balls are changing direction. As direction changes, velocity changes.

The third panel shows the path of a ball thrown into the air. The arrows show that both the ball's speed and direction change, so its velocity changes.

When either an object's speed or velocity changes, the object is accelerating. Acceleration is the measure of the change in velocity during a period of time.

Exit Concept Check

Can an object traveling at a constant speed have a changing velocity? Why or why not?

Discussion

Ask the class about how this section is the concept being discussed.



Constant Velocity

Have students read the paragraph and examine the diagram in Figure 4. Then ask the following questions to assess their understanding.

Guiding Questions

- AL If an object moves at a constant velocity, does its speed or direction change? *No, constant velocity means keeping the same speed and direction.*
- AL Why is one of the arrows in Figure 4 longer than the other? *The person on the skateboard is moving faster than the person walking, so he or she has traveled a longer distance in the same amount of time.*
- OL What is the difference between the velocity of the person walking and person skateboarding in Figure 4? *The difference between the two velocities is speed. The person walking and the person skateboarding are both traveling in the same direction, but the person on the skateboard moves at a faster speed.*
- SL If an object's direction changes but its speed doesn't, does its velocity change? Why or why not? *Yes, because velocity includes both speed and direction. So, if one of those changes, the velocity changes.*

Changing Velocity

Explain to students that moving objects usually do not travel at a constant speed or in the same direction. Have students imagine a girl walking down a street. She might turn a corner or slow down if the sidewalk becomes crowded, or turn around and walk back the way she came. Tell students that it is important to understand how velocity can change in order to describe how an object moves. Have them read the paragraphs and compare the three images in Figure 5.

Guiding Questions

- AL What is acceleration? *Acceleration is the change in the velocity of a moving object during a period of time.*
- OL Can an object traveling at a constant speed have a changing velocity? Why or why not? *Yes, if it is changing direction.*
- OL How do you know the speed is constant in the second panel in Figure 5? *The arrows are the same length.*
- SL How would the arrows in the third panel of Figure 5 appear if the ball falls to the ground and then up as it bounces back up after it fell to the ground? *The arrows would point down as the ball falls to the ground and then up as it bounces back up. They would be different lengths to show the changes in the ball's speed.*

Calculating Acceleration

Have students read the paragraphs and study the equation. Ask volunteers to identify each element in the equation. Explain that initial velocity occurs when an object starts to move and final velocity occurs when it stops moving. Then ask the following questions.

Guiding Questions

- AL** Why are there two velocities in the equation for acceleration? *v_i represents the velocity at the beginning of the time period. v_f represents the velocity at the end of the time period.*
- OL** How does acceleration differ from velocity? *Velocity is speed in a given direction. Acceleration is the rate at which the velocity changes.*
- BL** Why is it important to include the difference between final velocity and initial velocity to calculate acceleration? *Acceleration is a change in velocity, so it is important to know the difference between the velocity when an object started moving and when it stopped to find the acceleration.*

Positive and Negative Acceleration

Discuss students' experiences with acceleration. Ask them to describe how the velocity changed when they tossed the stopper to their partners. Review that acceleration is a change in velocity. Have students read both paragraphs to compare positive acceleration to negative acceleration. Then ask the following questions to assess their understanding.

Guiding Questions

- AL** During positive acceleration, how does the speed of an object change? *It increases during positive acceleration and decreases during negative acceleration.*
- OL** If a train slows down as it pulls into a station, is that positive acceleration or negative acceleration? *It is negative acceleration.*
- BL** Is direction important when calculating acceleration? Explain your answer. *Yes, because direction is represented as one of the two velocity variables in the acceleration equation.*

Differentiated Instruction

- AL Everyday Changes in Velocity** Have students work as a group to create a poster that shows two or three examples of an everyday change in velocity, such as a car changing direction or a jogger picking up speed or an airplane taking off, and so on. Ask students to label the poster to show positive and negative acceleration.
- OL Vehicles and Velocity** Have students work in pairs to create a rider information brochure for the Ferris wheel. **Figure 5** The brochure should explain how the rider will feel when the velocity of the vehicle is constant and when it changes. They should include pictures or diagrams with the brochure that show examples of the vehicle changing its velocity.
- LA Changing Velocity** Have students clear an area on a table or the floor to experiment with toy cars. They push the cars across the surface at different speeds and note when the cars increase or decrease speed. Ask them to set up two demonstrations for the class. Each demonstration should come with an index card that explains if acceleration will decrease or increase during the demonstration and

Teacher Toolbox

Reading Strategy

Compare and Contrast Have students complete a Venn diagram that lists one similarity and one difference between the terms *positive acceleration* and *negative acceleration*. For example, both involve a change in velocity. However, positive acceleration is an increase in speed, while negative acceleration is a decrease in speed.

Math Skills

What is the average acceleration? Present the following problem to students to solve. What is the acceleration of a car that increases from 15 m/s to 30 m/s in 15 seconds as it pulls onto a highway? 2 m/s^2 What is the acceleration of a car that decreases from 30 m/s to 10 m/s in 10 seconds as it drives off a highway exit? -2 m/s^2

Fun Fact

Formula One Racing Formula One racers drive single-seater cars that are the most technologically advanced in car racing. Their design creates air flow over and under the car that creates a downward force that keeps the vehicle glued to the ground, even at high speeds. This enables the cars to brake and accelerate very quickly.

Calculating Acceleration

When a ball is dropped, as in the first of **Figure 5a**, speed increases as it falls toward the ground. The velocity of the ball is changing. Therefore, the ball is accelerating. You can calculate acceleration using the following equation:

$$a = \frac{v_f - v_i}{t}$$

The symbol for acceleration is a . In this lesson, v represents only the speed of an object. You do not need to consider the object's direction. The symbol v_i represents the

initial speed, and the symbol v_f represents the final, or starting, speed. The symbol t stands for the time it takes to make that change in speed.

Positive Acceleration

When an object, such as a falling ball, speeds up, its final speed is greater than its initial speed. If you calculate the ball's acceleration, the numerator (final speed minus initial speed) is positive, so the acceleration is positive. In other words, when an object speeds up, it has positive acceleration.

Negative Acceleration

If a ball is thrown straight up into the air, it slows down as it travels upward. The initial speed of the ball is greater than its final speed. The numerator in the equation is negative, so the acceleration is negative. In other words, as an object slows down, it has negative acceleration. Some people refer to this as deceleration.

Using Equations

How does acceleration differ from velocity?

Math Skill

Solve for Acceleration

A skateboarder moving at 2 m/s starts skating down a ramp. As the skateboarder heads down the ramp, he accelerates to a speed of 8 m/s in 4 seconds. What is the skateboarder's acceleration?

1 This is what you know:

final speed: $v_f = 8 \text{ m/s}$
initial speed: $v_i = 2 \text{ m/s}$
time: $t = 4 \text{ s}$

2 This is what you need to find out:

acceleration: a

3 Use this formula:

$a = \frac{v_f - v_i}{t}$

4 Substitute:

$a = \frac{8 \text{ m/s} - 2 \text{ m/s}}{4 \text{ s}}$

5 Use values for v_i and t and subtract.

$a = \frac{6 \text{ m/s}}{4 \text{ s}}$

6 and divide.

$a = 1.5 \text{ m/s}^2$

Answer: the acceleration is 1.5 m/s².

Practice

As the skateboarder starts moving up the other side of the ramp, his velocity changes from 0 m/s in 3 seconds. What was his acceleration?

Using Graphs to Represent Motion

How can you track the motion of an animal that can move hundreds of kilometers without being seen by humans in order to understand the movements of animals, such as the polar bear in **Figure 6**, biologists use tracking devices on them. These devices constantly send information about the position of the animal to satellites. Biologists download the data from the satellites and create graphs of motion such as those shown in **Figures 7** and **8**.



Figure 6 Tracking devices help scientists record the movement of animals, not just on polar bears.

Displacement-Time Graphs

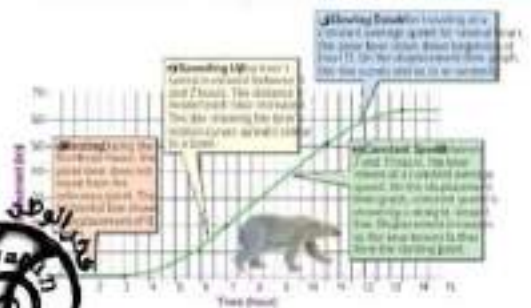
Figure 7 is a displacement-time graph of a polar bear's motion. The x -axis shows the time, and the y -axis shows the displacement of the polar bear from a reference point.

The line on a displacement-time graph represents the average speed of the bear at that particular moment in time. It does not show the actual path of motion. As the average speed of the bear changes, the slope of the line on the graph changes. Because of this, you can use a displacement-time graph to describe the motion of an object.

Visual Question

What does the average speed of the bear between points 7 and 11?

Figure 7 The displacement-time graph shows the bear's speed and distance from the reference point at any point in time.



Math Skill

Solve One-Step Equation

On chart paper or the board, write a list of some of the distance measurements that can be used to calculate acceleration, including meters, kilometers, and miles. Then list some of the units of time that can be used, such as seconds, minutes, and hours. Have students read the Math Skills box to learn how to calculate acceleration. Remind them that during positive acceleration, speed increases, and an acceleration equation will result in a positive number. During negative acceleration, speed decreases, and an acceleration equation will result in a negative number.

Practice

Have students solve the practice question. Then ask a volunteer to write the steps he or she used to find the answer on chart paper or the board.

-2 m/s^2

Using Graphs to Represent Motion

Have students read the paragraph and study the **Figure 6**.

Explain to students that the polar bears must be tranquilized so that the scientists can safely attach the radio collar. At the same time, the scientist may also examine the bear to determine how healthy it is. Tell students that once the tranquilizer wears off, the bear recovers and returns to its normal activities.

Displacement-Time Graphs

Explain to students that we can graph the motion of objects to better understand how they move and how they accelerate and change velocity. Have students read the paragraph and study the graph in **Figure 7**. Tell students that this is a line graph, which shows how a variable changes over time. A displacement-time graph shows how far an object travels from a reference point during a period of time.

Academic Vocabulary

satellite

Have students read the academic definition of satellite.

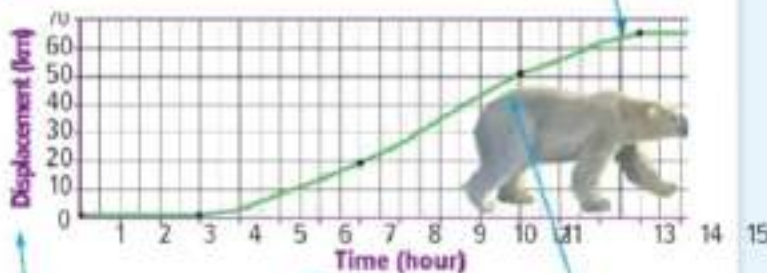
Ask What might be another use of a satellite?

Sample answers include: to provide information to GPS devices, transmit satellite phone and television signals, and so on.

Visual Literacy: Figure 7

Ask the following questions to informally assess your students' understanding of the graph in Figure 7.

Ask: Between the hours of 14 and 15 does the bear continue to move? no How can you tell? The line is horizontal and does not move from the new reference point.



Ask: What does the axis of a displacement-time graph show? What does this show? The x-axis shows increments of time and the y-axis shows increments of displacement.

Ask: What was the average speed of the bear between hours 7 and 11? 7.5 km/hr

Speed-Time Graphs

Explain to students that other kinds of graphs can also help us understand how an object moves. The graphs differ in the information that are shown on the x-axis and the y-axis. Have students read the paragraph and study the Figure 8. Explain that a speed-time graph can show how fast an object moved during a period of time and how its speed changed.

Guiding Questions

- AL** What does the x-axis of a speed-time graph show? What does the y-axis show? The x-axis shows increments of time and the y-axis shows increments of speed.
- GL** How can a graph help you understand an object's motion? It helps by showing you how either the distance or the speed changes over a period of time.
- BL** What element of velocity is not shown on a displacement-time graph or a speed-time graph? Direction.

Differentiated Instruction

AL Plotting a Graph Distribute graph paper to students and a table of data that includes distances (in kilometers) and times (in hours) for the motion of a bike rider one afternoon. Guide students in drawing the x-axis and y-axis on their graphs. Then have them use the data in the table to plot a displacement-time graph.

GL Create a Graph Have students use the diagram of the runner in Figure 3 to create a displacement-time graph. They should measure the distance between each image of the runner in the diagram and use that information to plot the displacement on the y-axis and use the seconds on a stopwatch for the x-axis. Their completed graphs should show a curving line that at first moves upward at an even slope and then becomes steeper as the speed increases.

LA Combining Vocabulary with a Graph students copy the speed-time graph in Figure 8 onto graph paper. Ask them to write sentences to describe the graph, using as many vocabulary words from the lesson as possible, including speed, velocity, acceleration, and so on.

Teacher Toolbox

Careers in Science

Preparing for Takeoff Engineers at NASA have to take many different calculations into account to determine if a space shuttle will launch into space. They have to graph the potential speed and displacement of the shuttle as it takes off to make sure that it launches safely.

Reading Strategy

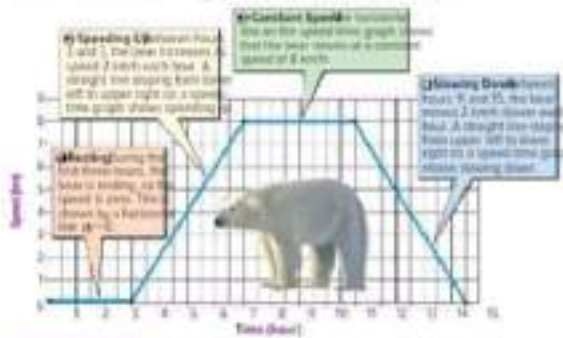
Compare and Contrast Have students write a short paragraph to compare and contrast displacement-time and speed-time graphs. They should list similarities and differences between the two. For example, both show changes in speed, but only the displacement-time graph shows a change in distance from a reference point.

Real-World Science

Radar Gun Police officers often use radar guns to measure the distance a car travels during a period of time. The radar gun emits a pulse of electromagnetic radiation. A passing vehicle reflects the pulse and sends it back. The speed of the reflection helps an officer know how fast the vehicle is moving.

2.1 Review

Figure 8 The speed-time graph shows the speed of the bear at any given time during its journey. A horizontal line on a speed-time graph shows an object with a constant speed.



Key Concept

How can you tell if an object is moving at a constant speed?

Key Concept

How can a graph help you understand an object's motion?

Visual Literacy

What happened to the bear's speed between hours 7 and 11?

Speed-Time Graphs

Figure 8 is a speed-time graph of the polar bear's motion. The x-axis shows the time, and the y-axis shows the speed of the bear. Notice that, in this case, the line shows how the speed, rather than the displacement, changes as the bear moves. A horizontal line at $y = 0$ means the bear is at rest because its speed is 0 km/h. Notice that a horizontal line at $y = 0$ on either a displacement-time graph or a speed-time graph represents the bear at rest.

Keep in mind that constant speed is describing average speed: the bear might have sped up or slowed down slightly each second. But, during hours 7–11, you could describe that the bear's average speed remained constant since it covered the same distance each hour.

Interpreting the lines on graphs can provide you with a lot of information about the motion of an object.

Visualize It!



A description of an object's **speed** is the distance traveled by an object per unit of time. **Velocity** is a change in position, a direction from the point of view. **Acceleration** is a change in velocity, a change in speed and/or direction. **Displacement** is the change in position, a direction from the point of view.

Summarize It!

1. What information do you need to describe the motion of an object?

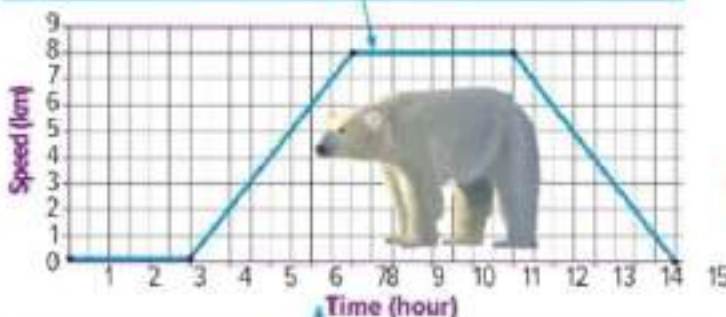
2. How are speed, velocity, and acceleration related?

3. How can a graph help you understand the motion of an object?

Visual Literacy: Figure 8

Students may have difficulty distinguishing between a displacement-time graph and a speed-time graph. Have students study the graph **Figure 8** and answer the following questions.

Ask: How can you tell that the bear moved at a constant speed between hours 7 and 11? *The line is straight and doesn't slope upward or downward.*



Ask: What happened to the bear's speed between hours 11 and 14? *The bear's speed decreased.*

Ask: What is the difference between the line when the bear speeds up and when it slows down? *When the bear speeds up, the line slopes upward; when the bear slows down, the line slopes downward.*

Ask: How are the time periods between hours 14 through 15 in Figure 7 and hours 7 through 11 in Figure 8 similar? *The horizontal line shows there is no change in either displacement or speed during those periods.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** Which Key Concept does each image relate to?

Summarize it!



- Motion
- Speed
- Velocity
- Calculating Acceleration
- Using a Graph to Represent Motion

Intervention Planner



Based on the results of the Lesson Review, use the chart below to address individual needs.

Teacher Notes


Use Vocabulary (1–2)

-  Guiding Questions, Motion and Reference Points
Visual Literacy: Figure 2
-  Quick Vocabulary
Content Vocabulary

Understand Key Concepts (3–5)

-  Key Concept Checks
Visual Literacy: Figure 8
-  Key Concept Builder



Interpret Graphics (6)

-  Visual Literacy: Figure 7

Critical Thinking (7)

-  Visual Literacy : Displacement-Time Graph
Guiding Questions, Speed-Time Graphs
-  Enrichment
Challenge

Math Skills (8)

-  Math Practice
-  Math Skills



Motion, Forces, and Newton's Laws

Use Vocabulary

1. **Describe** your own words how you would choose a reference point.

2. **Distinguish** between the terms distance and displacement.

Understand Key Concepts

3. **Describe** motion of a book as you lift it from the table and place it on a shelf.

4. Which of the following does NOT describe an object in motion?

- A. change in direction
- B. constant velocity
- C. slowing down
- D. speeding up

5. **Apply** Draw a speed-time graph of a parade float that accelerates from rest to 0.5 km/hr in 1 min and then moves at a constant speed for 10 min.

Interpret Graphics

6. **Draw** The table below includes information about the motion of an elevator. Draw a displacement-time graph using the data, and explain the elevator's motion.

Displacement	Time
0 m	0 s
4 m	3 s
4 m	10 s
10 m	11 s
10 m	12 s

Critical Thinking

7. **Analyze** Whether you could have a vertical line on a displacement-time graph. Why or why not?

Math Skill

8. What is the acceleration of a truck that goes from a speed of 0 m/s to a speed of 9 m/s in the east in 3 s?

My Notes

Use Vocabulary

1. A reference point is the place you pick to describe the motion of an object.

2. Distance is the total length of an object's path as it moves. Displacement is the distance between where the object started and where it finished.

Understand Key Concepts

3. Students should describe the motion of the book based on a reference point, such as the table or shelf, and its direction. Example: The book moved away from the table and toward the shelf.

4. B. constant velocity

5. The line should start at the origin (0,0), move up and to the right to point 0.5 (y), 1 min (x). The line should then be horizontal at 0.5 (y) to x=11.

Interpret Graphics

6. The elevator accelerated during the first three seconds. It started at ground level and accelerated for three seconds until it was 4 m above the ground. Then it stopped 10 m above the ground for one second.

Critical Thinking

7. No, because it would mean that the object traveled some distance in zero time.

Math Skill

8. 3 m/s² to the east

2.2 Forces

INQUIRY

Why is one side of the ball flat? Let's look at this tennis ball. It's usually round, so shape lets it roll faster and travel farther in the air. What could cause part of a ball to become flat like this one? Does the same thing happen when a baseball hits a bat? Or when a golf club hits a golf ball?

Write your responses in your science notebook.



52 Chapter 2 Motion and Forces

Explore Activity

How can you change an object's shape and motion?

You can probably think of many ways that things can change. For example, paper can change a flat sheet to a crumpled ball. A ball can change its location as it moves across a table. How can you change an object's shape and motion?

Procedure

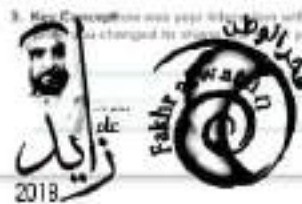
1. Read the procedure and identify the steps in your work pages.
2. Observe an object in your Science Journal. Try to make the following changes to the shape of a ball of clay.
3. Mold the clay into a log. Leave the log on a flat surface and then push it to stop rolling.
4. Leave the log to sit so that its speed changes. Then change the log's direction of motion. Observe and record in your Science Journal how you make these changes.

Think About This

1. Describe what you did to change the shape of the clay.

2. Explain how you changed the motion of the clay.

3. How do you think your information with the clay will be changed by these changes? How do you think your information will be changed by these changes?



Essential Questions

- How do different types of forces affect objects?
- What factors affect the way gravity acts on objects?
- How do balanced and unbalanced forces differ?

Vocabulary

force
contact force
noncontact force
motion
gravity
balanced forces
unbalanced forces

INQUIRY

About the Photo Why is one side of the ball flat? When a ball hits a tennis racket, the strings of the racket exert a force that impacts the shape of the ball. You can demonstrate this to students by having them press their hands together to observe how their palms subtly change shape.

Guiding Questions

- AL** How has the shape of this tennis ball changed? *It has slightly flattened on the side that makes contact with the tennis racket.*
- CL** Do you think a baseball changes its shape when a bat hits it? Why or why not? *Yes, although a baseball is less flexible than a tennis ball, so the change in shape is probably smaller and harder to see.*
- EL** How might the tennis ball look after it bounces off the racket and the racket has hit it? *As the ball bounces off the racket and flies back into the air, it regains its shape.*



LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.



Vocabulary

Compare Dictionary Definitions

1. Write the word **force** on chart paper three times.
2. Have students look up the word in a dictionary and write three definitions on the chart paper.
3. Compare and contrast the different definitions.
4. **Ask:** What are the various meanings of the word **force**? Students should see that meanings vary considerably but most relate to the ability to move something or change something.
5. Have students reflect on which of these definitions they have used or have heard others use in everyday speech. **Ask:** What moved or changed in your example?
6. Encourage students to spend the next week noting when they, their friends, their parents, the news media, or others use the word **force**. Augment the class definition by adding examples to the chart paper.

ExploreActivity

How can you change an object's shape and motion?

Prep 5 min Class 10 min

Purpose

To explore how a force can change the shape or motion of an object.

Materials

Student modeling clay

Before You Begin

Check to be sure the modeling clay you plan to use is not so sticky that students will be unable to roll it across a table or a piece of cardboard on the table.

Guide the Investigation

Encourage students to think about what they have to do in order to change the shape of the clay. Suggest that they ask themselves about cause-and-effect relationships when observing changes in the clay. *What caused this change? What was the effect of my action?*

Changing shape	Shape 1	Shape 2	Shape 3	Shape 4
Shapes	stick of modeling clay	round ball	flat disc	log
Done by	received like this	rolling between hands	pounding against the table	shaped with hands

Motion	Roll	Stop	Change speed	Change direction of motion
Done by	pushing down board with hands	blocking roll with an object	push again midway across table	tilt board



Think About This

1. Students should indicate that they pushed on the clay in different directions.
2. Answers should include that the speed and/or direction of the motion changed.
3. **Key Concept:** Students will indicate that they had to push or pull the clay to change its shape and to change its motion.

Teacher Notes

Understand
Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you have learned in the third column.

What I Know	What I Want to Learn	What I Learned



Figure 9 The arrows show forces with very different sizes acting in opposite directions.

What are forces?

When dropping on a computer, stirring a lake, and pushing on a window have in common? They all involve an interaction between you and another object. You push on the keys. You push or pull on the lake. You push on the window. **A push or pull on an object is a force.**

A force has both size and direction. The length of the arrow represents the size of the force. The direction in which the arrow points represents the direction of the force. The unit of force is the newton (N). It takes about 4 N of force to lift a can of soda.

There are two ways a force can affect an object. A force can change an object's speed. It also can change the direction in which the object is moving. In other words, a force can cause acceleration. Recall that acceleration is change in an object's velocity—its speed and/or its direction—in a given time. When you apply a force to a tennis ball, such as the one shown in the picture on the previous page, the force first stops the motion of the ball. The force then causes the ball to accelerate in the opposite direction, changing both its speed and direction.

Types of Forces

Some forces are easy to recognize. You can see a hammer strike a nail as it hits a nail. Other forces seem to act on objects without touching them. For example, what force causes you to fall toward the ground if it slips out of the car?

Contact Forces

The top left image in **Figure 10** shows a baker pushing his hand into dough, causing the top of the dough to accelerate downward. You can see the baker's hand and the dough come into contact with each other. **Contact forces** are a push or a pull applied by one object to another object that is touching it. Contact forces are called mechanical forces. The top **Figure 10** shows other types of contact forces.

Noncontact Forces

The bottom left image of **Figure 10** shows a girl's foot being pulled toward the slide even though it isn't touching the slide. A force that pushes or pulls an object without touching it is a **noncontact force**. The force that pulls the girl but is an electric force. The bottom **Figure 10** shows other noncontact forces, such as magnetism and gravity.

Figure 10 The pictures in the top row show examples of contact types of forces. The space in the bottom row shows examples of noncontact types of forces.



Figure 10 The pictures in the top row show examples of contact types of forces. The space in the bottom row shows examples of noncontact types of forces.

FOLDABLE!
Fold a 4x6 inch cardstock (book, label, or sheet) to use as a foldable. Write down what you want to learn. After you have completed this lesson, write down what you have learned in the third column.

What is the difference between contact and noncontact forces? What objects?



What are forces?

Have students describe the objects in **Figure 9**. Ask students what has set these objects in motion. In the top image, a finger pushes down on the button. In the bottom image, the person pulls the bicycle up. Then have students read the paragraph and learn more about forces and what happens when they push or pull on objects. Ask these questions to assess students' understanding.

Guiding Questions

- Q1** What is a force?
A force is a push or pull from one thing to another.
- Q2** In what ways can forces affect objects?
Forces can change the speed or direction of objects.
- Q3** Describe how a force sets a ball in motion. Is this positive or negative acceleration?
Sample answer: A person's hand throws the ball, pushing it into the air. This is an example of positive acceleration.

Types of Forces

Before reading the paragraph ask students to identify which objects exert a force on other objects in the photo on the lesson page. The racket causes the ball to stop, then fly outward. The ball also pushes back against the racket and makes the strings vibrate backward. The hand presses against the handle to make the racket move.

Contact and Noncontact Forces

Ask students to discuss some of the ways they changed the shape or the motion of the objects in **Figure 10**. Brainstorm ways to change the shape or motion of an object without touching it. Have students read the paragraph; then ask the following questions.

Guiding Questions

- Q1** What is the difference between the way contact and noncontact forces affect objects?
With contact forces, the objects must touch one another. Noncontact forces can act between two objects that are not touching.
- Q2** Use the terms contact and noncontact to describe the difference between the forces when a baseball is thrown into the air and when it falls to the ground.
Contact: a person throws the ball with his or her hand. A baseball falls to the ground because of a noncontact force: gravity pulls the ball down without touching it.

Visual Literacy: Figure 10

Have students compare the six images in **Figure 10**. Clarify that the blue arrows represent forces at work. Ask the first two questions to assess their understanding of the contact and noncontact forces in the figure. Ask the last two questions to assess how well they apply their understanding to different situations.

Ask: Why is the applied force in the first image an example of a contact force? The hand has to touch the dough to apply force and flatten it out.

Ask: Why is magnetism an example of a noncontact force? Magnetism repels the bar magnets and keeps them apart without the magnets touching each other.

Ask: When you pull a notebook from your bookbag, is that an example of a contact force or a noncontact force? Why? An example of a contact force because you have to touch the notebook to pull it out.

Ask: Does a compass work with contact force or noncontact force? A compass works with magnetic forces; these are noncontact.

**Differentiated Instruction**

Sir Isaac Newton's Famous Discovery Have students use the internet or school library to research the story of Sir Isaac Newton's "discovery" of gravity. According to the famous tale, ideas about gravity came to Newton while he was in his orchard. When an apple fell from a tree, he realized it had been pulled to the ground by an unseen force. Ask students to use what they learn to complete the following activities. Explain that they will learn more about Newton and his discoveries in the next lesson.

LA Sing a Song Have students work in pairs to write the lyrics for a song or a rap about Newton's discovery.

EL Write a News Report Have students work in pairs to write the script for a TV news report as though they were there when Newton began to piece together his ideas about gravity.

LA Perform a Skit Have students work in small teams to put on a skit that shows Newton making his famous discovery. They may choose to write down the skit in script form or ad-lib it for those who are just learning to read English.

Teacher Toolbox**Reading Strategy**

Main Idea and Supporting Details Have students reread the sections on friction and gravity. Ask them to complete two "main idea and supporting details" charts to explain each type of force. Their charts should provide definitions of friction and gravity and include supporting details, such as the fact that friction is a contact force and gravity is a noncontact force.

Real-World Science

Gravity and G When you jump in the air, you fall back down at a fixed acceleration. This is acceleration due to gravity, which measures 9.8 m/s^2 and is commonly known as G. Most roller coasters run at a maximum acceleration between 3 and 4 Gs, which is three or four times as fast as a free fall to Earth. No wonder they are so thrilling!

Gravity

List the Moon closer than this and list it in the correct spot below.

Figure 11 The player must overcome friction or he won't reach the base.

Friction

Why does the baseball player **Figure 11** slow down as he slides toward the base? **Friction** is a contact force that resists the sliding motion between two objects that are touching. The force of friction acts in the opposite direction of the motion, as shown by the blue arrow. Rougher surfaces produce greater friction than smooth surfaces. Other factors, such as the weight of an object, also affect the force of friction.

Gravity

Is there anywhere on Earth where you could drop a pencil and not have it fall? **Gravity** is a noncontact attractive force that exists between all objects that have mass.

Mass is the amount of matter in an object. Both your pencil and Earth have mass. They exert a gravitational pull on each other. In fact, they exert the same gravitational force on each other. Why doesn't your pencil fall Earth toward it? It actually does! The pencil has mass, so the force of gravity causes it to rapidly downward toward Earth's surface. Earth "falls" up toward the pencil at the same time, but because mass, Earth's mass is too small to see.

Distance and Gravity

You may have heard that astronauts become weightless in space. This is not true. Astronauts do have some weight in space, but it is much less in space than it would be on Earth. Weight is a measure of the force of gravity acting on an object. As two objects get farther apart, the gravitational force between the objects decreases. **Figure 12** shows how the weight of an astronaut changes as he or she moves farther from Earth.

You know that all objects exert a force of gravity on other objects. If the astronaut drops a hammer on the Moon, will it fall toward Earth? No, the attraction between the Moon and the hammer is stronger than the attraction between Earth and the hammer because the hammer is very close to the Moon and very far from Earth. The hammer will fall down toward the Moon.

Mass and Gravity

Another factor that affects the force of gravity between two objects is the mass of the objects. As the mass of one or both objects increases, the gravitational force between them increases. For example, **Figure 13**, if you double the mass of one of the objects, the force of attraction doubles.

The effect of mass on the force of gravity is most noticeable when one object is very massive, such as a planet, and the other object has much less mass, such as a person. Even though the force of gravity acts equally on both objects, the less massive object accelerates more quickly due to its smaller mass. Because the planet accelerates so slowly, all you observe is the object with less mass "falling" toward the object with greater mass.

Figure 12 As the astronaut's distance from Earth increases, his weight decreases. As the distance between the astronaut and Earth increases, the force of gravity between them decreases.

Figure 13 The force of attraction between the astronaut and Earth is based on the mass of both objects. The force of attraction between the astronaut and the planet is based on the mass of both objects.

56 Chapter 2 Motion, Forces, and Newton's Laws

Lesson 2.2 Forces 57

Friction and Gravity

Have students read the two paragraphs and study the photographs. **Figure 11** learn about friction and gravity. Then ask the following questions.

Guiding Questions

- OL** What would happen if the blue arrow were longer than the red arrow? *The player would slow down and stop sliding before he reached the base.*
- OL** Which types of forces are there between Earth and the Moon: contact, noncontact, or both? *There are only noncontact forces because Earth and the Moon do not touch.*

Distance, Mass, and Gravity

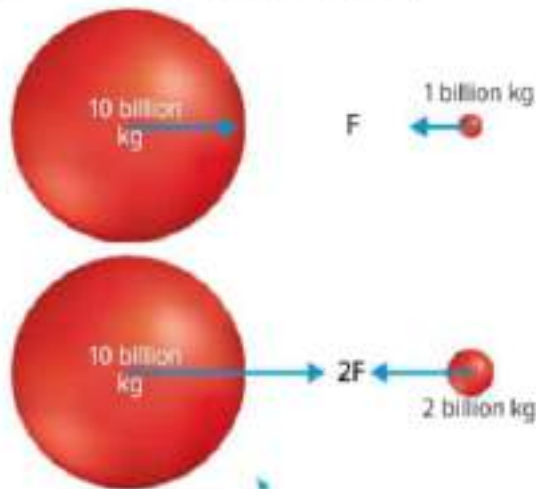
Explain to students that the strength of the noncontact force of gravity is affected by distance and mass. Review the terms **distance**, **mass**, and **gravity**. Distance affects the strength of the force of gravity. Have students read the paragraphs and study the diagram. **Figure 12** ask the following questions to assess their understanding.

Guiding Questions

- OL** What is weight? *Weight is the measure of the force of gravity that acts on an object.*
- OL** What effect does mass have on gravity? *They provide the major site of photosynthesis for the plant.*
- OL** In the diagram in Figure 12, what is 550 N; 56.25 N; 493.75 N the astronaut's weight on Earth and in space? What is the difference between the two? *As the mass of the objects increases, the force between them increases. As the distance between the objects increases, the force between them decreases.*

Visual Literacy: Figure 13

Have students compare the force of attraction between the two sets of spheres shown in Figure 13. Then ask the following.



Ask: Describe the acceleration of the bottom spheres due to the gravitational force between them. The bottom spheres accelerate toward each other with twice the gravitational force as the top spheres because the mass of the spheres on the right has been doubled.

Combining Forces

Ask students to imagine a tug-of-war game. Have them predict how a two-person team could beat a three-person team and if a five-person team could beat a four-person team. Then have students read the paragraph. Return to the imagined team configurations. Have students use the words forces and combined forces to explain their predictions.

Forces in the Same Direction and in Opposite Directions

Have students read the paragraphs and study the images in Figure 14 and Figure 15.

Guiding Questions

- OL** What would the total force be if the 200 N boy on the far right in Figure 14 stopped pulling?
- OL** Why is the net force of the top image in Figure 15 0 N? *The total force of the team on the right is 300 N and the total force of the team on the left is 300 N. When you add them together, the sum is 0 N.*
- BL** How could you explain the change from balanced to unbalanced forces in the two versions of Figure 15? *One of the individuals exerted more force in the second version of the image. That caused the net force on the left to be greater than the net force on the right.*

Differentiated Instruction

AL Play a Game of Concentration Have students work in pairs to write the following terms on separate index cards: contact force, noncontact force, balanced force, unbalanced force, net force, gravity, and friction. Ask them to use what they have learned from the lesson to write definitions for each term on another set of index cards. Then have them play a game of concentration by turning the cards face down on a table. They should take turns turning the cards over, two at a time, to match a term to its definition. After all the matches have been made, the player with the highest number of cards wins.

BL Forces and Rubber Balls Have partners play with rubber balls on the floor or a smooth surface while analyzing forces. Ask them to write a brief report to identify when the forces acting on the balls were balanced or unbalanced. For example, if a ball is resting on a table, the sum of the forces between the ball and the table and gravity are balanced, so the ball does not move.

LA Create a Picture Book Have students create a picture book to compare how gravity affects different objects on Earth and on the Moon. The pictures in their books should illustrate their understanding of how distance and mass affect gravity.

Teacher Toolbox**Teacher Demo**

Balanced or Unbalanced? Set up a two-pan balance scale. Place a 20-g mass on the right pan and a 40-g mass on the left pan. **Ask:** Is the scale balanced? **How do you know?** No, it is unbalanced because one pan is lower than the other. **Ask:** How could you balance the scale? Add a 20-g mass to the right pan. Add the additional 20-g mass. **Ask:** How do you know the scale is now balanced? The pans are now the same height. Explain that when the scale is balanced the pans are level; neither one is lower than the other. Something similar happens when balanced forces act on an object. Its motion does not change.

Real-World Science

Gravity Around the Solar System Gravity isn't just different on the Moon than it is on Earth. It's different on other planets because each planet has a different mass. Of the four terrestrial planets, gravity is weaker on Mercury and Mars, but it's about the same on Venus as it is on Earth.



2.2 Review



Figure 18 Forces in the same direction act as a single force.

Visualize It!

5. What would the total force be if the person on the right stopped pulling?



Figure 19 No change in motion occurs when forces on an object are balanced. Unbalanced forces cause the object to change its motion.

Engage Your Learners!

6. How do balanced and unbalanced forces differ?

Combining Forces

Have you ever played tug-of-war? If you alone pull against a team, you will probably be pulled over the line. However, if you are on a team, your team might pull the rope hard enough to cause the other team to move in your direction. When several forces act on an object, the forces combine to act as a single force. The sum of the forces acting on an object is called the net force.

Forces in the Same Direction

When different forces act on an object in the same direction, you can find the net force by adding the forces together. Figure 18 each team member pulls in the same direction. The net force on the rope is $100 \text{ N} + 100 \text{ N} = 200 \text{ N}$.

Forces in Opposite Directions

When forces act in opposite directions, you must include the direction of the force when you add them. Like numbers on a number line, forces in the direction to the right are normally considered to be positive values. Forces to the left are negative values. In the first panel of Figure 19, the team on the right pulls with a force of 100 N . The team on the left pulls with a force of -100 N . The net force is $100 \text{ N} + (-100 \text{ N}) = 0$.

Balanced and Unbalanced Forces

The net force on the rope in the Figure 18 is 0 N . When the net force on an object is 0 N , the forces acting on it are **balanced forces**. If the forces acting on an object are balanced, the object's motion does not change. When the net force acting on an object is not 0 , the forces acting on the object are **unbalanced forces**. The forces acting on the rope in the Figure 19 are unbalanced. Unbalanced forces cause objects to change their motion, or accelerate.

Visualize It!



Forces are pushes and pulls exerted by objects on other objects. Contact forces occur when objects are touching. Friction is a contact force that acts from a distance.



Gravity is a force of attraction between two objects. The amount of gravitational force depends on the mass of the objects and the distance between them.



Balanced forces do not change motion. Unbalanced forces change motion.

Summarize It!

5. How do different types of forces affect objects?

6. What factors affect the way gravity acts on objects?

7. How do balanced and unbalanced forces affect?

Balanced and Unbalanced Forces

Have students read the paragraphs and study the image in Figure 15 to explain the difference between balanced and unbalanced forces. Have them imagine a book resting on a classroom desk. Gravity exerts a downward force on the book while the desk exerts an upward force. The sum of these forces is 0 N . That means the forces are balanced and the book does not move. However, if the book rested on the back of a chair that exerted a much smaller upward force, the forces would become unbalanced; the book would fall off the chair and to the floor.

Guiding Questions

- AL** If an object begins to move faster, are balanced forces or unbalanced forces acting on it?
- CL** How do balanced and unbalanced forces differ? *Unbalanced forces affect the motion of an object. Balanced forces do not.*
- BL** How can you tell that an unbalanced force is acting on an object? *The motion of the object changes. It could change direction or change speed, or both.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. Which Key Concept does each image relate to?

Summarize It!

- What are Forces?
- Friction and Gravity
- Combining Forces

Use Vocabulary

1. Classify the following examples into contact forces or noncontact forces.

contact forces	noncontact forces
----------------	-------------------

Understand Key Concepts

2. As the distance between two objects increases, the gravitational force between the objects
 - A. increases.
 - B. decreases.
 - C. creates friction.
 - D. stays the same.

3. Describe forces acting on a cyclist who is slowing down as he or she climbs a hill.

4. Identify balanced and unbalanced forces acting on a book resting on a table.

Interpret Graphics

5. Copy and complete graphs to explain how distance and mass affect the force of gravity.



6. Analyze four forces acting on the airplane flying at an altitude of 5000 m, as shown below. How do the forces affect the plane's motion?



Critical Thinking

7. Construct a diagram that shows three forces acting on an object in the same direction and two forces acting in the opposite direction. Give the forces values that would cause no change in motion.

My Notes



Use Vocabulary

1. Friction is a contact force that slows down the sliding motion between two objects that are touching.

2. noncontact forces

Understand Key Concepts

3. B. decreases.

4. Gravity is pulling him down. The seat of the bike is pushing him up. The force produced by his feet pushing on the pedals is less than the force of friction on the bike, so the forces are unbalanced and he slows down.

5. There are no unbalanced forces. The upward force of the table balances the downward force of gravity.

Interpret Graphics

6. As two objects get farther apart, the gravitational force between them decreases. As the mass of one or both objects increases, the gravitational force between them increases.

7. The arrows indicate that the up and down forces (lift and gravity) are balanced. The front and back forces (thrust and drag) are also balanced. Therefore, the plane must be flying at a constant speed.

Critical Thinking

8. The diagram should show the sum of the three forces acting in one direction but equal the sum of the two forces acting in the opposite direction.

2.3 Newton's Laws of Motion

INQUIRY

How does this feel?

Rides like this are called thrill rides because the riders feel as if they are going to crash, fall, or take off into space. How do forces cause these sensations? Why are the bars that hold the riders in place so important?

Write your response in your Science Journal.



Explore Activity

How are forces and motion related?

In the last lesson, you read about different forces acting on objects. Sometimes forces can produce unexpected results. In this lab, you will observe the effect of forces on an object's motion.

Procedure

1. Read the patterns and identify the lightbeams before work begins.
2. Place a **card** on a **plastic** jar. Center it off the center top of the jar.
3. Pick the card away horizontally. Observe the reaction of the jar. Record your observations about the motion in your Science Journal.
4. Spread a sheet of **paper** on the table with about 10 cm hanging over the edge.
5. Place a **book** on the **paper** along top of the paper. Then quickly pull the edge of the paper straight down. Record your observations in your Science Journal.

Think About This

1. Identify the forces acting on the objects in steps 3 and 5.

2. Key Concept How do you think forces are related to the motion of the objects?

Essential Questions

- How do unbalanced forces affect an object's motion?
- How are the acceleration, the net force, and the mass of an object related?
- What happens to an object when another object exerts a force on it?

Vocabulary

- inertia: Newton's first law of motion
- Newton's second law of motion
- Newton's third law of motion
- force pair

INQUIRY

About the Photo How does this feel? Thrill rides at amusement parks must undergo rigorous tests to make sure they are safe. Bars, harnesses, helmets and other safety measures counteract the forces of gravity and the pushes and pulls exerted by the ride itself to protect the people who ride them.

Guiding Questions

- AL** Describe what it might feel like to go on this ride. *Sample answer: As the ride pushes and pulls the cars forward and back, up and down, it feels like you are flying and zipping through the air.*
- CL** How do the bars affect the motion of the riders? *The bars prevent the riders from flying off the ride and into the air. They keep the riders safe while the ride is in motion.*
- BL** How do the bars impact the force of gravity? *The bars counteract the force of gravity and prevent the riders from falling off the ride and toward the ground.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Build on Prior Knowledge

1. Have students discuss the meaning of the term *law*, and the ways we use it in everyday speech. For example, a law can be a rule, a practice, a custom, a way of organizing something, and so on.
2. Explain that, in science, a law is a fact or a rule that is based on evidence and observation. Scientific laws can be demonstrated and understood by using experiments.
3. Ask students to name a scientific law they may already know or have studied. For example, the Law of Conservation of Energy states that energy cannot be created or destroyed, only converted into another form. Students may also be familiar with the Law of Conservation of Mass, which states that mass cannot be created or destroyed, only changed into other forms.
4. Explain that in this lesson they will learn about three laws of motion that were revealed by English scientist I. Newton in the 1600s.

ExploreActivity

Teacher Notes

How are forces and motion related?

Prep 5 min Class 15 min

Purpose

To observe what happens to an object at rest when an unbalanced force acts on it and when balanced forces act on it.

Materials

Student: Index card, plastic jar, 5-fils coin, newspaper, book, paper clip, pen or pencil

Before You Begin

Ask students if they have ever seen a magician pull a tablecloth out from under dishes. Discuss how this is possible. Suggest that they think about the forces acting on the dishes and the tablecloth. Draw a data table on the board that students can copy into their Science Journals.

	Book	Pen	Paper clip	Nickel
Describe motion when force was applied				coin fell straight into the jar

Guide the Investigation

- Students should be able to describe motion and to explain how it affects contact forces and noncontact forces.
- Have students practice flicking the card off the glass. Put anything on top. Demonstrate how to pull the edge of the newspaper straight down quickly. Ask students to consider the different motion in each experiment.
- Troubleshooting:** If students push on the card or pull the paper too slowly, the activity will not work.

Think About This

- In each step, gravity pulls the object(s) down.
- Key Concept:** Simple answer: The card moved sideways because I pushed it. Gravity pulled the coin into the jar. The paper moved because I pulled it. Maybe gravity held the book down. The paper clip and pen were lighter so maybe gravity didn't pull as hard and they moved easier.



Journal

Before reading this module, write down what you already know in the first column. In the second column, write down what you expect to learn. After you have completed this module, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

FOLDABLE

Use two sheets of paper to make a folded book. Label it as shown. Use it to organize your notes on Newton's laws.

Science Use v. Common Use

Science Use: tendency to resist a change in motion

Common Use: lack of action

Newton's Laws

Newton's Laws recall that forces are measured in a unit called a newton (N), named after the English astronomer who studied the motion of objects. Newton summarized his findings as three laws of motion. You demonstrate Newton's laws when you run to catch a baseball or ride your bike. How could you use Newton's laws to explain how the rules and the games at an amusement park work?

Newton's First Law

What causes the motion of amusement park rides to give riders a thrill? Whether protective devices to hold you in your seat, you could fly off the ride! The tendency of an object to oppose a change in motion is **inertia**. Inertia acts to keep you at rest when the ride starts moving. It also keeps you moving in a straight line when the ride stops or changes direction. Your safety belt keeps you in the seat and moving with the ride.

Newton's First Law of motion: that if the net force acting on an object is zero, the motion of the object does not change. In other words, an object remains at rest or in constant motion unless an unbalanced force acts on it. Newton's first law of motion is sometimes called the law of **inertia**.

Effects of Balanced Forces

Suppose you are at an amusement park and you want to ride a free fall ride, such as the one shown in **Figure 18**. How does the ride illustrate Newton's first law of motion? Recall that when the forces acting on an object are balanced, the object is either at rest or moving with a constant velocity.

Objects at Rest: the top of the ride, the force of the cable pulling upward on the car is equal to the force of gravity pulling downward on the car. Gravity and the cables pull on the car equally, but in opposite directions, so the forces are balanced. The car is at rest, as shown in the first panel **Figure 18**. As long as the forces remain balanced, the car remains at rest.

Objects in Motion: lift the car to the top of the ride, the cable pulls upward. When a short acceleration, the car moves upward at a constant speed. The force of the cable pulling upward is the same size as the force of gravity pulling downward. With the forces once again balanced, the car rises to the top of the ride at a constant velocity. This is shown in the second panel of **Figure 18**. Newton's first law describes the car's motion when the forces applied to it are balanced.

Balanced forces act on the car only when it is at rest or moving with a constant velocity. When the car reaches the top of the ride, it doesn't remain at rest for long. When the operator releases the upward pull on the cable, the forces become unbalanced. Gravity causes the car to accelerate toward the ground. Because inertia tends to keep you at rest, the car feels as if it falls out from under you. Your safety belt acts as an unbalanced force to keep you attached to the car.




Figure 18 A free fall ride at an amusement park. The forces on the car are balanced in both images because the forces are balanced.

Thinking with Science

What happens to the velocity of the car when the upward pull of the cable is greater than the downward pull of gravity as the car rises toward the top?

Describe

Put the book down from this section in the book corner.

Newton's Laws

Have students discuss their experiences **Launch Lab**. Remind students that a force is a push or pull that sets objects in motion. **Ask** Would the book, pen, or paper clip have moved if you hadn't pulled on the paper?

Newton's First Law

Discuss how the **Launch Lab** relates to Newton's first law of motion. Ask students to name the parts of Newton's first law that relate to the lab. Objects such as the coin, book, pen, or paper clip remain at rest until a force sets them in motion. Once the index card was pulled, the coin was in motion until it was stopped by the bottom of the jar.

Science Use v. Common Use

Inertia

Have students compare the science definition of inertia to the everyday use of the word, for which *inactivity* and *motionless* are synonyms. **Ask:** How do all three terms relate to the science use of inertia? All three terms describe something that resists a change in motion. The science use of inertia relates to an object that is moving, as well as one that is still.

Effects of Unbalanced Forces

Remind students that the definition of acceleration is the change in an object's velocity during a period of time. Have students read the paragraphs and study the diagrams in **Figure 12** and the photo in **Figure 18**. Then ask the following questions to informally assess their understanding.

Guiding Questions

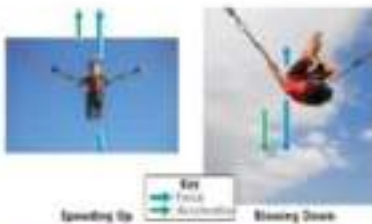
18 If the downward force on an object is greater than the upward force, are the forces balanced or unbalanced?

19 If one force on an object is 5 N upward and the other is 10 N downward, what is the object's motion?

The object is accelerating downward.

20 How might wind add to the forces acting on the people on the chair swing ride? Wind might push against the swings and make the ride bumpier as the people spin around.

Figure 12 Unbalanced forces cause the bungee jumper to speed up or slow down.



Key Concept

If a net force on an object is 5 N upward and the other is 10 N downward, what is the object's motion?

Effects of Unbalanced Forces

Take control of your seat in the amusement park with a ride on the reverse bungee jump. According to Newton's first law of motion, the motion of an object changes only when a net force acts on it. This ride gives you two chances to experience what a net force can do.

Speeding Up After the ride ascends, releases you, the upward force of the bungee cord is greater than the downward force of gravity. The forces are unbalanced as shown by the blue arrows in the left image. Figure 12 The net force acting on you is upward, and you **accelerate** upward as shown by the green arrow.

Slowing Down As you approach the top of your bungee jump, the cord becomes slack, as shown in the right image. The blue arrow shows that the upward force becomes less than the downward force of gravity. Even though you are still moving upward because of inertia, the net force is now due to the downward force of gravity. You slow down, or **decelerate**.

Changing Direction Your next stop is a swing ride such as the one shown in Figure 13. When the ride starts to turn, the force of the cables pulls you closer toward the center of the ride. The force of gravity acts downward. Because these forces don't act in opposite directions, the unbalanced force constantly changes your direction. You **accelerate** as you move in a circle.

The designers of amusement park rides use inertia to excitement. Much of what makes a swing ride fun is the fact that you might fly off the side with careless safety. The safety belt didn't hold you in place.



Figure 13 The unbalanced force of the cable is applied to swing riders, as evidenced in a circle.

Newton's Second Law of Motion

Suppose you play a carnival game in which you throw a ball to knock over wooden bottles, as in Figure 14. You throw the ball, but not all the bottles fall over. On your second try, you use all your strength to throw the ball as fast as you can. The ball hits the bottles and they all fall over.

When you throw the ball the second time, the ball left your hand with a greater final velocity than when you threw it the first time. This means the acceleration of the second ball was greater than the acceleration of the first ball. When this **Newton's second law of motion** states that the acceleration of an object is equal to the net force applied to the object divided by the object's mass. When you throw the ball the second time, you used your muscles and arms to push harder, or increase the force, on the ball. When you increased the force, the ball's acceleration increased. The decreased acceleration required for a greater final velocity of the ball at a left your hand.



Figure 14 Using a large force to throw a ball gives you the best chance of knocking over the bottles.

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}} \quad a = \frac{F}{m}$$

Calculating Acceleration

You can use the equation to calculate the acceleration of the ball. If you apply a net force of 10 N to a ball with a mass of 0.5 kg, what is the ball's acceleration?

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}} \quad \text{acceleration} = \frac{10 \text{ N}}{0.5 \text{ kg}} = 20 \frac{\text{m}}{\text{s}^2}$$

What do you think would happen to the acceleration if you double the force on the ball? The equation tells you!

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}} \quad \text{acceleration} = \frac{20 \text{ N}}{0.5 \text{ kg}} = 40 \frac{\text{m}}{\text{s}^2}$$

When you double the force, the acceleration also doubles.

Changing the Mass

What would happen to the acceleration if the force you apply stays the same, but the mass of the ball changed instead of 0.5 kg? The ball has a mass of 1.0 kg.

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}} \quad \text{acceleration} = \frac{10 \text{ N}}{1.0 \text{ kg}} = 10 \frac{\text{m}}{\text{s}^2}$$

If twice the mass has half the acceleration, Newton's second law helps you predict what combination of force and mass you need to get the acceleration you need.

Key Concept
How are the acceleration, the net force, and the mass of an object related?

Newton's Second Law of Motion

Have students read the paragraph and Figure 15 to learn how this relates to Newton's second law of motion. Then have students consider what new information they have learned about acceleration.

Ask What is the acceleration of the book or the pen? the net force exerted on it divided by the mass of the object. The bigger the mass, the smaller the acceleration.

Calculating Acceleration

Tell students that another way to express this concept is $F = ma$. Multiplying kilograms by meters/seconds squared results in Newtons, which is the unit of force. Newton is the "shorthand" version of $\text{kg} \times \text{m/s}^2$. Write the equation $F = ma$ on chart paper on the board to help students understand that force equals mass multiplied by acceleration.

Guiding Questions

GL How fast would a 0.3-kg ball accelerate if the net force were 6 N? The acceleration would be 20 m/s².

BL How does increasing the force affect the acceleration? How does decreasing the force affect it? Increasing the force increases the acceleration. Decreasing the force decreases the acceleration.

Visual Literacy: Calculating Acceleration and Changing the Mass

Students might find learning two equations for acceleration helpful. Explain the logical steps:

$$\begin{aligned} \text{If } a &= \frac{F}{m} \\ \text{and } a &= \frac{(v_f - v_i)}{t} \\ \text{then } \frac{F}{m} &= \frac{(v_f - v_i)}{t} \end{aligned}$$

These equations can be written on the board.

The final equation shows that if a larger force is applied to an object (left numerator), then a greater change in velocity will occur (right numerator). In addition, if the mass of an object increases (left denominator), then the time to make a given change in velocity must also increase (right denominator). **How are the acceleration, the net force, and the mass of an object related?** They are related using Newton's second law: $F = ma$. As either mass or acceleration increase, force increases.

Figure 20 Two cars exert a force on the same car in the opposite direction. The ground that each car exerts a force on is also shown.



Visual Question

A What happens when two objects exert a force on a second object?

Visual Question

B If the force of the player's head on the ball is 15 N upward, what is the force of the ball on the player's head?

Figure 21 The opposite forces of the player's head and the ball are shown.



Newton's Third Law of Motion

Suppose you are driving bumper cars with a friend, like in **Figure 20**. What happens when you crash into each other? **Newton's third law of motion** states that when one object exerts a force on a second object, the second object exerts a force of the same size, but in the opposite direction, on the first object. According to Newton's third law, the bumper cars apply forces on each other that are equal but in opposite directions.

Action and Reaction Forces

When two objects apply forces on each other, one of the forces is called the **action force**, and the other is called the **reaction force**. For example, if the left car hits the right car in **Figure 20**, the force exerted by the left car is the action force. The force exerted by the right car is the reaction force.

Force Pairs

As you walk, you push against the ground. If the ground did not push back with equal force, gravity would pull you down into the ground! When two objects exert forces on each other, the two forces are **force pairs**. The opposite forces of the bumper cars hitting each other in **Figure 20** are a force pair. Force pairs are not the same as balanced forces. Balanced forces combine or cancel each other out because they act on the same object. Each force in a force pair acts on a different object.

In **Figure 21**, the player exerts a force on the ball. The ball exerts an equal but opposite force on the player. When the two forces exerted change more than the player's motion, the player's head and neck work together. Newton's first law explains that the player's head and neck exert forces on each other. His third law explains that the forces of the head and neck are equal in size. The mass of the head is less than the mass of the player. A force of the same size gives the head a greater acceleration than the player's head.

Newton's Laws in Action

Newton's laws do not apply to all motion in the universe. For example, they don't exactly predict the motion of very tiny objects, such as atoms or electrons. They do not work for objects that approach the speed of light.

However, because Newton's laws apply to the moving objects you observe each day, from amusement park rides to the movements of stars and planets, they are extremely useful. Using Newton's laws, humans have traveled to other planets and invented many useful tools and machines. You can often see the effects of all three laws at the same time. Think about everyday examples of Newton's laws in action. Think about Newton's laws as you move through your day.

Table 1 Newton's laws explain the motions you experience every day.

Table 1 Newton's Laws in Action			
Example	Newton's First Law	Newton's Second Law	Newton's Third Law
Pushing 	The upward and downward forces on the ball are balanced. The motion of the ball is not changing. It is at rest.	Because the ball is at rest, its acceleration is 0 m/s ² . You can check force on the ball. The net force is 0 N. $F = ma$ $0 = 2 \text{ kg} \times 0 \text{ m/s}^2$ $0 = 0 \text{ N}$	The ball of gravity pulls the ball down, so it stays at rest. The ball exerts a force on the hand with a force that is the same size, but in the opposite direction.
Walking 	The forces acting on the leg walking along the ground are balanced. The leg moves forward at a constant speed in a straight line.	When an object moves at a constant speed, there is no acceleration. A net force is needed to make it start, stop, or change direction.	The foot pushes against the ground. The ground pushes on the foot. The foot moves forward.
Skateboarding 	Pushes against the ground with the skateboard on wheels, the board produces a net force by pushing the foot on the road.	When the foot pushes on the ground and the road, the board and the foot accelerate at a rate. The road exerts an equal but opposite force on the foot. The foot moves forward.	The foot pushes against the ground. The ground pushes on the foot. The foot moves forward.

Force Pairs

Have students read the paragraphs and study the photo of the soccer players in **Figure 21**. Clarify that you never combine forces in force pairs because the forces are acting on different objects. Review this in terms of the tug-of-war example. Then ask the following questions.

Guiding Questions

- AL** When two objects exert forces on each other, what are those forces called?
- CL** If the force of the girl's head on the ball is 15 N downward in **Figure 21** is 15 N upward, what is the force of the ball on the girl's head?
- BL** Picture two students pushing a wagon. Are the two forces a force pair? Do the forces exerted by the students on the wagon make a force pair? Why or why not?

Newton's Laws in Action

Have students review Newton's three laws of motion by restating them in their own words. Then ask them to read the paragraph and study **Table 1**.

Guiding Questions

- AL** Do Newton's three laws apply to all motion in the universe? Explain your answer.
- CL** Which kinds of motion do not necessarily follow Newton's three laws?
- BL** Newton did not realize that his laws did not apply to very small or very fast-moving objects. What might be one reason for this?

the motion of very tiny objects, such as atoms and electrons, and the motion of very fast objects that approach the speed of light.

Sample answer: Newton did not have any way to study very small or very fast-moving objects, so he was not able to determine whether his laws applied to them.

Visual Literacy: Newton's Laws in Action

Have students compare the examples in **Table 1**. Then ask the following questions to assess their understanding.

Ask: How do you know that the table is exerting a force on the bowl of fruit? *If it weren't, the bowl would move downward.*

Ask: How is the woman walking on the sand an example of a force pair? *The woman is producing a net force by pushing on the sand. The sand pushes back with equal force.*

Newton's First Law	Newton's Second Law	Newton's Third Law
The upward and downward forces on the bowl are balanced. The motion of the bowl is not changing. It is at rest.	Because the bowl is at rest, its acceleration is 0 m/s ² . You can use Newton's second law to calculate the force on the bowl: $F = m \times a$ $F = 2 \text{ kg} \times 0 \text{ m/s}^2$ $F = 0 \text{ N}$	The force of gravity pulls the bowl down so it exerts a force on the table. The table pushes up on that bowl with a force that is the same size, but in the opposite direction.
The forces acting on the woman are balanced. Their inertia keeps her moving at a constant speed in a straight line.	When an object moves at a constant velocity, there is no acceleration. A net force would have to act on her before she would speed up or slow down.	The woman's feet push against the sand as she walks. The sand pushes on the woman's feet with equal force, moving her forward.



Teacher Toolbox

Reading Strategy

Active Reading Have each student write down three sentences in this lesson that they believe most clearly represent the main ideas. Read key sentences in the text and have students raise their hands if they have written down the same sentence. Ask students to defend their choices.

Real-World Science

Seat Belts and Newton's First Law When a car moves forward, passengers inside the car also move forward at the same speed. But, if the car stops suddenly, the passengers would remain in motion unless an outside force caused them to stop. That's why seat belts are so important. When a car suddenly stops in an accident, the motion of the passengers would hurtle them against the car or out of the car altogether if they weren't wearing seat belts. Seat belts protect passengers and prevent injury by providing an unbalanced force that affects motion.

Intervention Planner

Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1–2)

- Science Use v. Common Use, inertia
- Visual Literacy: Newton's Laws in Action
- Content Vocabulary

Understand Key Concepts (3–4)

- Key Concept Checks
- Key Concept Builder

Interpret Graphics (5–6)

- Visual Literacy: Changing the Mass; Figures 17, 20

Critical Thinking (7–9)

- Visual Literacy: Newton's Laws in Action
- Enrichment
- Challenge

2.3 Review

Newton's Laws

Visualize It!



Newton's first law of motion states that the motion of an object remains constant, unless acted on by an outside force. This also is called the law of inertia.



Newton's second law of motion relates an object's acceleration to its mass and the net force applied to the object.



Newton's third law of motion states that for every action force, there is an equal and opposite reaction force. The two forces are called a force pair.

Summarize It!

1. How do unbalanced forces affect an object's motion?

2. How are the acceleration, the net force, and the mass of an object related?

3. What happens to an object when another object exerts a force on it?

Use Vocabulary

1. **Describe** example of Newton's third law of motion.

Understand Key Concepts

2. In order to accelerate, an object must be acted on by

- A. a force pair.
- B. a large mass.
- C. balanced forces.
- D. unbalanced forces.

3. **Interpret** A car moves with a constant velocity of 5 m/s. What would you need to know to calculate the net force on the car?

5. **Copy and complete** graphs by describing each of Newton's laws.



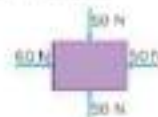
Critical Thinking

6. **Apply** Why does a bus on the way of a car slide around on the way when the car speeds up, slows down, or turns a corner?

7. **Predict** What would happen if two people with equal mass standing on skateboards pushed against each other?

Interpret Graphics

4. **Analyze** The diagram below shows the forces acting on a box. Describe the motion of the box.



8. **Solve** A hockey player hits a 0.2 kg puck that accelerates at a rate of 20 m/s². What force did the player exert on the puck?

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Which Key Concept does each image relate to?**

Summarize It!

- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Newton's Laws in Action

Use Vocabulary

1. **Sample answer:** When my feet press on the floor, the floor presses back on my feet with equal force, but in the opposite direction. When I press the keys on the computer, the keys push back with equal force, but in the opposite direction.
2. Newton's first law relates forces to objects that are at rest or in constant motion. Newton's second law relates forces to objects that are accelerating.

Understand Key Concepts

3. **Unbalanced forces.**
4. There is no net force because the rider is moving at a constant velocity.

Interpret Graphics

5. The box will move to the right, with a net force of 10.
6. Newton's first law states that if the net force acting on an object is zero, the motion of the object does not change. The second law states that the acceleration of an object is equal to the net force exerted on the object divided by the object's mass. Newton's third law says that when one object exerts a force on a second object, the second object exerts a force of the same size, but in the opposite direction, on the first object.

Critical Thinking

7. The inertia of the box keeps it moving in whatever direction the car was moving before it changes its speed or direction.
8. Both people would move backward with the same acceleration.
9. 4 N

2 Study Guide

The BIG Idea

Forces are pushes and pulls that may change the motion of an object. Balanced forces result in an object remaining at rest or moving at a constant speed. Unbalanced forces result in the acceleration of an object.

Key Concepts Summary

2.1 Describing Motion

- An object's **motion** depends on how it changes position. Motion can be described using **speed**, **velocity**, and **acceleration**.
- Speed is how fast an object moves. Velocity describes an object's speed and the direction it moves. Acceleration describes the rate at which an object's velocity changes.
- A graph can show you how either the displacement or the speed of an object changes over time.



Vocabulary

motion
reference point
distance
displacement
speed
velocity
acceleration

2.2 Forces

- A **force** is a push or pull on an object. **Contact forces** result from objects touching. **Noncontact forces** act without touching. Examples include gravity, magnetism, and static electricity.
- Gravity is a force of attraction between any two objects. Gravitational force increases as the masses of the objects increase and decreases as the distance between the objects increases.
- Balanced forces** acting on an object cause no change in the motion of the object. **Unbalanced forces** on an object cause the motion to change. If the forces are not equal in size, the unbalanced force causes acceleration.

Newton's second law

force
contact force
noncontact force
friction
gravity
balanced forces
unbalanced forces

2.3 Newton's Laws of Motion

- Inertia** is the tendency of an object to resist a change in motion. **Newton's first law of motion** states that an object will remain at rest or in constant motion unless acted upon by an unbalanced force.
- Newton's second law of motion** states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.
- Newton's third law of motion states that for every action force, there is an equal but opposite reaction force. The action-reaction forces are **interdependent**.



inertia
Newton's first law of motion
Newton's second law of motion
Newton's third law of motion
force pairs

FOLDABLES

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



Use Vocabulary

- An object is _____ if the reference between it and a fixed position is not changing.
- Give a specific example of motion.
- Explain what must happen to an object in order for it to accelerate.
- Explain what must happen to an object in order for it to accelerate.
- What kinds of things can you predict using Newton's second law of motion?
- The law of gravity is another name for _____.
- How can you explain the forces that act when a ball is thrown upward?
- A _____ describes how forces that act on different objects.

Link Vocabulary and Key Concepts

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



Key Concepts Summary



Vocabulary

Study Strategy: Match Pictures to Captions

Students sometimes remember what they have studied without developing a true understanding of the concepts.

- To help students better understand what they have read in this chapter, ask them to rewrite the key concepts in their own words in their Science Journals.
- Then ask them to locate photographs in magazines, newspapers, or on the Internet that illustrate those ideas. For example, for the key concept that explains speed they might clip a photo of a race car. For the key concept that relates to gravity, they might clip a photo of a football falling from the air in the middle of a game.
- After finding photos to match each concept, have students put them together on a poster, using their key concept sentences as captions for the different images.

The motion of an object can be described using a position or reference point.

Study Strategy: Write a Quiz

When students write possible test questions based on the vocabulary terms and definitions they have learned, it takes some of the mystery out of assessment.

- Divide students into groups of four.
- Have each student develop a ten-question quiz based on the vocabulary words. Encourage students to include a variety of question types including true-false, matching, fill-in-the-blank, multiple choice, and short answer.
- Have each student exchange papers with another group member, who will take the quiz. Then, that student passes the completed quiz to another group member, who will grade it.
- Encourage groups to discuss how writing questions helped them complete a quiz.

Example:

A _____ is a push or a pull from one object to another when the two are touching each other.

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.



Use Vocabulary

- | | |
|--|--|
| 1. displacement | 5. Newton's 2nd law can predict the mass of an object, an object's acceleration, or the force acting on an object. |
| 2. Motion takes place when a increases the distance between her and the starting line. | 6. Newton's first law of motion |
| 3. gravity, magnetism, electricity (any two) | 7. Newton's third law of motion |
| 4. its speed or direction must change. | |

Link Vocabulary and Key Concepts

- | | |
|---|-------------------------------------|
| 9. reference point | 13. unbalanced |
| 10. displacement | 14. no change in an object's motion |
| 11. how fast an object changes position | 15. Newton's second law of motion |
| 12. speed in a given direction | |

Teacher Notes

Understand Key Concepts

1. In which situations are the distance and the displacement the same?

- A girl flies from her room to the ground and back to her room.
- A car chases its tail in a circle four times.
- A fish swims all the way across a pond and then halfway back.
- A worm moves 5 cm along a straight crack in a sidewalk.

2. The graph below represents the motion of a swimmer. Which statement best describes the swimmer's motion?



- The swimmer is at rest.
- The swimmer is in constant motion.
- The swimmer's speed is changing.
- The swimmer is accelerating.

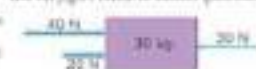
3. An airplane travels 200 km between Austin and Dallas in 1 h 15 min. What is its average speed?

- 160 km/h
- 200 km/h
- 212 km/h
- 250 km/h

4. Which represents a force pair?

- A book pushes down on a table, and gravity pulls the book toward the floor.
- A boy's foot pushes down on a bicycle pedal. The pedal pushes up on his foot.
- A golf club hits a golf ball. Gravity pulls the ball back down to Earth.
- A person's foot pushes on the floor, and the person's weight pushes on the floor.

Use the figure below to answer questions 5–7.



5. What is the net force on the object?

- 30 N to the right
- 30 N to the left
- 60 N to the right
- 60 N to the left

6. Which statement best describes the motion of the object?

- It accelerates to the right.
- It remains at rest.
- It doesn't change speed but changes its direction of motion.
- It moves at constant speed to the right.

7. What is the acceleration of the object?

- 0 m/s²
- 1.0 m/s² to the right
- 1.5 m/s² to the right
- 2.0 m/s² to the left

8. Which is a contact force?

- A girl pulls the plug of an electric hair dryer from the socket.
- A coal falls to the ground because of Earth's gravitational force.
- A magnet pulls on a coin 2 cm away.
- A sheet of paper is pulled toward an electrically charged comb.

9. Which best describes the relationship between the force acting on an object, the object's mass, and the acceleration of the object?

- Newton's first law of motion
- Newton's law of inertia
- Newton's second law of motion
- Newton's third law of motion

Critical Thinking

10. Contrast the force of gravity between these pairs of objects: a 1-kg ruler and a 2-kg mass that are 1 m apart; a 1-kg mass and a 2-kg mass that are 2 m apart; and two 2-kg masses that are 1 m apart.

11. Construct a displacement-time graph and a speed-time graph for an elevator moving at a constant speed to the second floor, which is 12 m above the first floor. The trip takes 15 s. Label a displacement-time graph and a speed-time graph of its ride.

12. Calculate the average speed of a runner who runs 42.0 km in 3 h 45 min. What was the runner's average speed?

13. Justice's brother measured the weight of an object in space and decided that there is no net force acting on the object. Which of Newton's laws helped the astronomer make this decision?

14. Astronauts photo showed an astronaut tethered to a spacecraft. Use Newton's laws to describe what will happen when the astronaut pushes against the spacecraft.



Math Skills

Solve One-Step Equations

- A runner covers a distance of 1,300 m in 8 min. What is the runner's average speed?
- Leaving the starting block, the runner accelerates from a speed of 0 m/s to a speed of 2 m/s in 3 s. What is the runner's acceleration?
- What acceleration is produced when a 3,000-N force acts on a 1,200-kg cart? Ignore any friction.
- What force would a boxer have to exert on a 4-kg ball?

Writing to Learn

15. Write a story about a person who is a surfer. Describe the surfer's motion as they ride the wave. Use Newton's laws of motion to write a judgment on the surfer's motion.

The BIG Idea

16. Write a story about a person who is a surfer. Describe the surfer's motion as they ride the wave. Use Newton's laws of motion to write a judgment on the surfer's motion.

17. In what ways did balanced and unbalanced forces affect the motion of the surfer in the air? What forces caused them to be into the air? What forces are acting on them in the water?



Understand Key Concepts

- D. A worm moves 5 cm along a straight crack in the sidewalk.
- B. The swimmer is in constant motion.
- C. 232 km/h
- B. A boy's foot pushes down on a bicycle pedal. The pedal pushes up on his foot.
- A. 30 N to the right
- A. It accelerates to the right.
- B. 1.0 m/s² to the right
- A. A girl pulls the plug of an electric hair dryer from the socket.
- C. Newton's second law of motion

Critical Thinking

- The force of gravity is the least between the 1 kg and 2 kg masses that are 2 m apart. It is greatest between the 2 2-kg masses that are 1 meter apart.
- The displacement-time graph should show a straight line with an upward slope extending from (0,0) to (15,12). The speed-time graph should show a horizontal line from (0,12) to (15,12).
- 11.2 km/hr
- She must have observed the object moving at a constant velocity, which would mean that the forces acting on it were balanced. Newton's first law
- When the astronaut pushes against the spacecraft, the spacecraft will exert an equal but opposite force on the astronaut, causing him to accelerate away from the spacecraft (Newton's third law) until he reaches the end of the tether and an outside force acts on him (Newton's first law). Because his mass is less than that of the spacecraft, the astronaut will accelerate away from the spacecraft at a greater rate than the spacecraft will move away from him (Newton's second law).

Writing in Science

15. Students should dismiss the claim of the man because, if the van had been moving forward and suddenly stopped, the surfboard would have continued moving forward, not backward (Newton's first law).

Intervention Planner

Based on the results of the Chapter Review, use the chart below to address individual needs.

Lesson	Questions	Intervention Options
Understand Key Concepts		
1	1–3	Key Concept Builders
2	5–6, 8	Content Practice
3	4, 6–7, 9	
Critical Thinking		
1	11–12	Enrichment
2	10	Challenge
3	13–14	
Writing in Science		
3	15	Language Arts Enrichment
Review the Big Idea		
2	16	Content Practice
3	17	Enrichment Challenge
Math Skills		
	18–21	Math Skills Math Practice: Solve for Average Acceleration

TheBIG Idea

16. As you carry the box up the stairs at a constant speed, the upward force you exert on yourself and the box is equal to the force of gravity. The forces are balanced. When you set the box down, the force of gravity downward equals the force of the step upward, so the forces are balanced. When you lift the box again, you must apply a net upward force to overcome inertia and get the box accelerating upward.
17. When the acrobats were standing on the bars, the forces on them were balanced. The men holding the bars caused the bars to exert an upward, unbalanced force that pushed the acrobats into the air. At present, their upward motion has stopped and the force of gravity is an unbalanced force that will start them falling back toward the bar.

Math Skill

Solve One-Step Equations

18. 375 m/min, or 6.25 m/s
19. 0.7 m/s
20. 2.5 m/s
21. 24 N



Standardized Test Practice

Standardized Test Practice

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

Multiple Choice

1. Which is the result of an object's motion?

- A a change in mass
- B a change in position
- C a change in reference point
- D a change in volume

2. Which would be used to calculate an object's acceleration?

- A change in its time divided by speed
- B change in its velocity divided by time
- C change in its speed divided by velocity
- D change in its velocity divided by speed

Use the table below to answer questions 3 and 4.

Car	Initial Speed (m/s)	Final Speed (m/s)	Time (s)
A	0	25	10
B	20	15	10
C	15	25	20
D	10	10	25

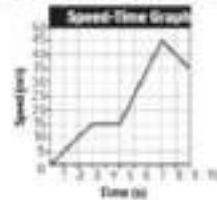
3. Which car had a negative acceleration?

- A car A
- B car B
- C car C
- D car D

4. Which car or cars had an acceleration greater than 2 m/s^2 ?

- A car A only
- B car B only
- C cars A and C
- D cars A, C, and D

Use the graph to answer questions 5 and 6.



5. During which time period did the object slow down?

- A 0–3 seconds
- B 3–5 seconds
- C 5–8 seconds
- D 8–10 seconds

6. Which term describes the motion in the time period from 3 to 5 seconds?

- A at rest
- B constant speed
- C slowing down
- D speeding up

7. Which is a contact force?

- A gravity
- B friction
- C magnetic force
- D electrical force

8. Which pair causes the force of gravity between two objects to increase?

- A if both objects start to spin
- B if one object decreases in mass
- C if both objects decrease in mass
- D if the objects move farther apart

9. Which could be the net force acting on an object when the forces are balanced?

- A 10 N
- B 0 N
- C 2 N
- D 10 N

Use the diagram to answer question 10.

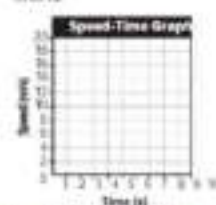


10. The skateboarder is hovering at a constant speed. Which describes the net force acting on the skateboarder when the two forces suddenly act on him?

- A The skateboarder stops.
- B The speed increases.
- C The speed decreases.
- D His motion stays the same.

Constructed Response

Use the blank graph to answer questions 11 and 12.



11. Describe how a period of constant acceleration would appear on a speed-time graph.

12. Describe how a period of nonconstant, positive acceleration would appear on a speed-time graph.

13. How does increasing the mass of an object affect the acceleration of an object if the forces acting on the object remain the same? Explain.

14. According to Newton's third law of motion, what happens when you push on a sturdy wall with a force of 50 N?

Multiple Choice

- 1 **B—Correct.** D: Incorrect. Both describe properties unaffected by motion. C: Incorrect. A change in reference point involves a change in the description of motion.
- 2 **B—Correct.** Incorrect. This formula does not include direction. C, D: Incorrect. These formulas do not include time.
- 3 **B—Correct.** C: Incorrect. These cars show a positive acceleration. D: Incorrect. This car shows no acceleration.
- 4 **A—Correct.** Incorrect. This car has an acceleration of -1 m/s^2 . C: Incorrect. This answer includes car C, which has an acceleration of 0.5 m/s^2 . D: Incorrect. This answer includes car D, which has an acceleration of 0 m/s^2 .
- 5 **D—Correct.** B, C —At 0–3 seconds the object is speeding up. At 3–5 seconds the object is at constant speed. At 5–8 seconds the object is speeding up.
- 6 **B—Correct.** B, C —Incorrect. From 3–5 seconds, the horizontal (zero slope) line of the speed-time graph indicates that the speed of the object was unchanging.
- 7 **B—Correct.** C, D—All are noncontact forces.

- 8 **B—Correct.** Incorrect. Both objects starting to spin does not describe a change in distance or mass. C, D: Incorrect. Both objects decreasing in mass or moving farther apart would reduce the force of gravity between the objects.
- 9 **B—Correct.** C, D—These show non-zero net forces, which means the forces are unbalanced.
- 10 **D—Correct.** The forces acting on the skateboarder are balanced. A, B, C— Stopped motion, increased speed, or decreased speed describe what could happen if the forces acting on the skateboarder were unbalanced.

Constructed Response

- 11** A period of constant acceleration would appear as a straight line: positive slope indicates positive acceleration, zero slope (horizontal) indicates zero acceleration, negative slope indicates negative acceleration.
- 12** A period of nonconstant, positive acceleration would appear as a curved line sloping upward.
- 13** Acceleration is force divided by mass. Thus, a constant force divided by an increased mass would give a decreased acceleration.
- 14** The wall pushes with an equal force of 10 N in the opposite direction, which is back on you.

Answer Key

Question	Answer
1	B
2	B
3	B
4	A
5	D
6	A
7	B
8	B
9	B
10	D
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.



Foundations of Chemistry

TheBIG Idea

What is matter, and how does it change?



3.1 Classifying Matter

- What is a substance?
- How do atoms of different elements differ?
- How do mixtures differ from substances?
- How can you classify matter?



3.2 Physical Properties

- What are some physical properties of matter?
- How are physical properties used to separate mixtures?



3.3 Physical Changes

- How can a change in energy affect the state of matter?
- What happens when something dissolves?
- What is meant by conservation of mass?



3.4 Chemical Properties and Changes

- What is a chemical property?
- What are some signs of chemical change?
- Why are chemical equations useful?
- What are some factors that affect the rate of chemical reactions?



Does amount matter?

Some properties of matter depend on how much matter there is. Put an X next to all of the statements you think are true about properties of matter.

- ___ A. The more you have of a substance, the greater its density is.
- ___ B. The more you have of a substance, the greater its volume is.
- ___ C. The more you have of a substance, the higher the temperature needed to reach its boiling point.
- ___ D. The more you have of a substance, the greater its mass is.
- ___ E. The more you have of a substance, the lower the temperature needed to freeze it.
- ___ F. The more you have of a substance, the less its electrical conductivity.

Explain your thinking. What rule or reasoning did you use to decide whether the amount of matter made a difference in its properties?

Chapter: Foundations of Chemistry 78

Foundations of Chemistry

TheBIG Idea

Accept all reasonable responses. Write student-generated questions on chart paper and return to them as you study the chapter.

Guiding Questions

- A1** Identify something that contains matter. *Encourage students to think about what matter is. They might name examples of solids and liquids. Guide them to see that air and other gases are also matter.*
- A2** In what ways can matter change? *Students might make observations related to seasonal changes, such as snow falling or leaves changing color. Responses might include: objects breaking, food decaying, or soil eroding. Help students recognize changes that takes place over a period of time or change that is subtle. Promote students' thinking about a visible change by having them compare matter before, during, and after a change has occurred.*
- B1** Name something that does not contain matter. *Students might be able to identify energy, thoughts, and emotions as not containing matter.*



Does amount matter?

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about the foundations of chemistry. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

- The atoms in all objects are the same.**
Disagree. Different substances contain different types of atoms.
- You cannot always tell by an object's appearance whether it is made of more than one type of atom.**
Agree. Tests must be performed to determine if the object is an element, a compound, or a mixture.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* American Association for the Advancement of Science (AAAS), Benchmarks for Science Literacy, New York: Oxford University Press.

* Materials may be composed of parts that are too small to be seen without magnification.

* Substances may move from place to place, but they never appear out of nowhere and never disappear.

* Objects can be described in terms of the materials of which they are made and their physical properties.

When a new material is made by combining two or more materials, it has properties that are different from the original materials.

* Many types of changes occur faster under warmer conditions.

Lesson 1

Classifying Matter



1 A substance is a type of matter that always is made of atoms in the same combinations.

2 Atoms of different elements have different numbers of protons.

4 Matter can be classified as either a substance or a mixture.

3 The composition of a substance cannot vary. The composition of a mixture can vary.

Lesson 2

Physical Properties



5 Physical properties of matter include size, shape, texture, and state.

2018

6 Physical properties, such as density, melting point, boiling point, and size, can be used to separate mixtures.

Lesson 3

Physical Changes



7 A change in energy can change the state of matter.

8 When something dissolves, it mixes evenly in a substance.

9 The masses before and after a change in matter are equal.

Lesson 4

Chemical Properties and Changes



10 Chemical properties include the acidity, ability to burn, and the ability to rust.

11 Some signs that might indicate chemical changes are the formation of bubbles and a change in odor, color, or energy.

12 Chemical equations are useful because they show what happens during a chemical reaction.

13 Some factors that affect the rate of chemical reactions are temperature, concentration, and surface area.

Identifying Misconceptions

Believing Is More Than Seeing Heat It Up!

Find Out What Students Think

Students may think that...

... properties don't exist unless they can be seen with our eyes. They might think that the only physical properties a substance has are those that are directly observable. Some students might not realize that some properties must be measured or calculated.

Discussion

Discuss with students different physical properties that can be determined by observation, such as luster, color, and shape. Then, discuss properties that must be measured, such as mass, volume, density, melting point, boiling point, conductivity, and solubility. Talk about some of the different ways to learn about the physical properties of substances. **Ask** What do all plants need to survive? **You can measure its mass and volume and calculate density by dividing mass by volume.** How can you find the melting point or boiling point of a substance? How do most plants get water and nutrients? **Plants can heat it and measure its temperature as it begins to melt.** Remind students that although direct observation is important, it is not the only way to learn about the properties of substances.

Promote Understanding Activity

1. Have students work in teams to investigate the properties of three different everyday substances, such as water, baking soda, and sugar. They should note the state of each substance at room temperature, the color, texture, and smell. They should also research properties that they can't observe, including density, and melting and boiling points.
2. After completing their research and investigations, have them create a table similar to **Table 1 in Lesson 2** to describe the properties of each substance. Encourage them to include drawings, diagrams, or images clipped from newspapers or magazines to illustrate each concept. Their tables should also identify ways to measure or observe the properties for each substance.
3. Each team should share their completed tables with other members of the class.

Find Out What Students Think

Students may think that...

the transfer of thermal energy happens only as the result of a chemical reaction. They might not realize that the addition or removal of thermal energy can also affect physical and chemical changes.

Discussion

Remind students that thermal energy can lead to a change of state, which relates to the physical properties of melting point and boiling point. **Ask** What happens to your bare hands when you hold a snowball? **They get cold.** **Ask** Where does the thermal energy from your hands go? **Thermal energy transfers from your hands to the snowball.** What happens to the snowball as a result? **It melts and changes state from a solid to a liquid.** Emphasize that the melting of the snowball was caused by the transfer of thermal energy. Explain that adding thermal energy can also increase the rate of chemical reactions, such as when you cook a meal.

Promote Understanding Activity

1. Have students work in groups. Distribute ice cubes, paper towels, and gloves or mittens to each group. Instruct students to hold an ice cube for 1 min and note their observations. Then have them dry their hands and place them into a glove or mitten to warm up.
2. Have the group discuss what they experienced both when holding the ice cube and when wearing the glove in terms of the transfer of thermal energy.
3. Lead a discussion about what it feels like outside on a hot day versus a cold day. During the discussion, reinforce that students should describe heating processes as the transfer of thermal energy to and from substances.



3.1 Classifying Matter

INQUIRY

Making Green? Do you have primary mixed paints together? Maybe you wanted green paint and had only yellow paint and blue paint. Perhaps you realized an artist mixing several colors gives the color he or she wanted. In all these instances, the final color came from mixing colors together and not from changing the color of a paint.

Write your response in your science notebook.



LABManager
MultiLabview can you make the colors?

80 Chapter 3

Explore Activity

How do you classify matter?

An object made of substances together might be classified as a **compound**. Painted metal objects might be classified as **mixtures**. How can you classify an object as it is used?

Procedure

- Read the procedure and identify the **variables** before work begins.
- Place the objects in the **bins** that you might separate the objects into groups with these characteristics:
 - Every object is one and has only **one** part.
 - Every object is made of more than one part.
 - Each object is a different. Some have one part, and others have more than one part.
- Identify the **bins** that meet the requirements for groups and record them in your Science Journal. Repeat with groups A and C. An object can be more than one group.

Think About This

- Does any object from the beginning is all three of the groups A, B, and C? Explain.

- What objects in your classroom would fit into group B?

- Key Concept** What descriptions would you use to classify items around you?



Essential Questions

- What is a **substance**?
- How do elements of different elements differ?
- How do mixtures differ from substances?
- How can you classify matter?

Vocabulary

matter
substance
element
compound
mixture
heterogeneous mixture
homogeneous mixture
soluble

INQUIRY

About the Photo Making Green? painter's palette is used to mix colors to create colors and shades. Painters can combine two or more colors to create a unique color. Discuss with students the three primary colors—blue, yellow, and red—and how they can be combined in many ways.

Guiding Questions

- How does the artist make new colors? *New colors of paint are made from different colors that have been combined. For example, pink is a mix of red and white.*
- How do you know that the wood of the palette is also made from different components of the wood things mixed together? *Answers might include that you can see different components of the wood.*
- How might the types of matter in this photo show that most materials are made from mixing things together? *Even the single-color paints are made from a pigment and an oil or an acrylic. Everything shown in the photo is formed from things mixed together.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary Describing the World Around Us

- Write the words **element** and **compound** on chart paper or on the board. Place each word in a separate column.
- Ask students to describe what they think an element or a compound is. **Ask:** What do you think these terms mean? **How might they be related?** Write their responses in the appropriate column. Students should be able to relate the analogy of pure colors and mixed colors and to elements and compounds.
- Brainstorm other relationships. Examples include numbers (10) and their divisors (5, 2; 1, 10); a car and the many parts and materials that make it; a recipe: separate ingredients and final dish.
- After completing the lesson, have students return to their initial answers. Ask them to compare their original ideas to the definitions and concepts they learned in the lesson.

ExploreActivity

How do you classify matter?

Prep 15 min Class 15 min

Purpose

To develop classification skills and raise questions about the composition of matter.

Materials

Student Group of 3-4: 1-sealing bag containing 4 of each of the following: large paper clips, metal washers, threaded metal bolts with nuts, large paper clips hooked to metal washers, nuts threaded onto bolts, bolt/washer/nuts all connected

Before We Begin

- Assemble the materials into bags.
- Have students think about how matter differs by asking them to identify 1) objects in the room that contain only one part, such as a rubber band or a blank piece of paper; and 2) objects that contain several parts, such as a pencil (eraser, body, lead), or a chair (plastic seat, metal legs).

Guide the Investigation

- Point out that several different objects can be used to form the groups. There is more than one correct answer for each group.
- If students have difficulty understanding how a group can contain objects that are alike but contain several parts, point out that the chairs/desks in the room are alike, but contain parts made of different materials.

Think About This

Encourage students to hypothesize if they don't know the answer.

1. No; each object has either one part or more than one part, so the same object could not go into both Groups A and B. Objects from Groups A and B can go into Group C, so long as no objects identical to them are already in the group.
2. Sample answers: books (covers and pages), chairs (seats, legs, backs, screws)
3. **Key Concept:** Sample answer: I could group things that look like one substance, such as aluminum foil, clear glass, or water, into one group, and objects made from more than one substance, such as soil or wood, in another.

Teacher Notes

Objective
Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Atoms

To understand why there are so many types of matter, it helps if you first learn about the parts of an atom. Look at the diagram of an atom, **Figure 2**. The center of an atom is a nucleus. Protons, which have a positive charge, and neutrons, which have a neutral charge, make up the nucleus. Negatively charged particles, or electrons, move quickly throughout an area around the nucleus called the electron cloud.

Not all atoms have the same number of protons, neutrons, and electrons. Atoms that have different numbers of protons differ in their properties. You will read more about the differences in atoms on the next page.

An atom is almost too small to imagine. Think about how small a nucleus has to be. The diameter of a nucleus has to be about a **million** times greater than the diameter of an atom. In addition, an atom is about 10,000 times wider than its nucleus. Even though atoms are so tiny, they determine the properties of the matter they compose.

Check Your Understanding

What are the parts of an atom?

Word Origin
Matter comes from the Latin word *materia*, meaning "material, stuff."




Figure 1 You can see different types of matter in this rock.

Understanding Matter

Have you ever seen a rock like the **Figure 1**? Why are different parts of the rock different in color? Why might some parts of the rock feel harder than other parts? The parts of the rock look and feel different because they are made of different types of matter. **Matter** is anything that has mass and takes up space. If you look around, you will see many types of matter. If you are in a classroom, you might see things made of metal, wood, or plastic. If you go to a park, you might see trees, soil, or water in a pond. If you look up in the sky, you might see clouds and the sun. All of these things are made of matter.

Everything you can see is **matter**. However, some things you cannot see also are matter. Air, for example, is matter because it has mass and takes up space. Sound and light are not matter. Forces and energy also are not matter. To decide whether something is matter, ask yourself if it has mass and takes up space.

Atoms are small particles that are the building blocks of matter. This lesson, you will explore the parts of an atom and how different atoms can differ. You will also read how different atoms of matter make up the many types of matter.

Chapter 3: Understanding Matter

Lesson 3.1: Understanding Matter

Understanding Matter

Students often associate the term matter with solid objects, rocks, books, and tables. Help them recognize that water and air are matter.

Guiding Questions

- AL** What are some questions you can ask to identify matter?
Sample questions: Does it have mass? Does it take up space?
- OL** How are atoms "building blocks of matter"?
Building blocks are used to construct different objects, just as atoms build types of matter.
- EL** If light, sound, force, and energy are not matter, how do we know anything about them?
Properties of things that are not matter have been determined by observing how they interact with matter.

Word Origin

matter

Have students read the Latin origin of matter and ask the following questions.

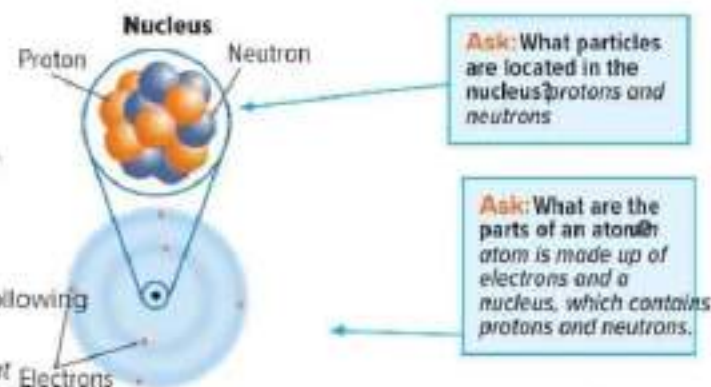
Ask: What stuff do you see in **Figure 1**? Students should note that rocks of different colors and textures are different kinds of matter.

Atoms

Explain that the atom shown in **Figure 2** is a two-dimensional simplification that makes it easier to think about a three-dimensional atom. In real life electrons move incredibly fast around a nucleus.

Visual Literacy: Figure 2

Have students examine the diagram of the atom **Figure 2**.



Ask: Where are the positively and negatively charged particles located in the diagram? *Protons have positive charge and are located in the nucleus, while the electrons, which move around the nucleus, have negative charge.*

Substances

Students will investigate a variety of atoms and the different ways that they can be combined. As each new term and concept is introduced, reinforce the proper use of the terms. This will help to identify whether a student is adopting a misconception. Use these questions to assess understanding.

Guiding Questions

- OL** What is a substance? *A substance is a classification of matter that is made up of one or more types of atoms in the same combinations. A substance is either an element or a compound.*
- AL** Name one example of something that is a substance. *Sample answers: aluminum, oxygen, water, sugar*
- BL** If you have a glass of pure water from a spring in Canada and a glass of water from a pond in California, would they be the same because both glasses contain the same substance (water)? A substance always consists of the same kinds of atoms arranged in the same way no matter where it is found. Explain your answer.

Differentiated Instruction

- AL Atom-a-Go-Go** Have students work in groups to create a model of an atom using building blocks or balls of clay. Students should make sure to include an equal number of protons and electrons in each atom.
- BL Element Detectives** Have students work in groups to brainstorm elements that they have heard of (or refer to the periodic table). Students should review the periodic table and list some basic properties of each element, including the number of protons and electrons; whether it is a solid, liquid, or gas; whether it is a metal; what it is used for; and where it can be found naturally.
- LA Fishing for Matter** Direct students to create a chemistry card game by dividing students into groups of three or four. Students can use markers and index cards. On a pair of index cards, each student will draw and label an image depicting each of the following four terms: matter, atom, substance, and element. Review their drawings. Have students mix up all the cards in the group and go fishing to match terms to images.

Teacher Toolbox



Fun Fact

The Fleeting Elements Atoms with more than 92 protons in their nucleus aren't stable, so scientists synthesize them artificially by colliding two atoms together. These super-heavy atoms break down extremely quickly.

Reading Strategy

K-W-L It Using a K-W-L worksheet and vocabulary terms, have students complete the first two columns from the lesson. After the lesson is completed, have them fill in the final column on their charts.

Teacher Demo

Deconstructing Matter Make a car, a plane, or other easily recognizable object out of toy building blocks.

1. Have students describe the object. Break it apart into individual building blocks.
2. Brainstorm ways that the blocks are similar and ways they are different.
3. Discuss ways to group the blocks, such as by color, size, or the number of pegs on each block.
4. Organize blocks according to their suggestions. Compare and contrast the blocks to atoms.
5. Students suggest ways the toy blocks could be used to demonstrate vocabulary terms. For example, a single block could represent an element, other blocks joined together could be a compound.

Substances

You can see that atoms make up most of the matter on Earth. Atoms can combine and arrange in millions of different ways. In fact, these different combinations and arrangements of atoms are what make up the various types of matter. There are two main classifications of substances and mixtures.

Substance matter with a composition that is always the same. This means that a substance is always made up of the same atoms. There are about 115 known elements, there are combinations of atoms. Also, various mixtures are made up of different types of atoms. Each type of water and sugar are examples of substances. **Atom** smallest particle of matter that cannot be created or destroyed. The number of protons in an atom is the atomic number of the element. Therefore, the atomic number of hydrogen is 1, as shown in Figure 3.

The atoms of most elements exist as individual atoms. For example, a roll of pure aluminum foil consists of millions of individual aluminum atoms. However, the atoms of some elements usually exist in groups. For example, the oxygen atoms in air exist in pairs. Whether the atoms of an element exist individually or in groups, each element consists only one type of atom. Therefore, its composition is always the same.

Figure 3: Atoms arranged in the periodic table showing different types of atoms.



of the same combinations of atoms. To gain a better understanding of what makes up substances, let's take a look at the two types of substances: elements and compounds.

Elements

Look at the periodic table of elements on the inside back cover of this book. The substances oxygen and aluminum are on the table. They are both elements. **Element** a substance that cannot be broken down into simpler substances by chemical means. It is made up of only one type of atom. There are about 115 different types of atoms. Each type of water and sugar are examples of substances. **Atom** smallest particle of matter that cannot be created or destroyed. The number of protons in an atom is the atomic number of the element. Therefore, the atomic number of hydrogen is 1, as shown in Figure 3.

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Elements

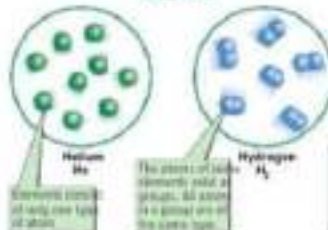
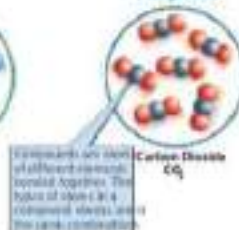


Figure 4: A substance contains only one type of atom. It is an element. It contains only one type of atom. It is an element.

Compound



Compounds

Water is a substance, but it is not an element. It is a compound. A **compound** is a type of substance made up of two or more different elements chemically bonded together. As shown in Figure 4, carbon dioxide (CO₂) is a compound. It consists of atoms of two different elements, carbon (C) and oxygen (O), bonded together. Carbon dioxide is a substance because the C and O atoms are always combined in the same way.

Chemical Formulas The combination of symbols and numbers that represents a compound is called a chemical formula. Chemical formulas show the different atoms that make up a compound, using their element symbols. Chemical formulas help explain how the atoms combine. As shown in Figure 5, CO₂ is the chemical formula for carbon dioxide. The formula shows that carbon dioxide is made of C and O atoms. The small 2 is called a subscript. It means that two oxygen atoms and one carbon atom form carbon dioxide. If no subscript is written after a symbol, one atom of that element is present in the chemical formula.

Properties of Compounds Think again about the elements carbon and oxygen. Carbon is a black solid, and oxygen is a gas. When they combine to form the compound carbon dioxide, which is a gas used in fire. A compound often has different properties than the elements that combine to form it. Compounds, like elements, are substances, and all substances have their own properties.

Figure 5: Carbon dioxide is a compound made of two different types of atoms (Carbon and Oxygen) bonded together.



Elements

Elements, organized by atom type and displayed in the periodic table, are the basic alphabet of the language of matter. It is important for students to understand how, like letters, one atom differs from another.

Have students locate the periodic table on the inside back cover of their books and find the symbols for oxygen (O) and aluminum (Al). Then have them read the paragraphs and examine the image in Figure 3. Explain that the unique structure of atoms determines the properties of matter. Ask the following questions to assess your students' comprehension.

Guiding Questions

- Q1** How do atoms of different elements differ? *Atoms of different elements contain different numbers of protons.*
- Q2** What is the total number of protons contained in two oxygen atoms? *There are 16 protons in two oxygen atoms.*
- Q3** Do you think most of the materials in the world are pure elements, or are they made up of a combination of elements? *Most materials are made up of a combination of elements, just as there are many more recipes for cake than there are cake ingredients alone.*

Compounds

Remind students that elements are always made of the same kind of atom, whereas compounds consist of different kinds of atoms that are bonded together. Writing out a compound's chemical formula is a helpful way to recognize the elements it contains.

Academic Vocabulary

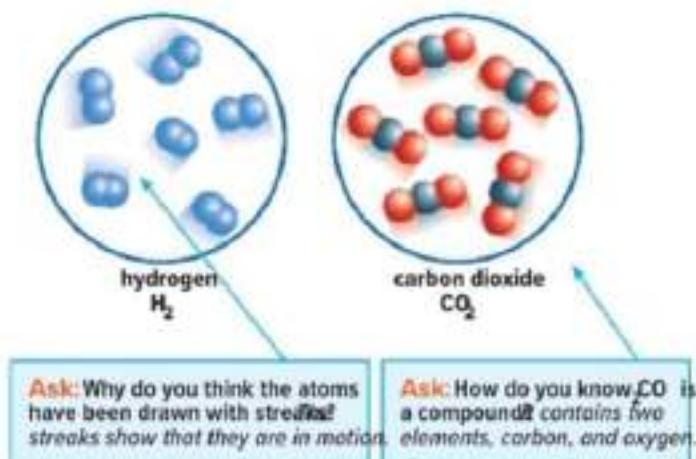
Unique How is the uniqueness of a compound similar to the uniqueness of a work of art, such as a painting? *A compound and a painting have a set of properties or qualities that no other substance or work of art has.*

Guiding Questions

- Q1** What does a chemical formula show? *It shows the different kinds and numbers of atoms that make up a compound, using their chemical symbols.*
- Q2** How do you know NaHCO₃ is a compound? *NaHCO₃ contains more than one type of atom, so it is a compound.*
- Q3** Are the properties of one compound always different from every other compound? *Compounds might have some properties that are similar, but the set of all properties of a compound is unique.*

Visual Literacy: Figure 4

To understand elements and compounds, students need to be able to differentiate between the two kinds of substances. Have students examine Figure 4 while you ask them the following questions.



Mixtures

Students might believe that you can identify a mixture by its appearance. That is, one must be able to see that two or more substances are mixed together for it to be a mixture. To address this misconception, use the following questions.

Guiding Questions

- AL** How do substances combine in a mixture? *In a mixture, substances blend together physically, but do not bond chemically.*
- OL** Could you separate all the substances that make up mud? Why or why not? *Yes, because mud is a mixture made up of substances that have blended together but not bonded together. So, it's possible to physically separate them.*
- BL** Do you think it is possible to identify something as a mixture just by looking at it? Why or why not? *Not necessarily. Some mixtures blend so well that you can't see the substances of which they are made. However, a microscope might help determine if a material is a mixture.*

Differentiated Instruction

AL Social Mixing Help students to envision the different kinds of mixtures by having them work together to model mixtures. Assign half the students as Substance A and the rest as Substance B. For a heterogeneous mixture, break the A group into teams of three to four students. Have them hold hands in a circle. Then instruct them to move as a group through the B group. The students in the B group should be "clumped" together or more spread out. For the homogeneous mixture, have the two groups intermingling individually with one another.

BL How pure is your water? Obtain the tap water test results from your local water district or research the water quality in your community online. Then have students research a list of the substances commonly found in the tap water in your area. Lead students in a discussion of each substance, have them describe where these substances might come from and how they might be removed, based on the results of their research.

LA Word Wizards Have students work together in groups to examine each of the vocabulary words in this lesson and come up with ways to simplify their sounds and meanings. Ask groups to come up with a creative way to learn the words, such as a rhyme, a song, hand gestures, or some other kinesthetic activity to help them understand the vocabulary terms.

Teacher Toolbox

Reading Strategy

20 Questions Have students work in teams to research the properties of five common compounds, such as water, sugar, and carbon dioxide. Then have them gather into a large group to play a game of 20 Questions. One person should pick a substance while the others ask no more than 20 yes-or-no questions to identify it.

Teacher Demo

Salty Solution Make a solution of Epsom salt in water in a clear container, so that the class is able to observe the dissolving. Show the students that the salt has completely dissolved and is a homogeneous mixture. Pour some of the solution into an aluminum pan and allow it to sit overnight so that crystals can form and students can observe that the salt and water were both present in the mixture.

Reading Strategy

Compare and Contrast Have students complete a two-column chart that lists the similarities and differences among compounds, homogeneous mixtures, and heterogeneous mixtures.

Mixtures

Another classification of matter is mixtures. **Mixtures** are combinations of two or more substances that are physically blended together. The amounts of the substances can vary in different parts of a mixture and from mixture to mixture. Think about sand mixed with water at the beach. The sand and the water do not blend together. Instead, they form a mixture. The substances in a mixture do not combine chemically. Therefore, they can be separated by physical methods, such as filtration.

Homogeneous Mixtures

Mixtures can differ depending on how well substances that make them up are mixed. **Homogeneous mixtures** are mixtures in which the substances are evenly mixed, but not chemically combined. For example, a mixture of sand and water from a beach will have the same composition throughout. **Heterogeneous mixtures** are mixtures in which the substances are not evenly mixed. For example, a mixture of oil and water will have different layers. **Compounds** are substances in which the atoms of different elements are chemically combined in a fixed ratio. For example, water (H₂O) is a compound. It is made of two hydrogen atoms and one oxygen atom. The composition of a compound is always the same.

Figure 3.1 Types of mixtures differ in how evenly their substances are mixed.



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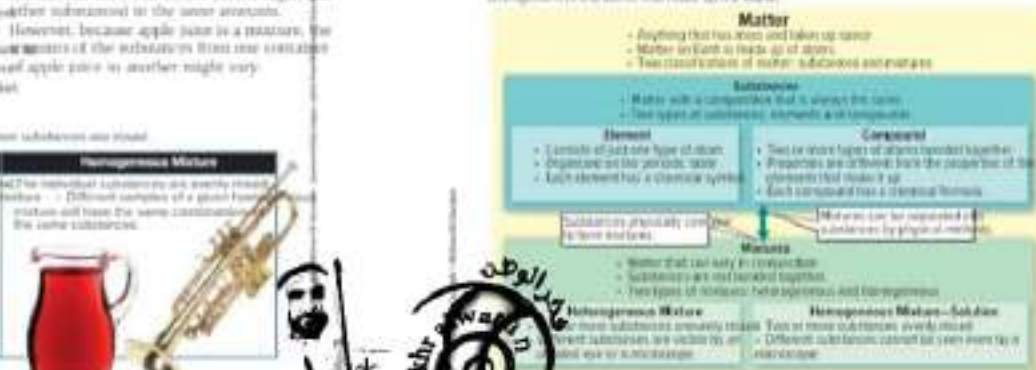
Compounds v. Solutions

If you have a glass of pure water and a glass of salt water, you tell which is which just by looking at them. You can see the compound (water) and the solution (salt water) appear identical. How do compounds and solutions differ? Because water is a compound, its composition does not vary. Pure water is always made up of the same atoms in the same combination. Therefore, a chemical formula can be used to describe the atoms that make up water. H₂O water is a homogeneous mixture, or solution. The solute (NaCl) and the solvent (H₂O) are evenly mixed but are not bonded together. Adding more salt to more water only changes the relative amounts of the substances. In other words, the composition varies. Because composition can vary in a mixture, a chemical formula cannot be used to describe mixtures.

Summarizing Matter

You have read in this lesson about classifying matter by the arrangement of its atoms. Figure 3.2 is a summary of this classification system.

Figure 3.2 Matter is classified by the arrangement of its atoms. Matter can be a pure substance or a mixture.



Lesson 3.1 Summarizing Matter 87

Heterogeneous Mixtures

When two substances are not mixed evenly, they are said to be heterogeneous. A common example of a heterogeneous mixture is vinaigrette, a type of salad dressing that is a mixture of vinegar and oil. When the mixture is shaken, the oil droplets seem to blend with the vinegar droplets. But in only a few moments, they begin to separate from each other. (You might opt to demonstrate this.) Help students understand these concepts with the following questions.

Guiding Questions

- AL** What type of mixture is trail mix? *Trail mix is a heterogeneous mixture because the components of trail mix do not mix completely.*
- CL** Will two portions of a heterogeneous mixture always have the same amounts of substances in them? *No, because the individual substances in a heterogeneous mixture do not mix completely, so composition can vary throughout the mixture.*
- BL** Name one example of a heterogeneous mixture that you might eat for breakfast. *Answers will vary. Possible answers include cereal with fruit and milk, fruit salad, or an omelet with cheese and other ingredients.*

Homogenous Mixtures

Homogeneous mixtures appear to be a single substance to the naked eye. For instance, when sugar or salt is dissolved completely in water, there is no way to visually detect that it is a solution instead

of a pure substance. This is because the substances in the mixture are mixed together at the atomic level. Students might have a difficult time recognizing matter as a mixture if it appears uniform. Guide students in thinking about homogenous v. heterogeneous mixture by asking them the following questions.

Guiding Questions

- AL** What is the difference between a homogeneous mixture and a heterogeneous one? *A homogeneous mixture is mixed evenly, and a heterogeneous mixture is not.*
- CL** How do mixtures differ from compounds? *If a substance contains more than one type of atom, the atoms are chemically combined. A mixture is two or more substances physically mixed together, but not chemically combined.*

Compounds v. Solutions

There are many instances in which a solution looks the same as one of the substances from which it is made. For example, if you dissolve salt in water, it looks just like water. Solutions take on the state of the solvent because it is most abundant. Demonstrate this by pouring water into two identical glasses. Then add a small amount of salt into one and have students observe as you mix it until the salt is completely dissolved. Hold them out and have students observe that they look similar.

Guiding Questions

- AL** What does it mean to say that a glass of water means they look the same even if of water looks identical to a glass of salt water? *they do not have the same composition.*
- OL** How is a compound different from a solution? *a substance is an element or compound. Mixtures are combinations of two or more substances. Unlike substances, mixtures can have varying compositions and can be separated by ordinary physical means.*
- BL** What is the chemical formula for salt water? *there is no chemical formula for salt water, because the ratios of atoms in the solution can vary depending on the sample.*

Summarizing Matter

Classifying matter is important to identifying and comparing the basic properties of matter. Have students read the paragraph and study the flowchart in **Figure 7**. Assess students' understanding by asking the following questions.

Guiding Questions

- AL** Do substances consist of mixtures, or do mixtures consist of substances? Explain. *Mixtures consist of substances.*
- OL** How can you classify matter? *Matter can be classified according to whether it is a substance or a mixture. If it is a substance, it can be classified as to whether it is an element or a compound. If it is a mixture, it can be classified according to whether it is homogeneous or heterogeneous.*
- OL** Where in Figure 7 would you classify the things you see each day? *Possible answer: Most of the things I see each day are compounds or mixtures.*
- BL** Which methods do you think you can use to separate the substances in a mixture? *Possible answer: You might be able to use physical methods, such as filtering, magnetism, or boiling.*

Intervention Plan

Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1–3)

- IE** Word Origins, Understanding Matter
- OL** Quick Vocabulary
- Content Vocabulary

Understand Key Concepts (4–7)

- IE** Guiding Questions, Summarizing Matter
- OL** Key Concept Builder

Interpret Graphics (8–9)

- IE** Visual Literacy: Figure 4

Critical Thinking (10–11)

- IE** Guiding Questions, Substances
- OL** Enrichment
- Challenge



3.1 Review

Classifying Matter

Visualize It!



A substance has the same atoms or the smallest particles throughout an object that has its own chemical composition. A substance is either an element or a compound. A mixture is a combination of two or more substances that are not chemically combined. Mixtures can be either heterogeneous or homogeneous.

Summarize It!

1. What is a substance?

2. How do atoms of different elements differ?

3. How do mixtures differ from substances?

4. How can you classify matter?

Use Vocabulary

1. Substances and mixtures are two types of _____.

2. Use the term **mixture** in a complete sentence.3. Define **substance** in your own words.

Understand Key Concepts

4. Explain why aluminum is a substance.

5. The number of _____ always differs in atoms of different elements.

- A. electrons C. neutrons
B. protons D. nuclei

6. Distinguish between a heterogeneous mixture and a homogeneous mixture.

7. Classify each item: describes matter that is a substance made of different kinds of atoms bonded together?

Interpret Graphics

8. Describe what each letter and number means in the chemical formula below.



9. Organize Information and fill in the graphic organizer below to classify matter by the arrangement of its atoms.

Type of Matter	Description

Critical Thinking

10. Record the elements aluminum, oxygen, fluorine, sodium, and hydrogen from the least to the greatest number of protons. Use the periodic table if needed.

11. Evaluate this statement: Substances are made of two or more types of elements.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. Which Key Concept does each image relate to?

Summarize It!

- Understanding Matter
- Atoms
- Substances
- Mixtures
- Summarizing Matter

Use Vocabulary

1. matter.
2. Sample answer: Each oxygen atom contains eight protons.
3. Sample answer: When something dissolves, it breaks down into its simplest parts, which evenly distribute throughout another substance.

Understand Key Concepts

4. Aluminum is a substance because it is an element and contains only one type of atom.
5. B protons
6. The parts of a heterogeneous mixture are not evenly mixed. The parts of a homogeneous mixture are evenly mixed.
7. compound

Interpret Graphics

8. The C stands for carbon, the H stands for hydrogen, and the O stands for oxygen. The subscripts tell how many atoms of each element are in each unit of the compound. One unit of the compound contains 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.
9. Sample answer:

Type of Matter	Description
Substance	has a definite makeup
Mixture	has no definite makeup

Critical Thinking

10. hydrogen, oxygen, fluorine, aluminum, calcium

11. The statement is not always true. Some substances are made of one type of element. Other substances are made of two or more types of elements.

Teacher Notes

Teacher's Toolbox

Real-World Science

Kinds of Steel Steel is not a substance, but a kind of mixture called an alloy, which is a solid solution of iron with about 2 percent carbon dissolved in it. The higher the carbon content, the lower the temperature required to melt it. Other kinds of metal can also be dissolved in iron, such as chromium and tungsten, making different alloys with unique properties.

Careers in Science

Spectroscopist Microscopes are important in understanding the nature of matter, but they are especially important when trying to differentiate between a heterogeneous and homogeneous mixture in solids, such as rock samples. A spectroscopist uses an electron microscope to examine tiny portions of a sample to determine whether the substances in the mixture are mixed evenly or not.



3.2 Physical Properties

EXPLORE

Panning by Properties

The man knows his pan holds the mass of a rock and scoops up a mixture of water, sediment, and hopefully gold. As he moves the pan in a circle, water sloshes out of it. If he is careful, gold will remain at the bottom after the water and sediment are gone. What properties of water, sediment, and gold enable this man to separate this mixture?

Write your response in your science notebook.



Explore Activity

Can you follow the clues?

Clues are lots of information that help you solve a mystery. In this activity, you will use clues to help identify an object in the classroom.

1. Read the procedure and identify the safety concerns before work begins.
2. Select an object in the room. Write a different clue about the object on each of **index cards**. Clues might include one or two words that describe the object's color, size, texture, shape, or any property you can observe with your senses.
3. Stack your cards face down. Have your partner turn over one card and try to identify the object. Respond either "yes" or "no."
4. Continue turning over cards until your partner identifies your object or runs out of cards. Repeat for your partner's object.

Think About This

1. What kind of clues are the most helpful in identifying an object?

2. How would your clues change if you were describing a substance, such as milk or water, rather than an object?

3. How do you think the clues change in your



Essential Questions

- What are some physical properties of matter?
- How are physical properties used to separate mixtures?

Vocabulary

- physical property
- mass
- density
- viscosity

INQUIRY

About the Photo How does it move? During the gold rush era of the 1800s, miners often searched for gold this way. They dipped pans into rivers and streams and sifted through the water for gold nuggets. The nuggets were heavier than sand and other materials that they scooped up in their pans, which made it to separate them.

Guiding Questions

- AI** How is gold different from water? How is gold different from rocks? *Sample answer: Gold is a solid at room temperature while water is a liquid. Gold and rocks differ in color and texture.*
- OL** What is another method this miner might use to separate gold from river water? *Sample answer: He could boil the water until it evaporates and only gold remains because gold has a different boiling point than water.*
- OL** How can you use the vocabulary terms learned in Lesson 1 to describe some of the matter in this photograph? *Sample answers: water, sand, and gold are all matter made up of atoms; water is a compound; sand is a mixture; gold is an element; the sand and gold do not dissolve in the water.*

Do you think it would be possible to separate gold from a solid mixture, such as the side of a cliff? Why or why not? *Yes, but you might have to locate the gold by color or texture to distinguish it from the surrounding rock and then chip or chisel it out of the cliffside.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Thinking About Properties of Matter

1. Write the term *physical property* on chart paper or on the board.
2. Have students reflect about characteristics or qualities of matter that they have observed, such as color, size, shape, and textures.
3. Explain to students that the words characteristic and quality are often used synonymously with property.

4. Brainstorm with students a list of properties. Record their responses on the board.
5. After completing the lesson, have students reexamine the properties they listed earlier and identify which ones are physical properties.

ExploreActivity

Can you follow the clues?

Prep: 5 min Class: 15 min

Purpose

To encourage observation of properties to recognize types of matter.

Materials

Student: 5 index cards

Before We Begin

Select an object in the room. Model the activity by giving one- or two-word clues that describe shape, color, physical dimensions, or texture.

Guide the Investigation

Tell students to write a set of clues that are neither too specific, such as "red" or "white," nor too general, such as "a solid."

Think About This

1. **Sample answer:** Clues that narrow the possibilities are the most helpful.
2. Students might realize it is easier to describe an object than a substance. An object has measurable properties, such as shape and size. Encourage them to think about properties that can be measured, such as boiling point or density.
3. **Key Concept** **Sample answer:** I use similar clues to recognize people, places, and things around me.



Teacher Notes

Discover

Before reading this lesson, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Review Vocabulary

property a characteristic used to describe something

Physical Properties

As you read in Lesson 1, the arrangement of atoms determines whether matter is a substance or a mixture. The arrangement of atoms also determines the **properties** of different types of matter. Each element and compound has a unique set of properties. When substances mix together and form mixtures, the properties of the substances that make up the mixture are still present.

You can observe some properties of matter, and other properties can be measured. For example, you can say that gold is shiny, and you can find the mass of a sample of iron. Think about how you might describe the different substances and mixtures in the photo on the previous page. Could you describe some of the matter in the photo as a solid or a liquid? Why do the water and the rocks inside the pen behave the gold dust? Could you describe the mass of the various items in the photo? Each of these questions asks about the physical properties of matter.

physical property a characteristic of matter that can be measured without changing the identity of the substance

many types of physical properties, and you will learn about some of them in this lesson.

States of Matter

How do the diamond, water, and air differ? Recall that diamond is an element, water is a compound, and air is a mixture. How do these three types of matter differ? At some temperature, diamond is a solid, water is a liquid, and air is a gas. Solids, liquids, and gases are called states of matter. The state of matter is a physical property of matter. Substances and mixtures can be solids, liquids, or gases. For example, water in the ocean is a liquid, but water in an iceberg is a solid. In addition, water vapor in the air above the ocean is a gas.

Did you know that the particles, or atoms and groups of atoms, that make up all matter are constantly moving and are attracted to each other? Look at your pencil. It is made up of trillions of moving particles. Every solid, liquid, and gas around you is made up of moving particles that attract one another. What makes one matter a solid and other matter a liquid or a gas? It depends on how close the particles in the matter are to one another and how fast they move, as shown in **Figure 8**.

Figure 8 The three common states of matter are (left to right) solid, liquid, and gas.

Physical Properties

To describe a physical property accurately, it must be observable or measurable. Students will recognize the importance of their senses, but they might not think about the role of measurement in describing a physical property.

Review Vocabulary

property

Explain that a characteristic is a unique trait. Rewrite the second sentence in the paragraph to read: *The arrangement of atoms also determines the unique traits of different types of matter.*

Ask: Which unique traits are physical properties? *volume, mass, density, color, velocity, shininess*

Ask: Besides mass, name one physical property that you would have to measure to describe. Explain your answer. *possible answer: you could melt or boil a substance and use a thermometer to measure its melting point or boiling point.*

States of Matter

Have students read and study the image. **Figure 8** Students likely have been exposed to states of matter previously, but they may not be aware of how the particles in matter behave in each state. Use the following questions to guide students through thinking about the states of matter.

Guiding Questions

- Q1** Can a substance exist in more than one state of matter? *Yes. Water, for example, can exist as a solid (ice), a liquid (water), or a gas (water vapor).*
- Q2** How do solids, liquids, and gases differ? *Solids, liquids, and gases differ in how close the particles are to each other and how fast the particles move (how much energy they have).*
- Q3** How is the motion of particles in a book different from the motion of particles in the air around it? *The particles in a book are close together and vibrate slowly. The particles in the air are spread out and move more quickly.*



Figure 9 Two large dumbbells have greater mass than the smaller dumbbells because they contain more matter.

Size-Dependent Properties

Mass is only one of many physical properties that you can use to describe matter. Some physical properties, such as mass and volume, depend on the size or amount of matter. Measurements of these properties vary depending on how much matter is in a sample.

Mass

Imagine holding a small dumbbell in one hand and a larger one in your other hand. What do you notice? The larger dumbbell seems heavier. The larger dumbbell has more mass than the smaller one. **Mass** is the amount of matter in an object. Both small dumbbells shown in Figure 9 have the same mass because they both contain the same amount of matter. Mass is a size-dependent property of a given substance because its value depends on the size of a sample.

Mass is often confused with weight, but they are not the same. Mass is an amount of matter in something. Weight is the pull of gravity on that matter. Weight changes with location, but mass does not. Suppose one of the dumbbells in the figure was on the Moon. The dumbbell would have the same mass on the Moon that it has on Earth. However, the Moon's gravity is much less than Earth's gravity, so the weight of the dumbbell would be less on the Moon.

Volume

Another physical property that depends on the size or the amount of a substance is volume. A unit often used to measure volume is the milliliter (mL). Volume is the amount of space something takes up. Suppose a full bottle of water contains 400 mL of water. If you pour exactly half of the water out, the bottle contains half of the original volume, or 200 mL, of water.



Size-Independent Properties

Unlike mass, weight, and volume, some physical properties of a substance do not depend on the amount of matter present. These properties are the same for both small and large samples. They are **size-independent properties**. Examples of size-independent properties are melting point, boiling point, density, electrical conductivity, and solubility.

Melting Point and Boiling Point

The temperature at which a substance changes from a solid to a liquid is its melting point. The temperature at which a substance changes from a liquid to a gas is its boiling point. Different substances have different boiling points and melting points. The boiling point for water is 100°C at sea level. Notice in Figure 10 that this temperature does not depend on how much water is in the container.

Density

Imagine holding a bowling ball in one hand and a feather of the same size in the other. The bowling ball seems heavier because the density of the material that makes up the bowling ball is greater than the density of the feather. **Density** is the mass per unit volume of a substance. Like melting point and boiling point, density is a size-independent property.

Math Skill

Use Ratios

What are the masses of the two samples? Density can be written as a ratio of mass and volume. What is the density of the sample of a 5-mL sample with a mass of 25 g?

1. Set up a ratio: $\frac{\text{mass}}{\text{volume}} = \frac{25 \text{ g}}{5 \text{ mL}} = 5 \frac{\text{g}}{\text{mL}}$
2. Divide the numerator by the denominator to get the ratio: $5 \frac{\text{g}}{\text{mL}}$
3. The density is 5 g/mL.

Practice

A sample of wood has a mass of 10 g and a volume of 50 mL. What is the density of the wood?

Word Check

density
from Latin *denso*, means "compact"; and Greek *phora*, means "to carry"

Reading Check

1. What is a common unit for volume?



Figure 10 The boiling point of water is 100°C at sea level. The boiling point does not change for different volumes of water.

Size-Dependent Properties

The terms mass and weight are often confused. Explain that although mass and weight are related, they are two different measurements. Weight is dependent on gravity, while mass is not. Therefore, the weight of an object is different on the Moon than it is on Earth, but the mass does not change in either place. Have students read the paragraphs and study the Figure 9. Ask them to identify items in the classroom that have the greatest mass, such as the board, the desks, or a bookcase. Then use the following questions to help your students understand the concepts and to assess their comprehension.

Guiding Questions

- AL How does the mass of a person differ on Earth and on the Moon? **Answer:** The mass of a person would be the same on Earth or on the Moon. Only the person's weight would change.
- AL Does the mass of a solution increase when the salt is added, the overall mass of the solution is the mass of the original solution plus the mass of the salt.
- AL What happens to the mass of the water in a puddle when the water evaporates? **Answer:** Each molecule of water has mass. The molecules still have the same mass. The only difference is that they are distributed over a wider area because the water molecules are now water vapor in the air.
- AL Do you think it is possible for an object to have mass but not volume? **Answer:** No. Even the lightest parts of an atom have volume.
- AL What is a common unit for volume? **Answer:** mL is a common unit for volume.
- AL If a liquid shake is blended into foam, does its volume change? Does its mass change? **Answer:** Yes, the volume changes because it takes up more space as foam than as a shake. However, the mass does not change because it still holds the same amount of matter, just spread out more.

Size-Independent Properties (continued)

Have students read the paragraphs and study the image in **Figure 10** to help them understand a little more about size-independent properties, show them an iron nail and some iron filings. Emphasize that both samples have the same density, and melt and boil at the same temperature, even though the size differs.

Guiding Questions

- AL** If two objects have the same volume but different densities, density is the same or different? *Densities are different. Density is mass divided by volume. If volume stays the same and mass changes, density also changes.*
- BL** If two objects have exactly the same melting points, are they the same substance? *Probably yes; point out that although such properties are unique to a substance, they might be close enough that the difference is difficult to distinguish.*

Word Origin

density

Have students compare the Greek and Latin origins of the word.

Ask: Which origin of the word **density** seems to relate to the scientific definition of the word, and why? *The Latin origin of the word seems to relate to the scientific definition. Density is the mass per unit volume of a substance, which relates to how compact or dense a material is.*

Math Skill

Use Ratios

Remind students that ratios can help you compare quantities by dividing one number by another. For example, to find the density of a substance, you divide its mass by its volume. The fraction mass/volume is an example of a ratio.

Pressure and Area

Ask students to answer the practice question. Then have a student write the equation he or she used to solve the problem on chart paper or on the board. 0.75 g/mL

Differentiated Instruction

AL Investigating Density and Ice Have pairs of students work together to use the density of ice and water to explain why fish can survive in a body of water when the temperature is below the freezing point of water. Explanations should include that the greater density of water compared to that of ice allows for survival of aquatic organisms.

BL Investigating the Density of Ice and Water Have pairs of students pour equal amounts of vegetable oil and water into a graduated cylinder. Ask each pair to place the ice on the surface of the oil (which should be the top layer) and observe the ice cube as it melts. Liquid water from the melting ice will fall through the oil to the water below. Discuss how the density changed as the ice melted.

LA Investigating the Relationship of Mass and Volume Have students use a graduated cylinder and a balance to measure different samples of water to show that although mass and volume are size-dependent properties, density is a size-independent property. **What is the density of 20 g of water? 30 g? 20 mL?** *Density of any quantity of water is always 1.0 g/mL .*



Teacher Toolbox

Teacher Demo

Ice and Water Fill a glass half full of water and place three ice cubes in it so that they float. Have students predict whether the water level will change once the ice melts. Allow the glass to sit until the ice melts. The water level should not change because the ice cube displaces the water to the same degree that the melted ice does. Explain to students that melting of icebergs or sea ice does not affect sea level because they are already displacing water. But melting of glaciers adds water and affects water level.

Cultural Diversity

How the World Describes Mass Most countries use the metric system, with mass described in terms of kilograms. The Imperial System, which is used in the United States, England, Canada, and to a lesser extent, in Australia, Ireland, New Zealand, and South Africa, describes the weight of an object in pounds. The use of the pound reflects the historical influence of Great Britain in this diverse set of countries.

Reading Check

4. What are two types of conductivity?

Conductivity

Another property that is independent of the sample size is **conductivity**, the ability of matter to conduct, or carry along, an electric current. Copper wires are used for electrical wiring because it has high electrical conductivity. Metals tend to have high electrical and thermal conductivity. Stainless steel, for example, often is used to make cooking pots because of its high thermal conductivity. However, the handles on the pots probably are made out of wood, plastic, or some other substance that has low thermal conductivity.

Solubility

Have you ever made lemonade at home? The powder mixes evenly in the water. In other words, the powder dissolves in the water.

The hotter the water you stir, the faster the powder dissolves.

Solubility is the ability of one substance to dissolve in another. The powdered drink mix is soluble in water, but **solids** explain how physical properties such as conductivity and solubility can be used to identify objects and separate mixtures.

Think Critically

5. How might you separate a mixture of iron filings and salt?

Table 1 This table contains the descriptions of several physical properties. It also shows examples of how physical properties can be used to separate mixtures.

Table 1 Physical Properties of Matter

Property	Property		
	Mass	Conductivity	Volume
Description of property			
	The amount of matter in an object.	The ability of matter to conduct, or carry along, electricity or heat.	The amount of space something occupies.
Size-independent or size-dependent?	Size-dependent	Size-independent	Size-independent
How the property is used to separate a mixture (example)	Mass typically is not used to separate a mixture.	Conductivity typically is not used to separate a mixture.	Volume could be used to separate mixtures whose parts can be measured by volume.

Separating Mixtures

In Lesson 1, you read about different types of mixtures. Recall that the substances that make up mixtures are not held together by chemical bonds. When substances form mixtures, the properties of the individual substances do not change. One way that a mixture and a compound differ is that the parts of a mixture often can be separated by physical properties. For example, when salt and water form a solution, the salt and the water do not lose any of their individual properties. Therefore, you can separate the salt from the water by using differences in their physical properties. Water has a lower boiling point than salt. If you heat salt water, the water will boil away, and the salt will be left behind. Other physical properties that can be used to separate different mixtures are described below.

Physical properties cannot be used to separate a compound into the elements it contains. The atoms that make up a compound are bonded together and cannot be separated by physical means. For example, you cannot separate the hydrogen atoms from the oxygen atoms in water by boiling water.

Science Use's Connection

Read Science Use's Connection: Properties of Matter. Properties of matter are used to identify substances and to separate mixtures.

Key Concept Check

6. How are physical properties used to separate mixtures?

Property				
Boiling Point	State of Matter	Density	Solubility	Magnetism
				
The temperature at which a material changes state.	Whether something is a solid, a liquid, or a gas.	The amount of mass per unit of volume.	The ability of one substance to dissolve in another.	Attractive force between particles.
Size-independent	Size-independent	Size-independent	Size-independent	Size-independent
A liquid can be poured off a solid.	Objects with greater density sink in liquids with less density.	Dissolve a soluble substance in a liquid.	Attract iron from a mixture of materials.	

Size-Independent Properties (continued) Guiding Questions

Explain that conductivity involves the transfer of thermal and electrical energy. Some substances can conduct both types of energy well. Others are good conductors of just thermal energy or just electrical energy, while others are not good conductors of either type of energy. Explain that all metals are good conductors.

Visual Literacy: Physical Properties of Matter

Ask students to examine the first three columns of Table 1. Explain that organizing properties into a table can help you compare and contrast them. Ask students to name a property in the first three columns that is not size-dependent.

Ask: Which property involves the movement of energy?

Ask: Why use mass, rather than weight, to identify matter? independent of gravity and does not change.

Size-Independent Properties

Have students read about solubility. Tell them that there is a definition of solubility that states that if one substance will dissolve in another substance, it is soluble. Solubility is also the maximum amount of a substance that will dissolve in a certain volume of another substance at a specific temperature. Ask students the following questions to assess their understanding of these concepts.

What is an example of a metal with high conductivity?
Sample answer: copper

What are two types of conductivity?
Two types of conductivity are thermal and electrical.

What are five different physical properties of matter?
Sample answer: color, shape, density, melting point, electrical conductivity

Which of these properties describes how one substance dissolves into another substance—conductivity, solubility, size, mass, or density?
Solubility is the one property that describes how the substance dissolves into another substance.

3.2 Review

Physical Properties

Visualize It!



A physical property is a characteristic of matter that can be observed or measured without changing the identity of the matter.



Examples of physical properties include mass, density, volume, melting point, boiling point, state of matter, and solubility.



Many physical properties can be used to separate the components of a mixture.

Summarize It!

1. What are some physical properties of matter?

2. How are physical properties used to separate mixtures?

Use Vocabulary

1. **Distinguish** between mass and weight.

2. Use the term **solubility** in a sentence.

3. An object's _____ is the amount of mass per a certain unit of volume.

Understand Key Concepts

4. **Explain** how to separate a mixture of sand and pebbles.

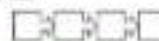
5. Which physical property is NOT commonly used to separate mixtures?

- A. magnetism C. density
B. conductivity D. solubility

6. **Analyze** how two size-dependent properties and two size-independent properties of an item aid

Interpret Graphics

7. **Sequence** Draw a graphic organizer like the one below to show the steps in separating a mixture of sand, iron filings, and oil.



Critical Thinking

8. **Examine** diagrams below.



How can you identify the state of matter represented by the diagram?

Main Idea

9. A piece of copper has a volume of 100.0 cm³. If the mass of the copper is 893 g, what is the density of copper?

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** To which Key Concept does each image relate?

Summarize It!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties

Use Vocabulary

1. **Mass** is the amount of matter in an object. **Weight** is the effect of gravity on mass.

2. **Sample answer:** The solubility of sand is low because sand does not seem to dissolve in water.

3. **density**

Understand Key Concepts

4. Pour the mixture through a large-holed strainer. The sand will flow through the strainer, but the pebbles will not.

5. **B. conductivity**

6. **Sample answer:** Size-dependent: mass, volume; size-independent: density, melting point

Interpret Graphics

7. Sample answer: (1) Use a magnet to remove the iron filings. (2) Stir the sand and salt into water to dissolve the salt. (3) Filter out the sand. (4) Boil the water, leaving behind the salt.

Critical Thinking

8. The matter is a gas because the particles are far apart from each other.



Math Skill

9. The density of copper is 8.90^3g/cm^3 .



Intervention Plan

Based on the results of the Lesson Review, use the chart below to address individual needs.


Use Vocabulary (1–3)

-  Word Origins, Density
-  Content Vocabulary



Understand Key Concepts (4–6)

-  Visual Literacy: Physical Properties of Matter
-  Key Concepts Builder

Interpret Graphics (7)

-  Guiding Questions, Separating Mixtures

Critical Thinking (8)

-  Visual Literacy: Solids, Liquids, and Gases
-  Enrichment
-  Challenge

Math Skills (9)

-  Guiding Questions, Size-Independent Properties
-  Math Skills
-  Challenge
-  Math Practice: Use Ratios



ExploreActivity

Where did it go?

Prep 5 min Class 20 min

Purpose

To observe the conservation of mass during a physical change.

Materials

Student Team of 3 or 4: balance, small paper cup, sugar, round balloon, 125-mL flask (or small plastic water bottle), water

Before You Begin

To save time, prepare 10 g of sugar in the paper cup for each team. Introduce the activity by asking students what happens to sugar when it dissolves in water. Have them explain their reasoning and predict whether the mass will change.

Guide the Investigation

- Suggest that one team member hold the flask and a second hold the balloon as the third team member stretches the neck of the balloon over the flask. Remind students to keep the balloon down at the side of the flask so that the sugar does not enter the water before step 5.
- Troubleshooting:** If the mass changes even the smallest amount, students might say it changed. Emphasize precision and accuracy; have them mass a clean flask in the middle and again at the sides of the pan.

Think About This

Students might not know the answers to all questions. Encourage them to hypothesize.

- Students might say that the sugar is still present because sugar water tastes sweet like sugar, and the mass doesn't change.
- When matter undergoes a physical change, such as dissolving or changing state, its mass stays the same because the same amount of matter is still present.

Teacher Notes



Thinner

Before reading this lesson, write down what you already know in the first column, for the deeper columns, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Smart Check

physicists use Greek "natural things"

change from Latin "change, move, to exchange"

FOLDABLES

Make a vertical two-tab book. Label the tabs as follows: Review, Examples, Defining, and Adding or Removing. Number the tabs 1 through 4.

Physical Changes

How would you describe water if you think about water in a stream, you might say that it is a cool liquid. If you think about water in ice, you might describe it as a cold solid. How would you describe the change from ice to water? As ice melts, some of its properties change, such as the state of matter, the shape, and the temperature, but it is still water. In Lesson 2, you read that substances and mixtures can be solid, liquid, or gas. In addition, substances and mixtures can change from one state to another.

physical change
a change in size, shape, form, or state of matter in which the matter's identity stays the same. During a physical change, the matter does not become something different, even though physical properties change.

Change in Shape and Size

Think about changes in the shapes and the sizes of solid matter, and mixtures you experience each day. When you chew food, you are breaking it into smaller pieces. This change in size helps make food easier to digest. When you pour juice from a bottle into a glass, you are changing the shape of the juice. If you fold clothes to fit them in a drawer, you are changing their shape. Changes in shape and size are physical changes. The identity of the matter is not changed.

Figure 10 Thermal energy is added to a material, temperature increases until the state of the material has not changed. Temperature stops for some during a change of state.

Change in State of Matter

Why does ice melt in your hand? Or, why does water turn to ice in the freezer? Matter, such as water, can change state for all three. Lesson 2 gave the particles in a solid, a liquid, and a gas before. To change the state of matter, the movement of the particles has to change. In order to change the movement of particles, thermal energy must be either added or removed.

Adding Thermal Energy When thermal energy is added to a solid, the particles in the solid move faster and faster, and the temperature increases. As the particles move faster, they are more likely to overcome the attractive forces that hold them tightly together. When the particles are moving too far for attractive forces to hold them tightly together, the solid reaches its melting point. The melting point is the temperature at which a solid changes to a liquid.

After all the solid has melted, adding more thermal energy causes the particles to move even faster. The temperature of the liquid increases. When the particles are moving so fast that attractive forces cannot hold them close together, the liquid is at its boiling point. The boiling point is the temperature at which a liquid changes into a gas and the particles spread out. The melting point, boiling point, and change of state relate to each other when thermal energy is added to a material.

Change directly to a gas without first becoming a liquid is a process called sublimation. An example of sublimation is dry ice. Figure 12 shows another example of sublimation in Lesson 3.

Physical Changes

After students read the paragraph, ask them to provide examples of physical changes: a change in shape, size, form, or state.

Word Origin

physical change

Note for students that the definition in the text is similar to changing the nature of matter, the idea behind the word origin.

Change in Shape and Size

Help students apply the idea of physically changing the shape and size of matter. Ask them to explain how the shape and size of the wood in the photo opener changed (wood pieces are being cut and reshaped), and how chopped food changes (when you chop you break up food into smaller pieces).

Change in State of Matter

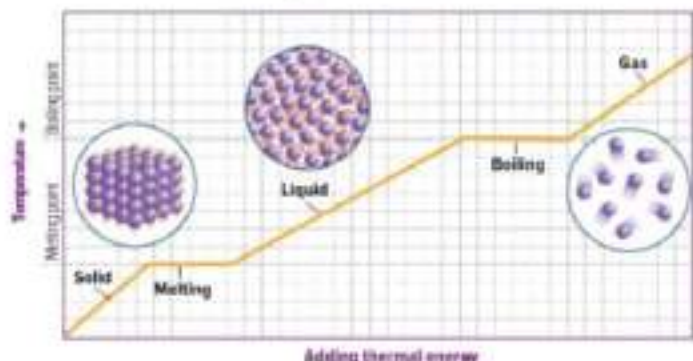
Students are familiar with objects becoming hot, but they are not as likely to have thought about why they are hot. Reinforce the particle view of matter and ensure that students understand that thermal energy affects the motion of the particles in a substance. Have students read the paragraphs on this page and study **Figures 11 and 12** then use the following questions to help guide the students into a deeper understanding of these concepts.

Guiding Questions

- What physical property identifies the melting point?
 temperature at which the attraction between particles in a substance becomes less, which allows particles to slide past each other?
- What kinds of forces must a particle overcome in order to become a liquid or a gas?
 Particles must gain enough thermal energy to overcome the attractive forces between them and spread out from one another.

Visual Literacy: Changing States

The diagram shows how a substance changes as thermal energy is added. Ask the following questions to assess students' understanding.



Ask: How do the particles in the substance change when it reaches its melting point? *The particles begin to move faster and slide by each other.*

Ask: How would the diagram look if the graph showed the effect of removing thermal energy instead? *The graph would be in reverse. It would begin with a gas that changes to a liquid and then to a solid, and it would show the condensing and freezing points instead of the boiling and melting points.*

Change in State of Matter (continued)

Have students read the paragraphs and **Figure 12** have students identify the water shown in each image and describe its current state. Explain that the ability of a substance to change state can provide a number of benefits, some of which might not be obvious. For example, soup can be turned from a liquid into a powder by evaporating the water within it. The resulting powder can be shipped in small packets instead of cans.

Guiding Questions

- AL** How does the freezing point of a substance compare to the melting point? *It is the same. A substance freezes from a liquid to a solid at the same temperature that it melts from a solid to a liquid.*
- EL** How can removing thermal energy affect the state of matter? *Decreasing thermal energy can change a liquid to a solid or a gas to a liquid. For some substances, it can change a gas directly to a solid.*
- BL** Describe how the movement of particles in water vapor changes when enough thermal energy is removed to cause deposition. *The speed of the particles decreases and they slow down to the point that they only vibrate back and forth.*

Differentiated Instruction

AL Create a Graph After students have completed the following **Melting Points of Similar Materials**, have this group of students use the data to create a bar graph of their results. Ask them to explain how the difference in melting points might affect how each item is used.

BL Melting Points of Similar Materials students work in pairs to find the melting points of several similar materials, such as butter, margarine, solid vegetable shortening, and coconut oil. Then ask them to create a graph of their results. Have them work together with the **Create a Graph** group to make a class presentation of the results.

LA Words Related to Change students work in pairs to generate flash cards of words that describe the various changes that they have learned about with other students.

Teacher Toolbox

Fun Fact

Ethanol Since ethanol has been chosen as a supplementary oil-based fuel, there has been a large increase in ethanol production. Ethanol is separated from water by distillation made possible because the boiling point of ethanol is 78.5°C, whereas water is 100°C.

Reading Strategy

Summarize Have students summarize the ways that matter can change state using bullet points. **Changes in State of Matter** Bullet points are an efficient way to summarize topics and supporting details.

Real-World Science

Companies that ship food long distances can use dry ice. Dry ice is another name for frozen carbon dioxide. In its solid state, dry ice has two properties that make it better for shipping than frozen water. As a solid, its surface temperature is extremely cold, -78.5 Celsius; when it changes state, it does not melt into a liquid but rather sublimates, changing directly into a gas. Melting frozen water would make a liquid mess. Dry ice leaves no mess at all.

Removing Thermal Energy

is removed from a gas, such as water vapor, particles in the gas move more slowly and the temperature decreases. Condensation occurs when the particles are moving slowly enough for attractive forces to pull the particles close together. Recall that condensation is the process that occurs when a gas becomes a liquid.

After the gas has completely changed to a liquid, removing more thermal energy from the liquid causes particles to move even more slowly. As the motion between the particles slows, the temperature decreases. Freezing occurs when the particles are moving so slowly that attractive forces between the particles hold them tightly together. Now the particles only can vibrate in place. Recall that freezing is the process that occurs when a liquid becomes a solid.

Freezing and melting are reverse processes, and they occur at the same temperature. The same is true of boiling and condensation. Another change of state is deposition. Deposition is the change from a gas directly to a solid, as shown in **Figure 13**: it is the process that is the opposite of sublimation.

Figure 13 Removing thermal energy to condense, freeze, or deposit particles occurs.



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Change

Let the heat added from this and back in the box below.

Key Concept

1. How can removing thermal energy affect the state of matter?



Figure 14 Dissolving occurs if a solute is that water in this solution.

Key Concept

2. What happens when something dissolves?

Key Concept

3. What is needed to conserve mass?

Visual Check

4. If a sample of water has a mass of 200 g and the final solution has a mass of 230 g, how much solute dissolved in the water?

Dissolving

Have you ever owned a saltwater aquarium, such as the one shown in **Figure 14**? You have, you probably had to add certain salts to the water before you added the fish. Can you see the salt in the water? As you added the salt to the water, it gradually disappeared. It was still there, but it dissolved, or mixed evenly, in the water. Because the identities of the substances water and salt are not changed, dissolving is a physical change.

Like many physical changes, dissolving is usually easy to reverse. If you heat the salt water, the liquid water will change to water vapor, leaving the salt behind. You can again see the salt because the particles that make up the substance do not change identity during a physical change.

Conservation of Mass

During a physical change, the physical properties of matter change. The particles in matter that are present before a physical change are the same as those present after the physical change. Because the particles are the same both before and after a physical change, the total mass before and after the change is also the same, as shown in **Figure 15**: it is known as the conservation of mass. You will read in Lesson 4 that mass is also conserved during another type of change—a chemical change.

Figure 15 Mass is conserved if matter is physically changed.



Lesson 3.2 Physical Change 105

Dissolving

Remind students that when a substance dissolves, its particles evenly disperse throughout a solution. Then have them read the paragraphs and study **Figure 14**. Ask the following questions to assess your students' understanding.

Guiding Questions

- AL** Why is dissolving an example of a physical change? *The identities of the substances don't change; they are just mixed together.*
- OL** What happens when something dissolves? *One substance breaks into small particles that mix evenly throughout another substance.*
- BL** What is one way to separate a substance that is dissolved in water? *If the boiling point of the substance is higher than 100°C, you can boil off the water and the substance remains. If the boiling point is lower than 100°C, add thermal energy to the solution and collect any gases that leave the solution.*

Conservation of Mass

Have students read the paragraph. Explain to students that if an ice melts into liquid water, its state, shape, and volume change but its mass remains the same. The amount of water in the liquid is the same as in the solid because the same number of particles is present in both.

Visual Literacy: Conservation of Mass

Have students examine **Figure 15** and ask them to identify the mass of the two substances on the left and the mass of the combined substances in the solution on the right.



Ask: How is mass conserved when making a solution? *Mass of the solution equals the total mass of all the substances in the solution.*

Ask: If a sample of water has a mass of 200 g and the final solution has a mass of 230 g, how much solute dissolved in the water? *30 g of solute dissolved.*

Ask: What is meant by conservation of mass? *Mass is conserved because it remains the same after a change, such as a physical change.*

Intervention Plan

Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1)

- LE** Word Origin, Physical Changes
- CV** Content Vocabulary

Understand Key Concepts (2–4)

- LE** Guiding Questions, Dissolving
- CV** Key Concepts Builder

Interpret Graphics (8–9)

- LE** Visual Literacy: Changing States

Critical Thinking (7)

- LE** Visual Literacy: Changing States
- CV** Enrichment
- Challenge



3.3 Review

Physical Changes

Visualize It!



During a physical change, matter can change its shape, size, or color, but the identity of the matter does not change.



Matter never changes temperature or changes state when enough thermal energy is added or removed.



Mass is conserved during physical changes, which means that mass is the same before and after the changes occur.

Summarize It!

1. How can a change in energy affect the state of matter?

3. What happens when something dissolves?

3. What is meant by conservation of mass?

Use Vocabulary

1. Use the term **physical change** in a sentence.

Understand Key Concepts

2. Describe a change in energy that change ice into liquid water.

3. Which never changes during a physical change?

- A. state of matter
- B. temperature
- C. total mass
- D. volume

4. Relate what happens when something dissolves?

Interpret Graphics

5. Examine the graph below of temperature over time as a substance changes from solid to liquid to gas. Explain why the graph has horizontal lines.



6. Take Notes on the graphic organizer below. For each heading, summarize the main idea described in the lesson.

Heading	Main Idea
Physical Changes	
Change in State of Matter	
Conservation of Mass	

Critical Thinking

7. Design a demonstration that shows that temperature remains unchanged during a change of state.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. To which Key Concept does each image relate?

Summarize It!

- Physical Changes
- Conservation of Mass

Use Vocabulary

1. Sample answer: A change in the state of matter is an example of a physical change.

Understand Key Concepts

2. When you heat ice, the energy of its particles increases, and the temperature of the ice increases. When it reaches its melting point, increasing thermal energy further causes the ice to melt.

3. Total mass

4. When something dissolves, one substance mixes evenly in another substance.

Interpret Graphics

5. The horizontal lines indicate that the temperature of a substance does not change during a change of state.

6. Sample answers: Physical Changes: A physical change is a change in matter in which the identity of the matter stays the same. Change in State of Matter: Changing energy can change the state of matter. Conservation of Mass: Mass is conserved during physical changes.

Critical Thinking

7. Sample answer: You could measure the temperature of ice water as you heat it and it changes from ice to liquid water to water vapor.

3.4 Chemical Properties and Changes

INQUIRY

A Burning Issue?

As this car burns, some materials change to gases and ashes. The metal might change form or state if the fire is hot enough, but it probably won't burn. Why do fabric, leather, and glass burn? Why do many metals not burn? The properties of matter determine how matter behaves when it undergoes a change.

Work and express a your ideas without.



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Explore Activity

What can color tell you?

You mix red and blue paint to get purple paint. Iron changes color when it rusts. Are color changes physical changes?

Procedure

1. Find the procedure and identify the steps you will work on.
2. Divide paper towel rectangles, label one section A, the second section B, and the third section C.
3. Dip one end of the section A towel in red cabbage juice (RCJ). Observe the color, and write the substance paper towel, one in each of the three sections.
4. Add one drop substance A to the end of the section A towel. Observe any changes, and record observations in your Science Journal.
5. Repeat step 4 with substance B at the end of the section B towel.
6. Observe substance C in the third section of the towel. Record your observations.

Think About This

1. What happened to the color of the red cabbage juice when substances A and B were added?
2. Key Concept: Most of the changes you observed do you think was a physical change? Explain your reasoning.

Essential Questions

- What is a chemical property?
- What are some signs of chemical change?
- Why are chemical equations useful?
- What are some factors that affect the rate of chemical reactions?

Vocabulary

chemical property
chemical change
concentration

INQUIRY

About the Photo Burning Issue? This firefighter is extinguishing a burning car. The ability to burn is a chemical property. Some materials burn easily, while others do not. But regardless of how quickly a material burns, it always undergoes a chemical change in the process.

Guiding Questions

- | | |
|---|--|
| <p>AL Why do you think metal is often used to make screens for fireplaces?</p> <p>OL How has the metal in this car changed? How is it the same?</p> <p>EL What materials in the car are now entirely different materials than those in the original car? What do you think caused this change?</p> | <p>Most metal does not burn or melt at temperatures reached in fireplaces.</p> <p>Its color, shape, and texture have changed. It is still metal.</p> <p>Sample answer: Anything that was leather, or plastic is now composed of different materials. Changes caused by the fire caused the materials to change identity.</p> |
|---|--|

LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Properties v. Changes

1. Discuss with students the differences between properties of matter and changes in matter.
2. **Ask:** What physical properties of a substance are related to the potential for the substance to undergo physical change? **TIP** If students have difficulty with this concept, begin by listing physical properties and ask students to think about the physical change that is associated with that property. **Sample answers:** state of matter, because it relates to a substance changing states; melting point and boiling point, because they also relate to a substance changing states; solubility, because it relates to a substance dissolving and becoming part of a solution.
3. Based on their responses, have students speculate about the possible connections between a chemical property and a chemical change.

ExploreActivity

What can colors tell you?

Prep 5 min Class 15 min

Purpose

To observe that not all color changes are physical changes.

Materials

Student Teams paper towels, beaker, cotton swabs, 2 dropper bottles labeled A and B, 1 mL white vinegar, 1 mL of water with ammonia, test tubes labeled C and D, 5 mL water with yellow food coloring, 5 mL water with blue food coloring, 3 mL of red cabbage juice in test tube labeled RCJ

Before You Begin

Prepare the red cabbage indicator by gently boiling grated red cabbage in enough water to cover for 20 min. Strain the liquid into a clean container. Provide each team with 2–3 mL of the juice in a small test tube.

Guide the Investigation

Encourage students to suggest color changes that they observe in nature.

Think About This

Students might hypothesize,

1. The juice turned from purple to pink with Substance A and from purple to blue with Substance B.
2. **Key Concept** Students might say that mixing the food coloring was a physical change because they were both colored in the first place and the colors just mixed. Substances A and B were colorless, but the colors still changed.

Teacher Notes



Themer

Before reading this section, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this paper, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Chemical Properties

Recall that a physical property is a characteristic of matter that you can observe or measure and chemical properties. All matter without changing the identity of the substance be described using both types of properties. For example, a wood log is observed only when the matter changes from one solid, rounded, heavy, and rough. These are substances to another **chemical property** physical properties that you can observe characteristic of matter that can be observed without your actions. The log also has mass, changes to a different type of matter. For example, mass and density, which are physical properties, are some chemical properties of a **physical property** that can be measured. The ability paper can you tell by just looking at it (darkwood to burn is a chemical property. This will burn easily? The only way to know this property is observed only when you burn the paper burns is by being a flame that the **physical**. It also will not, another chemical and watch it burn. When paper burns, a **chemical property** you can observe when the log into different types of matter. The ability after composition, becoming other substances, substance to burn is a chemical property. When you describe matter, you consider ability to not is another chemical property (both its physical and its chemical properties).

Key Concept 1.1

1. What are some chemical properties of matter?

Chemical Changes

Recall that during a physical change, the identity of matter does not change. How **chemical change** a change in matter in which the substances that make up the matter change into other substances with new physical and chemical properties. For example, when iron undergoes a chemical change with oxygen, rust forms. The substances that undergo a change no longer have the same properties because they no longer have the same identity.

Signs of Chemical Change

How do you know when a chemical change occurs? What signs show you that new types of matter form? As shown in **Figure 16**, signs of chemical changes include the formation of bubbles or a change in odor, color, or energy.

It is important to remember that these signs do not always mean a chemical change occurred. Think about what happens when you put water on a stove. Bubbles form in the water boils. In this case, bubbles show that the water is changing state, which is a physical change. The evidence of chemical change shown in **Figure 16** means that a chemical change might have occurred. However, the only proof of chemical change is the formation of a new substance.





Smoking Light

2. What is the difference between a physical change and a chemical change?

Flame Light

3. What signs show that a chemical change takes place when fireworks explode?

Figure 16 Sometimes you can observe clues that a chemical change has occurred.

Bubbles
Energy change
Odor change
Color change

Lesson 2: Chemical Properties and Changes

Chemical Properties

Substances are able to undergo a wide range of chemical changes. Knowing the chemical properties of a substance can be helpful when you are trying to cause a change or avoid an unwanted change.

Comparing Properties

Discuss the following questions to help students review and distinguish between physical and chemical properties.

Guiding Questions

- CL What are some chemical properties of matter? *Sample answer: ability to burn, ability to rust, ability to rot*
- SL How could you determine whether a substance has the ability to rust? *Sample answer: Determine if it is made of substances that rust, or test it by getting it wet and exposing it to air, and then observe what happens over time.*

Chemical Changes

Help students visualize how a chemical change impacts physical properties, encourage them to focus on the atoms in the substances involved. As each substance undergoes a change, the atoms rearrange into different combinations. Chemical changes create new substances with their own physical properties. Use the following questions to assess your students' understanding of this concept.

Guiding Questions

- CL How does rust form? *A chemical change occurs between iron and oxygen.*
- CL What is the difference between a physical change and a chemical change? *During a physical change, no new substance forms. During a chemical change, new substances form.*

Signs of Chemical Change

Explain to students that to understand what happens during a chemical change, it is necessary to describe each substance at the beginning and at the end of the change, and then determine what happened during the process.

For example, a fresh apple has a certain color and odor. But shortly after the apple is cut, a chemical change occurs as the apple reacts with oxygen. As a result, the color of the fruit darkens, and its odor changes.

To help students consider the signs of chemical change, have them read the paragraphs, **Figure 16**, and compare the different signs. Then ask the following questions.

Guiding Questions

- AL** Does the formation of bubbles always indicate a chemical change? *Yes, because bubbles form when water boils, which is a physical change, not a chemical change.*
- OL** What are signs of a chemical change? *Sample answer: formation of bubbles, energy change, change in color or odor*
- OL** What signs show that a chemical change takes place when fireworks explode? *Sample answer: There is an energy change when light and thermal energy are released.*
- BL** Do you think a chemical change occurs when you bake cookies? Why or why not? *Yes, because the physical properties of the ingredients used to bake the cookies change as they cook in the oven. The dough changes color and odor, and new products form.*

Word Origin

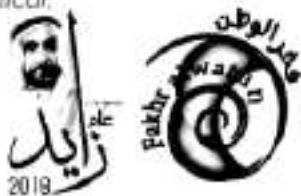
chemical

Have students read the Greek origin of chemical, then ask the following questions.

Ask: Is the word *chemical* a verb or an adjective?

adjective Is the Greek origin of *chemical* a descriptive term or an action? *It is an action.*

Ask: How do you think the action in the Greek origin relates to the way we use the word *chemical* today? *Answer: During a chemical reaction, substances are "cast together," which causes a chemical change. The action leads to a change that can be described with the adjective chemical.*



Differentiated Instruction

AL Create a Change and Property Grid Pairs of students work together to prepare a grid with two columns (physical and chemical) and two rows (properties and changes). In each box, instruct students to write appropriate terms that correspond to that cell. (For example, *melting point* would be placed in the cell for physical properties.)

BL Everyday Chemical Changes Have students identify two or three chemical changes that occur in their classrooms, homes, or neighborhoods. Have them research these changes to learn more about them. Then have students discuss what they learned as a group and create a flowchart of the changes to the substances involved from the beginning to the end of each kind of change.

LA Physical Change or Chemical Change? Create a list of physical changes, such as freezing, dissolving, and changing in shape and size, and a list of chemical changes, such as burning, rotting, and rusting. Then have the class divide into groups and play a speed game of Physical or Chemical Change? Call out one of the changes from the lists and have students to identify it as physical or chemical.

Teacher Toolbox

Fun Fact

Explosive Nitroglycerin is a compound that is highly unstable under certain conditions. It can be explosive, which is why it is used as a component in dynamite. When it undergoes a chemical change during an explosion, it produces carbon dioxide, water, nitrogen, and oxygen gases.

Teacher Demo

Cleaning a 1-fils coin Obtain some old 1-fils coins and add them to a beaker of vinegar for a few minutes. Ask students to predict what will happen. Then carefully remove the coins with tongs and place them onto a paper towel to dry. Have students observe that each coin appears cleaner. Explain that the acid in the vinegar reacts with the tarnish on the outside and removes it, exposing the shiny copper layer.

Describe
List the reactants from the equation in the box below.

Explain
What does it mean to say that atoms rearrange during a chemical change?

Evaluate
Why are chemical equations useful?

Explaining Chemical Reactions

You might wonder why chemical changes produce new substances. Recall that particles in matter are in constant motion. As particles move, they collide with each other. If the particles collide with enough force, the bonded atoms that make up the particles can break apart. These atoms then rearrange and bond with other atoms. When atoms bond together in new combinations, new substances form. This process is called a reaction. Chemical changes often are called chemical reactions.

Using Chemical Formulas

A useful way to understand what happens during a chemical reaction is to write a chemical equation. A chemical equation shows the chemical formula of each substance in the reaction. The formula on the left of the arrow represents the reactants. Reactants are the substances present before the reaction takes place. The formula on the right of the arrow represents the products. Products are the new substances present after the reaction. The arrow indicates that a reaction has taken place.

Balancing Chemical Equations

When balancing an equation, you cannot change the chemical formula of any reactants or products. Changing a formula changes the identity of the substance involved, so that is not allowed. Coefficients, or numbers, in front of formulas can change the amount of the substance. For example, in the equation $2\text{H}_2\text{O}$, the coefficient 2 before H_2O means that you double the number of H_2O molecules. This is called a balanced chemical equation, and it illustrates the conservation of mass. Figure 18 shows how to write and balance a chemical equation.

$2 \times 2 \text{ H atoms} = 4 \text{ H atoms}$
 $2 \times 1 \text{ O atom} = 2 \text{ O atoms}$

Note that 2H is still water. However, it describes two water particles instead of one.

Figure 18 Equations must be balanced because mass is conserved during a chemical reaction.

Balancing Chemical Equations Example
When methane (CH_4) gas burns in oxygen (O_2), the reaction produces carbon dioxide (CO_2) and water (H_2O). Write and balance a chemical equation for this reaction.

- Write the equation, and check to see if it is balanced.

Reactants	Products
$\text{CH}_4 + \text{O}_2$	$\text{CO}_2 + \text{H}_2\text{O}$
C: 1	C: 1
H: 4	H: 2
O: 2	O: 3

 Not balanced.
- Count the atoms of each element in the reactants and in the products.

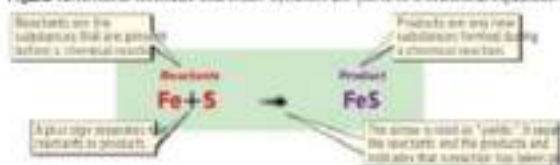
Element	Reactants	Products
C	1	1
H	4	2
O	2	3

 Not balanced.
- Add coefficients to the chemical formulas to balance the equation.

Element	Reactants	Products
C	1	1
H	4	2
O	2	3

 Not balanced.

Figure 17 Chemical formulas and other symbols are parts of a chemical equation.



Explaining Chemical Reactions

Using Chemical Formulas

A chemical change involves bond-breaking and bond-making.

Guiding Questions

- What does it mean to say that atoms are the same atoms are present before and after a chemical reaction, they are in different substances as products.
- Why are chemical equations useful? A chemical equation shows the chemical formula and number of units of each substance in the reaction.

Balancing Chemical Equations

Have students read the paragraphs and Figure 18. Use the following questions to guide students through the balancing of chemical equations.

Guiding Questions

- When balancing a chemical reaction, why can you change the chemical formula of the reactants or products? Why or why not? No; by changing chemical formulas, you would indicate that different substances were involved in the chemical reaction, why not?
- What part do coefficients play in a chemical equation? They are used to show the number of units of each reactant and product involved in the reaction, showing that mass is conserved in a chemical reaction.
- How do you know that a chemical equation is balanced? The total number and types of atoms in the reactants equals the total number and types of atoms in the products.

Visual Literacy: Balancing Chemical Equations

The process that is shown in **Figure 18** is a good model of how to write and balance equations. Go through the process with students, using the example given. Have students take a closer look at the equation in **Figure 17** and compare it to the table in **Figure 18**. Then ask the following questions.

Ask: Why is the equation in **Figure 17** considered to be a balanced equation? The number and type of atoms in the reactants equals the number and type of atoms in the products.

Have students point to part 2a in their textbooks.

a. $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ **not balanced**

b. C=1 C=1 balanced

H=4 H=4 balanced

O=2 O=4 not balanced

c. $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ **balanced**

C=1 C=1 balanced

H=4 H=4 balanced

O=4 O=4 balanced

Ask: If the numbers of each type of atom in the reactants and products are not equal, is the equation balanced? No; it means that different amounts of each reactant and product are involved in the reaction.

Ask: Is it necessary to add coefficients only to the products? reactants and products could have coefficients other than 1.

Have students balance a sample equation on their own, using **Figure 18**.

Ask: What is the balanced chemical equation for the reaction between iron (Fe) and oxygen (O_2) to form iron (III) oxide (Fe_2O_3)?



Differentiated Instruction

AL Molecular Models Provide groups of students with clay and toothpicks. Instruct them to use the materials to build two hydrogen gas molecules, H_2 , and one oxygen gas molecule, O_2 . Then have them demonstrate that using these three models, they can create two water molecules, H_2O .

BL Balancing Equations Research a few basic chemical equations, such as the reaction of vinegar with baking soda, the combustion of butane, or the production of ammonia from hydrogen and nitrogen gas. Write each equation on the board without the coefficients. Ask students to balance each equation.

LA Plan a Demonstration Organize students into teams and have them plan a demonstration to model balancing an equation for the rest of the class. For example, two students could wear signs with Os for oxygen and four students could wear signs with Hs for hydrogen. Have them form H_2 molecules and one O_2 molecule and then rearrange themselves to form two water molecules.

Teacher Toolbox

Reading Strategy

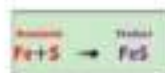
Semantic Mapping Guide the class in building a semantic map of the terms related to chemical change. Have students suggest any term related to chemical change, and write these on the board. Then have students break into small groups to organize the terms into a web pattern with the main ideas attached to *chemical change* and the secondary ideas as branches.

Real-World Science

Common Chemical Reactions Provide students with the reactants and products for an everyday chemical reaction and ask them to write a balanced chemical equation. For example, when propane burns, propane reacts with oxygen and produces carbon dioxide and water. A balanced equation would be $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$. Another example is the reaction between zinc and hydrochloric acid ($\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$).

3.4 Review

Visualize It!



A chemical reaction is observed only as a change in color, texture, or other physical properties.

Chemical reactions involve changes in the chemical identity of the substances involved.

Chemical reactions involve changes in the chemical identity of the substances involved.

Summarize It!

- What is a chemical property?
- What are some signs of chemical change?
- Why are chemical equations useful?
- What are some factors that affect the rate of chemical reactions?

Figure 18 The rate of most chemical reactions increases with an increase in temperature, concentration, or surface area.

1 Temperature



Chemical reactions that occur during cooking happen at a faster rate when temperature increases.

2 Concentration



Acid rain reacts with a higher concentration of limestone in a solid, so it reacts more quickly than a solid exposed to normal conditions.

3 Surface Area



When an antacid tablet is broken into pieces, the pieces have more total surface area than the whole tablet does. The pieces react more quickly with water because more of the tablet is in contact with the water.

Try Learning It!

- List three factors that affect the rate of a chemical reaction.

The Rate of Chemical Reactions

Recall that the particles that make up matter are constantly moving and colliding with one another. Different factors can make these particles move faster and collide harder and more frequently. These factors increase the rate of a chemical reaction, as shown in Figure 18.

1 Temperature usually increases the rate of reaction. When the temperature is higher, the particles move faster. Therefore, the particles collide with greater force and more frequently.

2 Concentration is the amount of substance in a certain volume. A reaction occurs faster if the concentration of at least one reactant increases. When concentration increases, there are more particles available to bump into each other and react.

3 Surface area affects reaction rate if one of the reactants is a solid. If you drop a whole tablet into water, the water must wait until the tablet dissolves. However, if you break the tablet into several pieces and then add them to the water, the reaction occurs more quickly. Smaller pieces have more total surface area, so more space is available for reactants to collide.

Chemistry

In everyday chemistry, you need to understand matter. You need to know how the arrangement of atoms results in different types of matter. You also need to be able to distinguish physical properties from chemical properties and describe ways these properties can change. In later chemistry chapters, you will examine each of these topics closely to gain a better understanding of matter.

The Rate of Chemical Reactions

Chemical changes involve particle collisions that might or might not result in a chemical reaction, depending on how fast the reaction is. Particles are moving and how reactive they are. Temperature, concentration, surface area, and even orientation can affect how often collisions occur between reactants and the amount of force with which they collide.

Have students read the paragraphs and Figure 19. Ask them to describe how the different factors affect the chemical reactions in each photo. Then ask the following Guiding Questions to assess students' understanding of this concept.

Guiding Questions

- AL** In general, how does an increase in temperature affect a chemical reaction?
In general, increasing thermal energy makes it possible for the particles in the substances to move faster and collide harder than at a lower temperature. This speeds up the chemical reaction.
- OL** List three factors that affect the rate of a chemical reaction.
Temperature, concentration, and the amount of surface area affect reaction rate.
- BL** If digestion involves chemical reactions, why would chewing food into tiny pieces before swallowing make digestion easier?
Chewing food into tiny pieces increases the surface area of the food, which then increases the reaction rates of digestion so food is broken down sooner and more easily in the digestive system.

Chemistry

Share with students how chemistry connects the atomic world to everyday observations. By understanding the core principles of chemistry, we are able to both appreciate and predict chemical reactions in nature as well as those occurring in the lab. Use the following questions to summarize what the students have learned about chemistry.

Guiding Questions

- AL** Can you understand matter without understanding how it changes?
No, the properties of a substance are important, but understanding physical and chemical change is necessary to understand matter.
- OL** How do the properties of the reactants in a chemical reaction compare to the properties of the products of the reaction?
The atoms in a substance are configured into a different arrangement, the properties will change because new substances form.
- BL** How do you think understanding chemistry can help you better understand the world around you?
Sample answer: Understanding chemistry can help in understanding why chemical and physical changes take place in our world and ways to prepare for them or avoid them.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Task:** To which Key Concept does each image relate?



Summarize It

- * Chemical Properties
- * Comparing Properties
- * Chemical Changes
- * Signs of Chemical Change
- * Explaining Chemical Reactions
- * The Rate of Chemical Reactions
- * Chemistry



Intervention Plan

Based on the results of the Lesson Review, use the chart below to address individual needs.


Use Vocabulary (1–2)

-  Word Origins, Signs of Chemical Change
-  Content Vocabulary

Understand Key Concepts (3–6)

-  MiniLab, Can you spot the clues for chemical change?
-  Key Concept Builder

Interpret Graphics (7–8)

-  Guiding Questions, Signs of Chemical Change

Critical Thinking (9–10)

-  Guiding Questions, The Rate of Chemical Reaction
-  Enrichment Challenge



Chemical Properties and Changes

My Notes

Use Vocabulary

1. **Thousand of substance** in a certain matter is the _____.
2. **Use the term** chemical change in a complete sentence.

Understand Key Concepts

3. **List** some signs of chemical change.

4. What **properties** of matter changes during a chemical change but does NOT change during a physical change?

A. energy C. mass
B. identity D. volume

5. **State** why chemical equations are useful.

6. **Analysis** What affects the rate at which acid rain reacts with a statue?

Interpret Graphics

7. **Examine** Explain how the diagram below shows conservation of mass.



8. **Compare and Contrast** **and** **NOT** in the graphic organizer to compare and contrast physical and chemical changes.

Physical and Chemical Change	
Alike	
Different	

Critical Thinking

9. **Complete** list of three physical changes and three chemical changes you have observed recently.

10. **Recommend** How could you increase the rate at which the chemical reaction between vinegar and baking soda occurs?

Use Vocabulary

1. **concentration**
2. **Sample answer:** A chemical change occurs when you bake a cake. This change in matter creates bubbles and wonderful smells.

Understand Key Concepts

3. **Sample answers** include formation of bubbles, energy change (light, heat), and change in odor or color.
4. **B. identity**
5. **Sample answer:** Chemical equations provide a simple yet clear way to describe what happens during a chemical reaction.
6. **The concentration of acid in the rainwater or the temperature of the water affects the rate at which the reaction occurs.**

Interpret Graphics

7. **The number of each type of atom in the reactants equals the number of each type of atom in the products.**
8. **Sample answer:**

Physical and Chemical Changes

Alike	Both change physical properties. Atoms present before and after the change are the same.
Different	Physical changes do not change the identity of matter, but chemical changes do.

Critical Thinking

9. **Sample answers:** Physical changes are folding paper, melting ice, and breaking glass. Chemical changes are burning wood, rusting metal on a bicycle, and baking cookies.
10. **Sample answer:** You can increase the temperature or increase the concentration of one or both of the reactants.

3 Study Guide

TheBIG Idea

Matter is anything that has mass and takes up space. Its physical properties and its chemical properties can change.

Key Concepts Summary

3.1 Classifying Matter

- Substance** is a type of matter that always is made of atoms in the same ratio.
- Atoms** of different elements have different numbers of protons.
- The composition of a substance cannot vary. The composition of **mixture** can vary.
- Water can be classified as either a substance or a mixture.



Vocabulary

matter
atom
substance
element
compound
mixture
heterogeneous mixture
homogeneous mixture
dissolve

3.2 Physical Properties

- Physical properties** include size, shape, texture, color, and state.
- Physical properties such as **melting point**, **boiling point**, and **density** can be used to separate mixtures.



physical property
mass
density
solubility

3.3 Physical Changes

- A change in energy can change the state of matter.
- When something dissolves, it mixes evenly in a substance.
- Two masses before and after a change in matter are equal.



physical change

3.4 Chemical Properties and Changes

- Chemical properties** include ability to burn, oxidize, and decay to rust.
- Some signs that might indicate **chemical changes** are the formation of bubbles and a change in color, odor, or energy.
- Chemical equations are useful because they show what happens during a chemical reaction.
- Some factors that affect the rate of chemical reactions are temperature, concentration, and heat area.



chemical property
chemical change
concentration

FOLDABLES

Chapter Project

Assemble your lesson foldables as shown to make a Chapter Project. Use the project to review what you have learned in this chapter. Fold the Foldable from Lesson 4 on the back of the book.



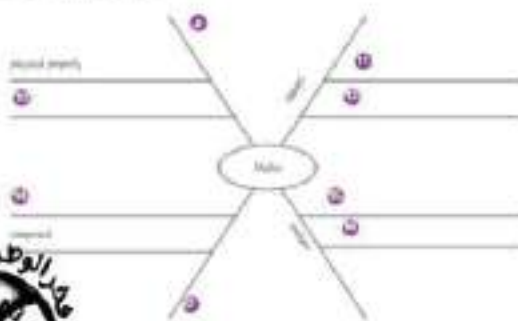
Use Vocabulary

Give two examples of each of the following:

- element
- compound
- heterogeneous mixture
- homogeneous mixture
- physical property
- chemical property
- physical change
- chemical change

Link Vocabulary and Key Concepts

Use this concept map and then use vocabulary terms from the previous page to complete the concept map.



Key Concepts Summary



Vocabulary

Study Strategy: Concept Web

Have students create a concept web that defines the concepts and shows their interconnections.

- Organize students into groups and provide a large sheet of paper or poster board for them to use to create a concept web.
- Prompt students to read the Key Concepts Summary. For each key concept, have them create a box for the concept and arrows connecting that concept to other related concepts. Along each arrow, students should include an explanation of the connection between the two concepts.
- Have each group explain their map to the class. Address any gaps or misconceptions with an open discussion.

Example:



Study Strategy: I Have... Who Has...?

Divide index cards into left and right halves. Write **START HERE** on the top of the first card. On the left side write *I have* and write a vocabulary term. On the right side write *Who has* and write a definition for a different vocabulary term. On the next card write *I have* and write the vocabulary term that matches the definition on the right side of the previous card. Repeat this process until all vocabulary terms are used. The definition on the last card should define the term on the first card.

- Distribute the cards to the students in random order. The student with the **START HERE** card begins the game by reading the *I have* statement and asking the *Who has* question. Then, the student who has the answer to the question reads their card. For example: "I have *substance*. Who has *anything that takes up space and has mass*?"

2. Continue playing until all of the cards are read and the last question ends with the answer on the first card.

Example:

I Have...	Who Has...
substance	anything that takes up space and has mass?

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.



Use Vocabulary

1. element: carbon, aluminum
2. compound: sodium chloride, carbon dioxide
3. homogeneous mixture: salt water, bronze
4. heterogeneous mixture: powdered drink mix, granite
5. physical property: roughness of sandpaper, round shape of a basketball
6. chemical property: ability of iron to rust, ability of wood to burn
7. physical change: cutting a piece of paper, water boiling
8. chemical change: logs burning in a fireplace, bicycle left outside rusting

Link Vocabulary and Key Concepts

- | | |
|---|-----------------------------------|
| 9. properties | 13. substance |
| 10. chemical property | 14. element |
| 11. 12. physical change/chemical change | 15. 16. homogeneous/heterogeneous |

Teacher Notes

CHAPTER 3 Review

Understand Key Concepts

5. The formula Ag_2O represents a compound made of which atoms?

- 1 Ag, 1 N, 1 O
- 1 Ag, 1 N, 3 O
- 1 Ag, 3 N, 3 O
- 2 Ag, 3 N, 3 O

2. Which is an example of an element?

- oil
- water
- sodium
- sugar

3. Which property explains why copper often is used in electrical wiring?

- conductivity
- density
- magnetism
- viscosity

4. The table below shows densities for different substances.

Substance	Density (g/cm^3)
1	1.58
2	0.32
3	1.52
4	1.62

For which substance would a 4.50-g sample have a volume of 2.89 cm?

- substance 1
- substance 2
- substance 3
- substance 4

5. Which would decrease the rate of a chemical reaction?

- increase in concentration
- increase in temperature
- decrease in surface area
- increase in both surface area and concentration

6. Which physical change is represented by the diagram below?



- condensation
- deposition
- evaporation
- sublimation

7. Which chemical equation is unbalanced?

- $2\text{H}_2\text{O} + 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
- $\text{O}_2 + 2\text{H}_2 \rightarrow 2\text{H}_2\text{O}$
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2 + 2\text{O}_2$
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

8. Which is a state-dependent property?

- boiling point
- conductivity
- density
- mass

9. Why is the following chemical equation said to be balanced?



- There are more reactants than products.
- There are more products than reactants.
- The atoms are the same on both sides of the equation.
- The coefficients are the same on both sides of the equation.

10. The elements sodium (Na) and chlorine (Cl_2) react to form the compound sodium chloride (NaCl). Which is true about the properties of these substances?

- Na and Cl have the same properties.
- NaCl has the properties of Na and Cl.
- All the substances have the same properties.
- The properties of NaCl are different from the properties of Na and Cl.

Chapter Review

Critical Thinking

11. Complete list of ten materials in your home. Classify each material as an element, a compound, or a mixture.

12. Evaluate: Build a periodic table based on the number of electrons in an atom, not on the atomic number. Why or why not?

13. Develop: Demonstration to show how weight is not the same thing as mass.

14. Construct: Explanation for how the temperature and energy of a material changes during the physical changes represented by the diagram below.



15. The definition of physical change is in this chapter so it involves the type of atoms.

16. Find an example: physical change in your home or school. Describe the change in a physical property that occurs during the change. Then explain how you know the change is not a chemical change.

17. Develop: List of five chemical reactions you observe each day. For each, describe one way that you could either increase or decrease the rate of the reaction.

The BIG Idea

18. Evaluate: You are made of matter that undergoes changes. Provide specific examples in your explanation.

Math Skill

Use Ratios

19. A sample of ice at 0°C has a mass of 25 g and a volume of 25 cm. How many times as large is the volume of water as the volume of ice? (The density of water is $1.00 \text{ g}/\text{cm}^3$.)

20. The table below shows the masses and the volumes for samples of two different elements.

Element	Mass (g)	Volume (cm^3)
Gold	396	20
Lead	227	20

Which element sample in the table has greater density?

Understand Key Concepts

1. B. 1 Ag, 1 N, 3 O
2. C. sodium
3. A. conductivity
4. A. substance 1
5. C. decrease in surface area
6. B. deposition
7. B. $\text{Fe} + \text{CO} \rightarrow 2\text{Fe} + 2\text{CO}_2$
8. D. mass
9. C. The atoms are the same on both sides of the equation.
10. D. The properties of NaCl are different from the properties of Na and Cl.

Critical Thinking

11. Sample answers: salad, heterogeneous mixture; water, compound; copper used in wiring, element.
12. A periodic table based on number of electrons would not be as effective, because the number of electrons in an atom can change. The number of protons cannot change without changing the type of element.
13. If students have difficulty, refer them to **MiniLab Lesson 2**.
14. Sample answer: As energy is removed from the gas, its temperature decreases. At its condensation point, the temperature remains constant, and the gas changes to a liquid. The temperature then continues to decrease. At its freezing point, the temperature again remains constant, and the liquid changes to a solid.
15. Sample answer: A physical change is a change in matter in which the type of atoms and the way in which those atoms are arranged do not change.
16. Sample answer: Using sandpaper to sand a piece of wood changes the texture of the wood. It is not a chemical change because the material is wood before and after the change.

17. Accept all reasonable responses. Sample answers: increase the heat in order to cook eggs faster, refrigerate fruit to slow the rate of its spoiling, decomposing organic material, burning wood, digesting food, cleaning or polishing metals

TheBIG Idea

18. Sample answer: Skin changes into smaller pieces and flakes off (physical change), and sugar burns in cells (chemical change).

Math Skill



















Use Ratios

19. The density of the ice is 0.92 g/cm^3 . It floats in liquid water because its density is less than that of liquid water.
20. Gold has greater density (19.3 g/cm^3 compared to 11.4 g/cm^3 for lead).



Intervention Plan

Based on the results of the Chapter Review, use the chart below to address individual needs.

Lesson	Questions	Intervention Options
Understand Key Concepts		
1	1–2	 Key Concept Builders  Content Practice  Animations: Atomic Structure; States of Matter and Molecular Motion; Temperature and Molecule Motion  Interactive Concept Map: Matter  Personal Tutors: Parts of an Atom; Chemical Formula; Density; Balancing a Chemical Equation
2	3–4, 8	
3	6	
4	5, 7, 9–10	
Critical Thinking		
1	11–12	 Enrichment  Challenge  Virtual Lab: What is a balanced chemical equation?  WebQuests: Solutes, Solvents, and Solubility; The Chemistry of Fireworks
2	13	
3	14–16	
4	17	
Writing in Science		
1	18	 Language Arts Enrichment  WebQuests: Solutes, Solvents, and Solubility; The Chemistry of Fireworks
Review the Big Idea		
4	19–20	 Content Practice  Enrichment  Challenge  Online Test Practice
Math Skills		
2	21–22	 Math Skills  Math Practice: Use Ratios  Math Personal Tutor: Find Unit Rates

Standardized Test Practice

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

Multiple Choice

1. Which describes how mixtures differ from substances?
- Mixtures are homogeneous.
 - Mixtures are liquids.
 - Mixtures can be separated physically.
 - Mixtures contain only one kind of atom.

Use the figure below to answer questions 2.



2. Which change in the figure above is a model for a compound?
- A
 - B
 - C
 - D
3. Which is a chemical property?
- the ability to be compressed
 - the ability to be stretched into thin wires
 - the ability to melt at low temperatures
 - the ability to react with oxygen
4. You drop a sugar cube into a cup of hot tea, and the sugar disappears in the tea.
- It breaks into elements.
 - It evaporates.
 - It melts.
 - It dissolves evenly.

5. Which is an example of a substance?
- air
 - antacid
 - salt
 - water

Use the figure below to answer questions 6.

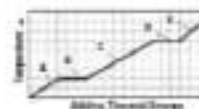


6. The figure above is a model of a solid at room temperature. Which physical property does this sample have?
- It can be poured.
 - It can expand to fill its container.
 - It cannot easily change shape.
 - It has a low boiling point.
7. Which observation is a sign of a chemical change?
- bubbles escaping from a carbonated drink
 - new filings sticking to a magnet
 - light flashing from fireworks
 - water turning to ice in a freezer

Standardized Test Practice

Constructed Response

Use the graph below to answer questions 11 and 12.



8. Zinc, a solid metal, reacts with a hydrochloric acid solution. Which will increase the reaction rate?
- cutting the zinc into smaller pieces
 - decreasing the concentration of the acid
 - lowering the temperature of the zinc
 - pouring the acid into a larger container



9. In the figure above, what will be the mass of the final solution if the solid dissolves in the water?
- 5 g
 - 145 g
 - 150 g
 - 155 g
10. Which is NOT represented in a chemical equation?
- chemical formula
 - product
 - conservation of mass
 - reaction rate

11. Use the graph above to explain why ice will keep water cold on a hot day.

12. Use two sections of the graph to explain what happens when you put a pot of cold water on a stove to boil. Specify which two sections you used.

13. Describe how you would separate a mixture of sugar, sand, and water.

14. The reaction of zinc metal with hydrochloric acid produces zinc chloride and hydrogen gas. A student writes the following to represent the reaction:



Is this equation correct? Use conservation of mass to support your answer.

Multiple Choice

1. **C—Correct.** Incorrect. Not all mixtures are homogeneous. B: Incorrect. Not all mixtures are liquids. D: Incorrect. Mixtures contain more than one kind of atom.
2. **C—Correct.** A, B, D—All show models in which the atoms are the same.
3. **D—Correct.** A, B, C—All are physical properties.
4. **D—Correct.** Incorrect. This describes a reaction (decomposition). B, C: Incorrect. The solid does not change state when it dissolves.
5. **D—Correct.** A, B, C—All are mixtures.
6. **C—Correct.** Incorrect. This is a property of only liquids and gases. B: Incorrect. This is a property of only gases. D: Incorrect. The sample is a solid at room temperature. That means its melting point is higher than room temperature and its boiling point must be higher than its melting point.

7. **C—Correct.** A, D: Incorrect. Both are signs of physical changes. B: Incorrect. This is a physical property.

8. **A—Correct.** B, C: Incorrect. Both will decrease the rate of the reaction. D: Incorrect. This will have no effect on the rate of the reaction.

9. **D—Correct.** A, B, C—None show the conservation of matter.

10. **D—Correct.** A, B, C—All are shown in a chemical equation.

Constructed Response

- 11** Part B on the graph shows that the temperature does not increase as a solid melts. As the ice in water melts, the temperature of the water and the ice will stay at the melting point of water, 0°C .
- 12** Parts C and D of the graph show what happens to cold water that is put on a stove to boil. First the temperature of the water will increase as energy is added to it. Then, when the water begins to boil, the temperature stays at the boiling point of water.
- 13** The first step would be to filter the mixture to separate the sand from the water and sugar. The next step would be to boil the mixture to make the water evaporate. The sugar will be left behind.
- 14** The equation is incorrect because it is not balanced. A correct equation would show conservation of mass by showing equal numbers of atoms for each element on both sides of the arrow. The products side shows more hydrogen and chlorine atoms.



Answer Key

Question	Answer
1	D
2	D
3	D
4	D
5	C
6	D
7	A
8	B
9	D
10	C
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.

Understanding the Atom



The BIG Idea

What are atoms, and what particles make up?



4.1 Discovering Parts of an Atom

- What is an atom?
- How would particles that are part of an atom?
- How has the atomic model changed over time?



4.2 Protons, Neutrons, and Electrons — How Atoms Differ

- What happens during nuclear decay?
- How does the number of protons in an atom determine its chemical properties?



Seeing Inside an Atom

Five friends looked at a piece of aluminum foil. They wondered what they would see if they could see inside an atom of aluminum. This is what they said:

Sam: I think there would be a tiny, dense center surrounded by a lot of empty space where some particles are whirling around.

Ali: I think there would be a huge center made up mostly of empty space with particles whirling around and it would be surrounded by electron shells.

Wahid: I think there would be all empty space with many tiny particles whirling around through all the space.

Rashed: I think I would see like a tiny, dense ball with tiny particles tightly packed inside it.

Fahad: I think it would look like a lot of tiny balls, all floating with no space in between them.

Circle the friend you agree with and explain why you agree.

Chapter 4 Understanding the Atom 124

Understanding the Atom



The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL If you could see an atom, what do you think it would look like? *Accept all reasonable responses. You may also want to show students images of atoms from magazines or the Internet.*

CL Why is it sometimes hard to imagine that visible matter is made up of atoms? *Atoms are too small to see with the unaided eye.*

SL Describe an atom using the modern atomic model. *The modern atomic model has a nucleus made up of protons and neutrons. The majority of the weight of an atom is in the nucleus. Electrons form an electron cloud. The electron cloud is the area around the nucleus where an electron is most likely to be located.*



Seeing Inside an Atom

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook*.

Get Ready to Read

What do you think?

Use the anticipation guide to gauge students' background knowledge and preconceptions about the atom. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. The earliest model of an atom contained only protons and electrons.

Disagree Early models of the atom were small, solid objects that could not be divided, created, or destroyed.

2. Air fills most of an atom.

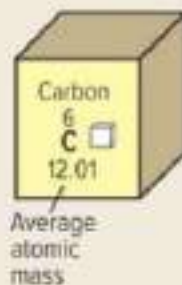
Disagree Most of an atom is filled with empty space.

Science Content Background

Lesson 2

Protons, Neutrons, and Electrons—How Atoms Differ

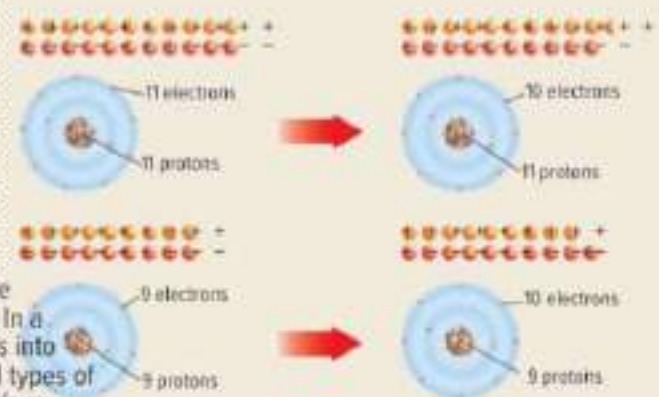
Isotopes Nearly the entire mass of an atom is determined by protons and neutrons. The mass number of an atom is defined as the sum of the protons and neutrons in the nucleus. Isotopes are atoms of the same element that have different numbers of neutrons. Most atoms have several isotopes. The average atomic mass of an element is a weighted average of all of the naturally occurring isotopes of that element. To calculate the average atomic mass, each exact atomic mass is multiplied by its percentage of abundance, expressed as a decimal. The results are then added together.



Radioactivity Elements that spontaneously emit radiation are radioactive. Radioactive elements contain unstable nuclei. In a process called nuclear decay, an unstable nucleus changes into another more stable nucleus by emitting radiation. Several types of radiation can be emitted during the process of radioactive decay.

The radiation can be alpha, beta, or gamma. An alpha particle is basically a helium nucleus—two protons and two neutrons. When an atom emits an alpha particle, the resulting atom has two fewer protons and two fewer neutrons. Beta decay occurs when a neutron changes into a proton and a beta particle. A beta particle is a fast-moving electron. When an atom emits a beta particle, the resulting atom has one more proton and one fewer neutron. Gamma rays do not contain particles, just energy. The release of gamma rays does not change the number of protons or neutrons in an atom.

Ions Ions are atoms that have a positive or negative charge. An ion is formed when a neutral atom gains or loses electrons. When a neutral atom loses electrons, it has fewer electrons than protons. As a result, it has a positive charge. A positively charged ion is called a cation. When a neutral atom gains electrons, it has more electrons than protons. As a result it has a negative charge. A negatively charged ion is called an anion.



Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Adapted from Association for the Advancement of Science (WIS), Benchmarks for Science Literacy, New York: Oxford University Press.

* Materials may be composed of parts that are too small to be seen without magnification.

* A lot of different materials can be made from the same basic materials.

* Substances may move from place to place, but they never appear out of nowhere and never just disappear.

* A model of something is similar to, but not exactly like, the thing being modeled. Some models are physically similar to what they are representing, but others are not.

Lesson 1

Discovering Parts of an Atom



1. If you were to divide an element into smaller and smaller pieces, the smallest piece would be an atom.

2. Atoms are so small that they can be seen only through powerful scanning microscopes.



3. The first model of the atom was a solid ball. Now, scientists know that an atom has a dense positive nucleus surrounded by an electron cloud.

Lesson 2

Protons, Neutrons, and Electrons—How Atoms Differ



4. Nuclear decay occurs when an unstable atomic nucleus changes into another more stable nucleus by emitting radiation.

5. Different elements contain different numbers of protons. Two isotopes of a given element contain different numbers of neutrons. When a neutral atom gains or loses an electron, it becomes an ion.

Identifying Misconceptions

An Atom Isn't Flat

Find Out What Students Think

Students may think that...

... atoms are two-dimensional objects. This misconception may arise because students see atoms as diagrams on paper. They may need help conceptualizing that the smallest piece of an element has volume.

Discussion

Have students consider the flat-looking aluminum foil (Figure 2), the more three-dimensional solid (Figure 3), and the Modern Atomic Model (Figure 10). Ask: What are the limitations of drawing models to represent a three-dimensional object?

Drawings are two-dimensional, but atoms are three-dimensional. Obtain a basketball or rubber playground ball. Cut a large circle from a piece of cardboard or poster board. Try to cut the circle so that it is about the size of the ball. Ask: What is the difference between these two objects? One is a circle and the other is a sphere. The circle has two dimensions and the ball has three dimensions.

Ask: Which object would more accurately represent the shape of the atom? The ball. Explain to students that objects in the real world are three-dimensional. They are sometimes drawn in two dimensions because it is easier to show their parts that way.

Ask: Do you think atoms are two-dimensional like the circle, or three-dimensional like the ball? They are three-dimensional. Ask: Why does the aluminum foil (Figure 2) look so flat if it is made up of atoms with three dimensions? Atoms are so small that the aluminum appears two dimensional to the eye. Under a microscope, it has three dimensions, as shown in Figure 4.

Promote Understanding

Activity Have each student redraw The Modern Atomic Model (Figure 10) on a sheet of paper. Then tell students they will use the materials in front of them to construct a three-dimensional representation of the model.

1. Hand out large polystyrene balls, gumdrops, raisins, and toothpicks. Remind students never to eat any food in the lab.
2. Ask students to refer to their drawing and decide which three-dimensional object they will use to represent the atomic model, the nucleus, and its protons and neutrons.
3. If students have a difficult time with relative size, point them to Table 2 in Lesson 2.
4. Ask students to recreate their two-dimensional drawing using the three-dimensional objects and connecting them with toothpicks.
5. Facilitate a discussion with students about how much easier it is to represent an atom in two dimensions, yet how the three-dimensional objects' models accurately represent the structure of an atom and of each of its components. Also discuss with students the limitations of both types of models in representing the true structure of atoms.

Is It Crowded in There?

Find Out What Students Think

Students may think that...

the electron cloud is "crowded" with electrons. This misconception may arise because they may have seen diagrams of the electron cloud model that show probability patterns as clouds, and students may think that these diagrams show numerous electrons. An understanding of probability and how a probability distribution is obtained will help clear up this misconception.

Discussion

Explain to students that probability is a measure of how likely something will occur. May want to review the concept of probability with students using a pair of number cubes and the following question: Ask: If I were to roll a number cube one time, what is the probability of it landing on the number 4? The probability is 1 in 6, or 17%, chance of landing on the number 4.

Ask: If I were to roll a number cube one time, what is the probability of it landing on an even number? The probability is 1 in 2, or 50%, chance of landing on an even number. Connect this demonstration to the probability model used for electron clouds by asking students to work through the demonstration below.

Promote Understanding

Activity Students can use a marker and a target to demonstrate the probability distribution of an electron in relation to the nucleus.

1. Tell students to create a target by drawing a large circle on a sheet of paper. Have them draw another, slightly smaller circle inside of the first, and repeat until they have created a target with a total of 10 concentric circles.
2. Instruct students to place the target on the floor, and to drop a marker from about 90 cm above the target 50 times. Explain to students that the "crowded areas", the areas with the most marks, represent areas where the marker has a high probability of landing, and the less-crowded areas represent areas where the marker has a low probability of landing.
3. Have students number each circle beginning with the smallest circle. Then have them count the number of marks on each circular ring and record this information in a data table.
4. Have students create a bar graph of area number (x-axis) v. the number of marks (y-axis).
5. Explain to students that the graph they created shows the probability of finding a single electron in an atom. Remind students that the probability of finding an electron increases then decreases as the distance from the nucleus increases. Have students check to see if their graphs represent this fact.



4.1 Discovering Parts of an Atom



Explore Activity

What's in there?

When you look at a sandy beach from far away, it looks like a solid surface. You can't see individual grains of sand. What would you see if you looked in on one grain of sand?

Procedure

1. Read the procedure and identify the safety precautions work begins.
2. Have your partner hold a test tube of a substance. Hold the height of 2–3 cm.
3. Observe the substance from a distance of at least 1 m. Write a description of what you see in your Science Journal.
4. Pour about 1 cm of the substance into a small container. Record your observations.
5. Use a test tube to separate out one particle of the substance. Suppose you could do this. What do you think you would see? Record your ideas in your Science Journal.

Think About This

1. Do you think one particle of the substance is made of smaller particles? Why or why not?

2. Key Concept Do you think you could use a microscope to see what the particles are made of? Why or why not?

Essential Questions

- What is an atom?
- How would you describe the size of an atom?
- How has the atomic model changed over time?

Vocabulary

atom
electron
nucleus
proton
neutron
electron cloud



INQUIRY

About the Photo A Microscopic Mountain Range? Scanning tunneling microscopic (STM), which provided the first images of individual atoms, was not invented until 1981. However, scientists had known of the existence of atoms and had understood a great deal about their structure well before these images were obtained.

Guiding Questions

- | | |
|---|---|
| AL What are these tiny particles? | Individual atoms. |
| OL How small do you think they are? | Accept all reasonable answers. Students should understand that atoms cannot be viewed with the unaided eye and that a STM is much more powerful than a microscope they may have in their classroom. |
| OL How might scientists have learned so much about atoms before being able to see them? | Scientists used observations and experiments to study atoms before being able to see them. |
| SL Why do you think it would be useful for scientists to be able to see objects at the atomic level? | Possible answers: Scientists can study the behavior of atoms and how they join together to form molecules. |

LAB Manager

All the labs for this lesson can be found in the Student Resource Handbook and the Activity Lab Workbook.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Modeling an Atom

1. Have students create models of an atom before and after exploring this lesson. Instruct students to draw a large circle on a sheet of notebook paper. Then have students draw a smaller circle inside the large circle. Students should use their prior knowledge to label the model of an atom by placing the vocabulary terms in the appropriate places on and inside the large and small circles. Have students pair up to compare their models and to make changes, if necessary.
2. Have students create another model of an atom by drawing a large circle on a new sheet of paper. As new information is explored in this lesson, students should use the information

to add vocabulary terms to their models. At the end of the lesson, have students compare their two atomic models. Facilitate a discussion with students about what they have learned in this lesson. You may want to use this as an opportunity to clear up any misconceptions they may have about the structure of an atom and to discuss the limitations of models.

Teacher Notes

ExploreActivity

What's in there?

Prep: 5 min Class: 10 min

Purpose

To learn the concept of relative size.

Materials

Materials per team of two students: test tube filled with two to three cm of table salt (sugar or sand also work), waxed paper, toothpick

Before You Begin

Explain to students that before the invention of tools such as microscopes philosophers and scientists relied on observations and experiments to develop ideas about matter. In this lab, students will observe certain properties of matter and hypothesize what might be there that they cannot see.

Guide the Investigation

- Have students take turns viewing the test tube from a distance. Ask students to observe the test tube as if they know nothing about what it contains and to simply record what they observe.
- When they pour the substance onto the waxed paper, some of the particles will separate out. It should become obvious that the apparently "solid" white substance is made of smaller pieces.
- As they mentally "zoom in," remind students of movies or television programs that "zoom in" on parts that normally can't be seen or "zoom in" from outer space to a single person on Earth.

Think About This

Students may not know the answers to all questions. Encourage them to hypothesize.

1. Answers will vary. Some students may say that the particle is made of smaller particles that look the same because the larger one can be smashed. Some students may say that the substance is not made of smaller particles because they cannot see any smaller particles.
2. **Key Concept:** Answers will vary. Some students may propose that the particle is made of smaller versions of the larger particle. Some students may think that the particle is the smallest unit of the substance and would not look any different under a microscope.

Democritus

Before reading this lesson, write down what you already know in the first column. As the lesson progresses, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

Democritus

Democritus believed that matter is made of small, solid objects that cannot be divided, created, or destroyed. He called these objects *atoms*, from which the English word *atom* is derived. Democritus proposed that different types of matter are made from different types of atoms. For example, he said that smooth matter is made of smooth atoms. He also proposed that nothing is between these atoms except empty space. One philosopher who challenged Democritus's ideas was Aristotle.

Aristotle

Aristotle (384–322) did not believe that empty space exists. Instead, he favored the more popular idea—that all matter is made of fire, water, air, and earth. Because Aristotle was so influential, his ideas were accepted. Democritus's ideas about atoms were not studied again for more than 2,000 years.

Dalton's Atomic Model

In the late 1700s, scientist John Dalton (1766–1844) revived the idea of atoms. Since Democritus's time, advancements had been made in scientific methods. Dalton made careful observations and measurements of chemical reactions. He combined data from his research with data from other scientists to propose the atomic theory.

Early Ideas About Matter

Look at your hands. What are they made of? You might answer that your hands are made of things such as skin, bone, muscle, and blood. You might recall that each of these is made of even smaller structures called cells. Are cells made of even smaller parts? Imagine dividing something into smaller and smaller parts. What would you end up with?

Greek philosophers discussed and debated questions such as these more than 2,000 years ago. At the time, many thought that all matter is made of only four elements: fire, water, air, and earth, as shown in **Figure 1**. However, they weren't able to test their ideas because scientific tools and methods, such as experimentation, did not exist yet. The proposal by the most influential philosopher was usually more accepted over the ideas of other influential philosophers. One philosopher, Democritus (460–370), challenged the popular idea of matter.

Figure 1 Most Greek philosophers believed that all matter is made of only four elements—the water, air, earth, and fire.

Table 1 Similarities Between Democritus's and Dalton's Ideas

Democritus	Dalton
1. Atoms are small solid objects that cannot be divided, created, or destroyed.	1. Atoms are small solid objects that cannot be divided, created, or destroyed.
2. Atoms are constantly moving in empty space.	2. Atoms are constantly moving in empty space.
3. Different types of matter are made of different types of atoms.	3. Different types of matter are made of different types of atoms.
4. The properties of the atoms determine the properties of matter.	4. The properties of the atoms determine the properties of matter.

Early Ideas About Matter

In this lesson, students will explore how the concept of the atom has changed over time beginning with the early Greek philosophers. Use these questions to help students focus on the ideas the early philosophers held about matter, and why they held those ideas.

Guiding Questions

- Q1** Why do you think the early philosophers thought that matter was made of fire, water, air, and earth?

Q2 What do you know about matter that conflicts with the ideas proposed by these early philosophers?

They thought that matter was made up of the things that were around them—things that they could see and feel.

Possible answers: Matter is anything that has mass and occupies space. Matter is made up of atoms. A substance made up of only one kind of atom is an element. These atoms also can combine to form compounds. Air and water are not elements.

Democritus

Students should understand that Democritus was a Greek philosopher who proposed the idea that matter is made up of small, solid spheres he called *atomos*.

Ask: According to Democritus, what might atoms of gold look like? *Democritus thought that matter was made of atoms that share the characteristics of the matter. The atoms of gold might be gold-colored and shiny. Scientists now know that atoms all look similar and have different numbers of protons, neutrons, and/or electrons.*

Aristotle

Both Aristotle and Democritus were philosophers who had ideas about matter. Aristotle favored the more popular idea—that matter is made of fire, water, air, and earth. Aristotle was a more influential philosopher than Democritus, so his ideas were more widely accepted.

Ask: In what ways were Aristotle's and Democritus's ideas about matter different, and in what ways were they similar? *Differences include: Aristotle's ideas were more popular than Democritus's ideas. Aristotle did not think that empty space exists, while Democritus did, and Aristotle thought that matter is made of water, fire, air, and earth while Democritus thought that matter is made of atoms. Similarities include: Both ideas were based on philosophy rather than experimentation. Both ideas attempted to describe what matter is made of.*

Dalton's Atomic Model

Use these questions to guide students in comparing and contrasting Democritus's and Dalton's atomic theories.

Guiding Questions

- OL** How did Dalton's and Democritus's methods differ in determining their atomic theories?
Democritus philosophized about atoms, whereas Dalton made observations and took measurements to reach his conclusions.
- SL** Part of Dalton's atomic theory states that matter is made up of atoms that cannot be divided, created, or destroyed. How does this compare to today's atomic theory?
This statement does not apply to today's atomic theory, because we know an atom can be broken down into smaller particles—protons, electrons, and neutrons.

The Atom

Students learn that all matter is made of atoms with empty space between them. Students might think that this empty space is made of air. Tell students that air is made of atoms that are very far apart and with much more empty space between them than is the case with solids. Point out that students can feel the atoms in the air by blowing on their skin. The pressure they feel is the pressure of the atoms in the air. Use the following questions to guide students in understanding exactly what an atom is.

Guiding Questions

- OL** What is a copper atom?
A copper atom is the smallest piece of copper that still has the properties of copper.
- SL** Why is it inaccurate to define an atom as "the smallest part of an element"?
An atom is not the smallest part of an element. This definition is incomplete because an atom contains smaller particles. However, an atom is the smallest part of an element that still has the properties of that element.

The Size of Atoms

Students often have difficulty visualizing the size of an atom. Help students by explaining that the number of carbon atoms that could fit into the period at the end of the last sentence in the paragraph is 75 followed by 11 zeros. You may want to write this number (7,500,000,000,000) on the board or chart paper. Use these questions to guide students in understanding the size of atoms.

Guiding Questions

- OL** How would you describe the size of an atom?
Students should demonstrate that they understand that atoms are far too small to be seen even by most microscopes. Students might say that they are so small that 7.5 trillion atoms take up the space of a period at the end of a sentence.
- SL** Which is smaller, a cell or an atom?
Atoms are smaller than cells. Cells are made up of atoms.

Differentiated Instruction

AL Democritus v. Dalton Have students use the information in **Table 1** to create a Venn diagram comparing and contrasting the atomic theories of Democritus and Dalton.

SL Inaccuracies in Dalton's Atomic Theory Have students write the statements of Dalton's atomic theory in **Table 1**. Ask students to note how these statements have been proved or disproved as they explore the information in chapter.

LA Illustrate Concepts Have students create an index card for each of the three major ideas explored so far in this lesson. Instruct students to write the major idea on one of an index card. On the other side, they should illustrate the idea. For example, students could illustrate the early ideas about matter by drawing Aristotle arguing with Democritus.

Teacher Toolbox

Cultural Diversity

Early Atomic Theory in India Some of the earliest known ideas about atoms arose in ancient India between the 6th and 2nd century B.C. Kanada, a Hindu philosopher, theorized that atoms were inactive and did not have physical properties on their own. Another Indian theory of atoms linked the behavior of matter to the nature of its atoms.

Teacher Demo

How small is an atom? Give each student a 1-fils coin. Write the number 2.4×10^{24} in standard form on the board or chart paper. Explain to students that although small coins haven't been made of pure copper since 1837, a 1-fils coin was made of pure copper, it would contain 2.4×10^{24} copper atoms. Put it into perspective, remind students that the population of the world is less than 7 billion, so the number of copper atoms in a pure copper 1-fils coin is more than three times the population of the world.

Fun Fact

Moving Individual Atoms Scanning tunneling microscopy can be used not only to see atoms, but can also be used to move them. In 1989, after figuring out how to move individual atoms in a process called atom manipulation, scientists at IBM used 35 xenon atoms to write the letters "IBM" on a nickel surface. The scientists were able to do this by changing the current in the tip of the scanning tunneling microscope first to attract the individual atoms and then to let them go in another place on the surface.

Figure 21 You could keep dividing a piece of aluminum, you could finally end up with the smallest possible piece of aluminum—an aluminum atom.



The Atom

Today, scientists agree that matter is made of atoms with empty space between and within them. What is an atom? Imagine dividing the piece of aluminum in Figure 20 into smaller and smaller pieces. At first you would be able to cut the piece with scissors, but eventually you would have a piece that is too small to see much larger than the smallest piece you could cut with scissors. This small piece is an aluminum atom. An aluminum atom cannot be divided into smaller aluminum pieces. **Atoms** are the smallest piece of an element that still represents that element.

The Size of Atoms

Just how small is an atom? Atoms of different elements are different sizes, but all are very, very small. You cannot see atoms with your eyes or even with most microscopes. Atoms are so small that about 7.5 trillion carbon atoms could fit inside period at the end of this sentence.

Seeing Atoms

Scientists' experiments verified that matter is made of atoms long before scientists were able to see atoms. However, the 1981 invention of a high-powered microscope, called a scanning tunneling microscope (STM), enabled scientists to see individual atoms for the first time (Figure 23). An STM uses a tiny metal tip to trace the surface of a piece of material. The result is an image of atoms on the surface.

Even today, scientists still cannot see inside an atom. Over the years, scientists have learned that atoms are not the smallest particles in matter. In fact, atoms are made of much smaller particles. What are these particles, and how did scientists discover them if they could not see them?



Figure 23 Scanning tunneling microscope created this image. The yellow spheres are a magnification of atoms on the surface of silicon.

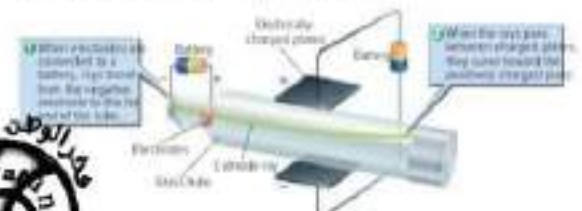
Thomson—Discovering Electrons

Not long after Dalton's findings, another English scientist, named J.J. Thomson (1856–1940), made some important discoveries. Thomson and other scientists of that time worked with cathode ray tubes. If you ever have seen a neon sign, an older computer monitor, or the color display on an ATM screen, you have seen a cathode ray tube. Thomson's cathode ray tube, shown in Figure 4, is a glass tube with pieces of metal, called electrodes, attached inside the tube. The electrodes were connected to wires, and the wires were connected to a battery. Thomson discovered that if most of the air was removed from the tube and electricity was passed through the wires, greenish-yellow rays traveled from one electrode to the other end of the tube. What were these rays made of?

Negative Particles

Scientists called these rays cathode rays. Thomson wanted to know if these rays had an electric charge. To find out, he placed two plates on opposite sides of the tube. One plate was positively charged, and the other plate was negatively charged, as shown in Figure 4. Thomson discovered that these rays bent toward the positively charged plate and away from the negatively charged plate. Recall that opposite charges attract each other, and like charges repel each other. Thomson concluded that cathode rays are negatively charged.

Figure 4a The cathode rays bent toward the positively charged plate. Thomson concluded that the rays must be negatively charged.



Lesson 4: Discovering Particles of an Atom

Seeing Atoms

Use these questions to guide students in understanding the of the invention of the scanning tunneling microscope on the study of atoms.

Guiding Questions

- OL** How do you think scientists have been able to conclude that atoms are made of smaller particles even though these particles cannot be seen even with a scanning tunneling microscope? Scientists performed experiments to verify that atoms contain subatomic particles.
- SL** What are some reasons why it was important for scientists to be able to see atoms and how they interact with one another, had been verified by scientific experiments? Scientists wanted to see the shapes of atoms and how they interact with one another.

Thomson—Discovering Electrons

J.J. Thomson discovered electrons through experimenting with cathode ray tubes. Use these questions to introduce students to the cathode ray tube.

Guiding Questions

- OL** What are some examples of modern cathode ray tubes? Examples include neon signs, older computer monitors, and ATM screens.
- SL** What do you think the rays are made of? The rays are made of electrons.

Negative Particles

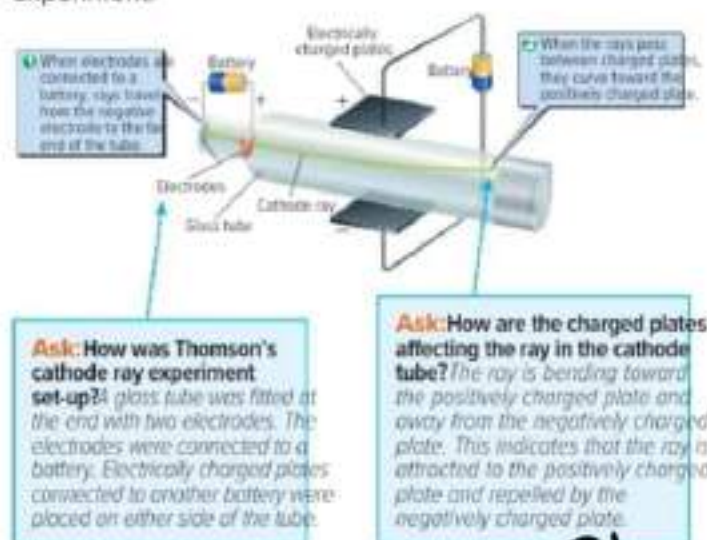
Use these questions to emphasize to students that cathode rays are negatively charged and to prepare students to be introduced to the electron.

Guiding Questions

- OL** Why did Thomson conclude that the rays were negatively charged? The rays bent toward the positively charged plate and away from the negatively charged plate.
- OL** If the rays were positively charged, what would Thomson have observed? Because opposite charges attract, the rays would have bent toward the positively charged plate.

Visual Literacy: Thomson's Cathode Ray Tube Experiment

Students may need help understanding the set-up and implementation of the cathode ray experiment. Use the questions below to help students understand the results of Thomson's cathode ray tube experiment.



Parts of Atoms

Thomson's cathode ray experiment did not in itself prove the existence of electrons. Thomson used other scientific data and measurements to reach his conclusions. Use these questions to help students understand the evidence that led Thomson to conclude that atoms contain smaller particles.

Guiding Questions

- AL** What part of an atom did Thomson discover? *the electron*
- CL** What is an electron? *A particle with a single negative charge*
- BL** Based on Thomson's findings, how would you describe the structure of an atom? *An atom contains electrons—small particles with a single negative charge. However, since an atom is not electrically charged, it must also contain a positive charge to balance the negative charges.*

Thomson's Atomic Model

Use this question to compare and contrast Thomson's atomic model with Dalton's atomic model.

Guiding Questions

- CL** How did Thomson's atomic model differ from Dalton's atomic model? *Thomson's model is not a solid sphere, as proposed by Dalton. Thomson's model contains negatively charged electrons embedded in a sphere of positive charge.*

Differentiated Instruction

AL Write a Newspaper Article Have students write a newspaper article announcing Thomson's discovery of electrons. Instruct students to include appropriate illustrations. Encourage them to use factual information explored so far in this lesson.

BL Write a Skit Have students work in pairs to write and act out a short skit of a fictional conversation between J.J. Thomson and a student. Instruct students to imagine what their conversation would have been like if they had met after Thomson discovered electrons. Encourage students to use factual information explored so far in this lesson.

LA Visual Literacy Have students examine Figure 4 and Figure 5 in this section before reading the captions. Encourage students to think first of a description of what is happening in each figure. Then have them record their thoughts on paper. Finally, instruct students to compare their written descriptions with the captions.

Teacher Toolbox

Reading Strategy

Summarize Have students write a one-paragraph summary about Thomson's discovery of electrons. Instruct students to write one sentence for each heading in this section and include it in the paragraph.

Teacher Demo

Like Charges Repel Demonstrate that like charges repel by blowing up two balloons and rubbing them both on a piece of wool. Explain to students that rubbing the balloons on the wool creates a buildup of negative charge. Ask students to predict what will happen when the balloons are moved closer to each other. Then move the balloons close to each other. Explain to students that when the balloons are moved next to each other, the collection of like charges cause the balloons to move away from each other.

Real-World Science

Modern Cathode Ray Tubes Up to the last decade, most televisions and computer monitors were powered by cathode ray tubes, or CRTs. In devices powered by CRTs, images are produced when an electron beam strikes a screen coated with phosphor. The collision of electrons with the phosphor causes it to glow and display different colors.

FOLDABLES

Use two sheets of paper to make a layered book. Label it as shown. Use it to organize your notes and diagrams for the parts of an atom.



Word Wall

electrolysis Great electron, means "under," the physical force so called because it first was generated by rubbing amber. Amber is a fossilized substance produced by trees.

Writing Prompt

5. How did Thomson's atomic model differ from Dalton's atomic model?

Parts of Atoms

Through more experiments, Thomson learned that these rays were made of particles that had mass. The mass of one of these particles was much smaller than the mass of the smallest atoms. This was surprising information to Thomson. Until then, scientists understood that the smallest particles of matter is atoms. But these rays were made of particles that were even smaller than atoms.

Where did these small, negatively charged particles come from? Thomson proposed that these particles came from the neutral atoms in the electrode. Thomson discovered that identical rays were produced regardless of the kind of metal used to make the electrode. Putting these clues together, Thomson concluded that cathode rays were made of small, negatively charged particles. He called these particles **electrons**: a particle with one negative charge. These atoms are neutral, not electrically charged. Thomson proposed that atoms also must contain a positive charge that balances the negatively charged electrons.

Thomson's Atomic Model

Thomson used this information to propose a new model of the atom. Instead of a solid, neutral sphere that was the same throughout, Thomson's model of the atom contained both positive and negative charges. He proposed that an atom was a sphere with a positive charge evenly spread throughout. Negatively charged electrons were mixed throughout the positive charge, similar to the way chocolate chips are mixed in cookie dough. **Figure 5** shows this model.



Figure 5 Thomson's model of the atom contained a positively charged sphere with negatively charged electrons within it.

Rutherford—Discovering the Nucleus

The discovery of electrons inspired scientists. Ernest Rutherford (1871–1937) was a student of Thomson's who eventually had students of his own. Rutherford's students set up experiments to test Thomson's atomic model and to learn more about what atoms contain. They discovered another surprise.

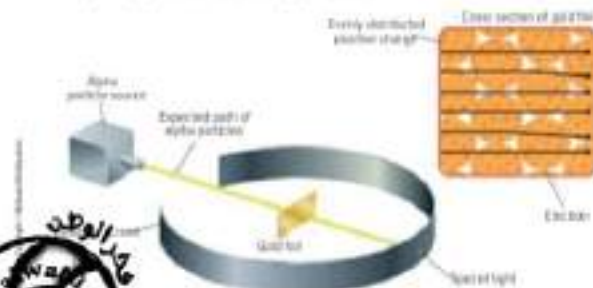
Rutherford's Predicted Result

Imagine throwing a baseball into a pile of fabric-covered balls. The baseball likely would knock the fabric-covered balls out of the way and continue moving in a relatively straight line. This is similar to what Rutherford's students expected to see when they shot alpha particles into atoms. Alpha particles are dense and positively charged because they are so dense, only another dense particle could deflect the path of an alpha particle. According to Thomson's model, the positive charge of the atom was ion spread out and not dense enough to change the path of an alpha particle. Electrons wouldn't affect the path of an alpha particle because electrons didn't have enough mass. The result that Rutherford's students expected is in **Figure 6**.

Writing Prompt

6. Explain why Rutherford's students did not think an atom could change the path of an alpha particle.

Figure 6 If Thomson's model of the atom did not contain a charge that was dense enough to change the path of an alpha particle, Rutherford expected the positive alpha particles to travel straight through the foil without changing direction.



Word Origin

electron

Ask: Does the word **electron** sound like any other scientific word with which you are familiar? Possible answers: electric, electricity, electrolyte, electronics, and electroscope.

Ask: What do these words have in common? Possible answers: They all have to do with electrical charge.

Ask: Why do you suppose Thomson named the particle with a single negative charge after the Greek word for **amber**? Possible answer: Amber was known to generate electrical charge.

Visual Literacy: Thomson's Atomic Model

Thomson proposed a new atomic model based on his findings. Use these questions to help students analyze Thomson's atomic model in **Figure 5**.

Ask: What do the little circles represent in Thomson's atomic model? Possible answer: The negatively charged electrons.

Ask: What does the sphere represent in Thomson's atomic model? Possible answer: The sphere is the whole atom.

Ask: What is indicated by the cutaway part of the diagram? Possible answer: The cutaway part of the diagram indicates that the electrons are mixed throughout the positively-charged sphere, not just on the surface of the sphere.

Rutherford—Discovering the Nucleus

Remind students that scientists test their theories via experiment. Sometimes those experiments yield the expected results and the scientists confirm their ideas. Other times scientists make an unexpected discovery. Connect this to the learning students do in the many labs they perform. When Rutherford's students set up an experiment to test his idea, they made an unexpected discovery.

Rutherford's Predicted Result

It is important for students to understand the predicted results of Rutherford's experiment in order to appreciate the significance of the actual results.

Guiding Questions

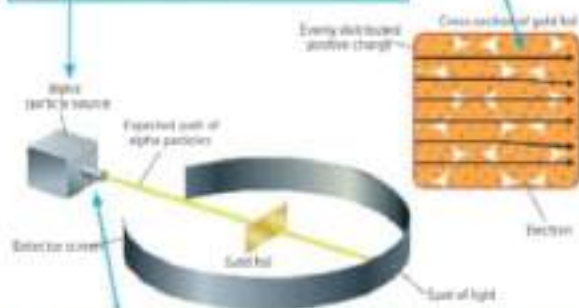
- | | |
|--|--|
| <p>CL How would you describe an alpha particle?</p> <p>CL Explain why Rutherford's students didn't think an atom could change the path of an alpha particle.</p> <p>CL How did the experiment test Thomson's atomic model of a sphere with particles?</p> | <p>An alpha particle is a dense and positively charged particle.</p> <p>According to Thomson's model, an atom didn't contain a dense, positive charge that could change the path of the positive alpha particle.</p> <p>If there was nothing inside an atom that had a mass and density higher than the alpha particle, then the alpha particle would travel straight through the gold foil.</p> |
|--|--|

Visual Literacy: Rutherford's Predicted Result

Students may have difficulty understanding the set-up of Rutherford's experiment. Use these questions to help students analyze the diagram.

Ask: What do the arrows represent in the cross section of the gold foil? *The alpha particles traveling in a straight path through the foil.*

Ask: Where do the alpha particles originate? *At the alpha particle source.*



Ask: What was the expected path the particles would take? *They were expected to travel in a relatively straight line through the gold foil and strike the detector screen.*

The Gold Foil Experiment

Use these questions to facilitate a discussion with students about how the gold foil experiment was set up and implemented.

Guiding Questions

- AL** Identify the three components of the alpha particle source, gold foil, and a screen.
- OL** Why was it important to surround the gold foil with a screen? *The screen would show where the alpha particles hit. Rutherford's students would then know the starting point and the ending point of the alpha particles' path.*

The Surprising Result

Based on Thomson's atomic model, the alpha particles were expected to pass through the gold foil unchanged. Instead, some particles struck the foil and bounced off to the side, while a few bounced straight back. Explain to students that the term shell in the phrase "fifteen-centimeter shell" refers to a projectile that would be launched from a cannon. Imagine launching a cannonball larger than a basketball at a piece of tissue paper and the cannonball bouncing back! This is why Rutherford's team was so surprised by the result of their gold foil experiment.

Guiding Questions

- OL** Given the results of the gold foil experiment, how do you think an actual atom differs from Thomson's model? *If a dense, positive charge is needed to change the path of an alpha particle, then an atom must contain a dense positive charge. This is different from Thomson's model that proposed that the positive charge was spread throughout an atom.*
- BL** Explain how Rutherford and his students knew the object that the alpha particles struck was positively charged. *Alpha particles are positively charged. In order for them to be deflected, they would have to come into contact with an object of like charge.*

Differentiated Instruction

AL Play a Word Game Have students write a paragraph or two to summarize what they have read about atomic models, the parts of atoms, and how those parts were discovered. They should leave a blank space for each vocabulary word or scientist included in their paragraph. Then have them swap their paragraphs with those of other students to fill in the blanks.

BL Concise and Correct Content Challenge interested students to describe Rutherford's experiment as concisely and correctly as possible. Have the rest of the class choose the student who is able to correctly describe the experiment using the fewest words. Encourage them to use the baseball and table tennis ball analogy explained in the section Rutherford's Predicted Result.

LA Visual Literacy Have students read Figure 6 in their Science Journal using a pencil. Then have them use a pencil and annotate that drawing with the real results of the experiment. Have students write a paragraph below their drawing that explains how the alpha particles behaved in the experiment.

Teacher Toolbox

Reading Strategy

Write a Class Summary On the board or chart paper, have students collaborate in order to write a class summary of this section. Instruct them to use the reading checks and key concept checks as their guide. Have one student start up with the first sentence, and have student volunteers contribute additional sentences until the entire section has been summarized.

Real-World Science

Smoke Detectors Most common household smoke detectors contain a small amount of the alpha emitter americium-241. Alpha particles released from the americium remove electrons from the atoms of the air, forming ions in a chamber inside of the alarm. Once the air is ionized, a small amount of current is able to run through it. Smoke particles neutralize the ions, which stops the electric current, setting off an alarm.

The Gold Foil Experiment

Rutherford's students were to work. They placed a source of alpha particles near a very thin piece of gold foil. Recall that all matter is made of atoms. Therefore, the gold foil was made of gold atoms. A screen surrounded the gold foil. When an alpha particle struck the screen, it created a spot of light. Rutherford's students could determine the path of the alpha particles by observing the spots of light on the screen.

The Surprising Result

Figure 7.10 shows what the students observed. Most of the particles did indeed travel through the foil in a straight path. However, a few particles struck the foil and bounced off to the side. And one particle in 10,000 bounced straight back! Rutherford later described this surprising result, saying it was almost as incredible as if you had fired a 50-cal shell at a piece of tissue paper and it came back and hit you. The alpha particles must have struck something dense and positively charged inside the nucleus. Thomson's model had to be refined.

Exit Ticket

5. Given the results of the gold foil experiment, how do you think an atom's structure differs from Thomson's model?

Think Critically

6. What do the dots on the screen indicate?

Figure 7.10 Some alpha particles traveled in a straight path, as expected. But some changed direction, and some bounced straight back.

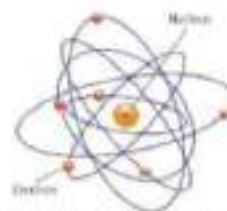
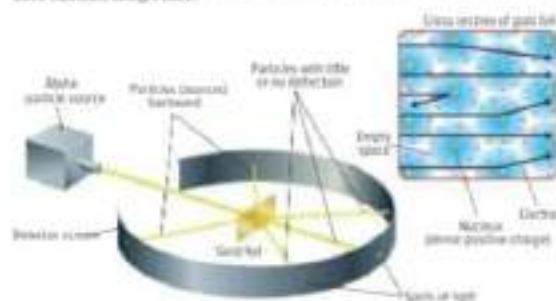


Figure 7.11 Rutherford's model contains a small, dense, positive nucleus. Tiny, negatively charged electrons travel in empty space around the nucleus.

Rutherford's Atomic Model

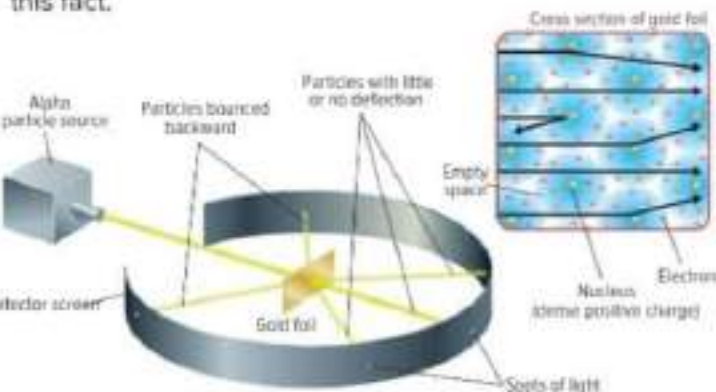
Because most alpha particles traveled through the foil in a straight path, Rutherford concluded that atoms are made mostly of empty space. The alpha particles that bounced backward must have hit a dense, positive mass. Rutherford concluded that most of an atom's mass and positive charge is concentrated in a very small region in the center of the atom called the nucleus. Rutherford's atomic model. Additional research showed that the positive charge in the nucleus was made of positively charged particles called protons, an atomic particle that has one positive charge (+). Negatively charged electrons travel in the empty space surrounding the nucleus.

Discovering Neutrons

The modern model of the atom was beginning to take shape. Rutherford's colleague, James Chadwick (1891–1974), also researched atoms and discovered that, in addition to protons, the nucleus also contained another neutral particle that exists in the nucleus of an atom.

Visual Literacy: The Surprising Result

The position of the dots of light on the screen provided evidence that the alpha particles struck something dense and positively charged inside of the nucleus. Use these questions to emphasize this fact.



Ask: How would you describe the position of the dots on the detector screen?
Ask: What do the dots on the screen indicate?

Rutherford's Atomic Model

Use these questions to guide students in understanding how the results of the gold foil experiment led Rutherford to conclude that an atom contains a small, dense, positively charged center called the nucleus.

Guiding Questions

- CL** How did Rutherford explain the observation that some of the alpha particles bounced directly backward?
 Rutherford concluded that some alpha particles bounced directly backward because they came into contact with a dense, like-charged mass—the nucleus.
- SL** How does Rutherford's atomic model differ from the Thomson model of an atom?
 Rutherford's model contains positively charged protons. Instead of the positive charge being spread through an atom like Thomson's model, the charge is concentrated in the center of an atom.

Discovering Neutrons

James Chadwick discovered the third major subatomic particle, the neutron. Use these questions to help students understand the properties of neutrons and to review the properties of protons and electrons.

Guiding Questions

- BL** Based on Chadwick's discoveries, describe the composition of the nucleus. *The nucleus contains positive protons and neutral neutrons. The overall charge of the nucleus is positive.*
- CL** What are the names, charges, and locations of the three major subatomic particles? *The proton is positive and is located in the nucleus. The neutron is neutral and is located in the nucleus. The electron is negative and is located outside of the nucleus.*

Bohr's Atomic Model

The Rutherford atomic model depicted the composition of the nucleus accurately, but it failed to depict the arrangement of electrons in an atom accurately. Use this question to guide students in understanding the limitations of the Rutherford atomic model.

Guiding Questions

- BL** Which aspect of atomic structure was Rutherford's atomic model able to explain and which aspect was it unable to explain? *Rutherford's atomic model explained the composition of the nucleus, but was unable to explain the behavior of the electrons.*

Electrons in the Bohr Model

The Bohr model of an atom attempted to describe the arrangement of electrons in atoms. Use these questions to guide students in understanding the arrangement of electrons in the Bohr atomic model and the observations that led to that arrangement.

Guiding Questions

- BL** Describe the arrangement of electrons in the Bohr atomic model. *In the Bohr model, electrons move in circular energy levels around the nucleus.*
- CL** What is the relationship between an electron's location around the nucleus and the amount of energy it has? *The farther away from the nucleus an electron is located, the more energy it has.*
- BL** How did the Bohr model explain the observation that if certain elements are heated in a flame they give off specific colors of light? *In the Bohr model, electrons are arranged around the nucleus in increasing energy levels. When electrons gain energy, they move from a lower energy level to a higher energy level. When the electrons return to a lower energy level, they release energy in the form of light.*

Limitations of the Bohr Model

The Bohr model was not able to depict the arrangement of electrons in atoms with more than one electron. Use these questions to facilitate a discussion with students about the importance of the Bohr model, as well as the other atomic models explored so far.

Ask: How did Bohr's model of the atom differ from Rutherford's? *Bohr's model, electrons travel in circular orbits around the nucleus and have different and specific amounts of energy. In Rutherford's model, electrons move in the empty space around the nucleus.*

BL Approaching Level **CL** On Level **BL** Beyond Level **LA** Language Acquisition

Differentiated Instruction

- AL** **Create a Venn Diagram** Have students create a three-circle Venn diagram of the similarities and differences among the Thomson, Rutherford, and Bohr atomic models. Instruct students to include an illustration of each model.
- BL** **Create a Timeline** Have students create a timeline illustrating and organizing the progression of the atomic model from the Dalton model through the Bohr model. Instruct students to include the principal scientists and brief description of their experiments, along with illustrations.
- LA** **Play a Card Game** Have students create a set of index cards with various information about each of the three subatomic particles explored in this lesson. Each card should include one piece of information (particle name, the scientist who discovered it, its charge, or its location in an atom). Shuffle the cards and work in teams to arrange them in a logical manner.

Teacher Toolbox

Reading Strategy

What's the Main Idea? Have students write down what they think is the main idea of each section. Then have pairs of students discuss the section's ideas in order to reach a decision on what they think is the main idea of each section. Next have each pair combine with another pair of students to discuss and decide what they think is the main idea of each section. Finally have each group share their results with the class.

Fun Fact

All in the Family Niels Bohr was awarded the Nobel Prize in physics in 1922 for his investigation of the structure of atoms and of the radiation emanating from them. His son, Aage Bohr, shared the Nobel Prize with two other physicists in 1975 for the discovery of the connection between collective motion and particle motion in atomic nuclei. The development of the theory of the structure of the nucleus that was based on this connection.

Teacher Demo

Electron Energy Levels Place a ring-shaped wintergreen candy between the jaws of a pair of pliers. Turn out the lights and use the pliers to break the candy. When the candy is crushed, electrons in the wintergreen flavor molecules become excited, absorb energy, move to a higher energy level, then move back to the lower energy level, releasing the energy in the form of light. Be sure to practice this demonstration on your own ahead of time. Some brands of wintergreen candy work better than others.

Bohr's Atomic Model

Bohr's model explained much, but not all, of his students' experimental evidence. For example, scientists noticed that if certain elements were heated in a flame, they gave off specific colors of light. Each color of light had a specific amount of energy. Where did this light come from? Niels Bohr (1879–1962) proposed an answer. Bohr studied hydrogen atoms because they contain only one electron. He experimented with adding electric energy to hydrogen and studying the energy that was released. His experiments led to a revised atomic model.

Electrons in the Bohr Model

Bohr's model is shown in **Figure 9**. Bohr proposed that electrons move in circular orbits, or energy levels, around the nucleus. Electrons in an energy level have a specific amount of energy. Electrons closer to the nucleus have less energy. When energy is added to an atom, electrons gain energy and move to a higher energy level. When the electron returns to the lowest energy level, they release a specific amount of energy as light. This is the light that is seen when elements are heated.

Limitations of the Bohr Model

Bohr reasoned that if his model were accurate for atoms with one electron, it would be accurate for atoms with more than one electron. However, research showed that energy levels are not arranged in circular orbits.



Figure 9 In Bohr's atomic model, electrons are more likely to be found closer to the nucleus than further away.

The Modern Atomic Model

In the modern atomic model, electrons form an electron cloud.

An **electron cloud** is an area around an atomic nucleus where an electron is most likely to be located. Imagine taking a time-lapse photograph of bees around a hive. You might see a blurry shape. The cloud might be denser near the hive because the bees spend more time near the hive.

In a similar way, electrons constantly move around the nucleus. It is impossible to know both the speed and exact location of an electron at a given moment in time. Instead, scientists only can predict the likelihood that an electron is in a particular location. The electron cloud represents this.

The electron cloud is mostly empty space but represents the likelihood of finding an electron in a given area. The darker areas represent areas where electrons are more likely to be.

Quarks

You have read that atoms are made of smaller particles: protons, neutrons, and electrons. Are these particles made of even smaller parts? Scientists have discovered that electrons are not made of smaller parts. However, research has shown that protons and neutrons are made of smaller particles called quarks. Scientists discover that there are six types of quarks. They have named these quarks up, down, charm, strange, top, and bottom. Protons are made of two up quarks and one down quark. Neutrons are made of two down quarks and one up quark. Just as the model of the atom has changed over time, the current model might also change with the invention of new technology or the discovery of new information.

Think Concept Change

10. How did Bohr's atomic model differ from Rutherford's?

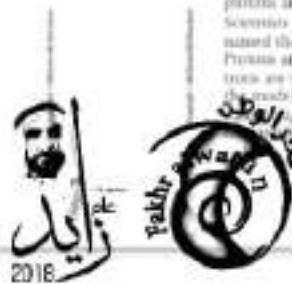
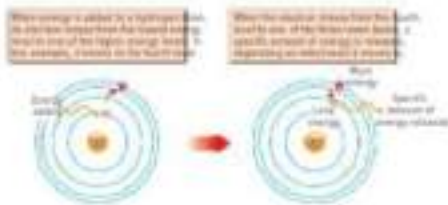
Think Concept Change

11. Why do you think the model of the atom doesn't show the electron's path?

Think Concept Change

12. How has the model of the atom changed over time?

Figure 9 In Bohr's atomic model, electrons move in precise orbits around the atom. When an electron moves from a higher energy level to a lower energy level, energy is released—sometimes as light. Further research proved that electrons are not arranged in orbits.



The Modern Atomic Model

The modern atomic model is based on the idea that it is impossible to know both the speed and exact location of an electron at any given moment. Scientists can only predict the likelihood that an electron is in a particular location. The electron cloud describes the region of an atom where electrons are most likely to be. Use these questions to guide students in understanding the electron cloud concept.

Guiding Questions

- AL** What is the electron cloud?
It is an area around an atomic nucleus where an electron is most likely to be.
- OL** How has the model of an atom changed over time?
The model has changed from a solid sphere to a sphere that contains protons and neutrons in a nucleus, and electrons in an electron cloud.
- SL** What does "more likely to be" mean?
It means that there is a higher probability of finding an electron in a particular place than in other places.
- SL** What are the limitations in using the analogy of bees around a hive to illustrate electrons in the electron cloud?
Possible answers: Bees can freely leave the hive, whereas electrons need energy to be removed from the electron cloud. Scientists cannot be sure of the exact position and speed of an electron at a given moment, but these could be determined for a bee around a hive.

Visual Literacy: The Modern Atomic Model

Help students understand that the electron cloud is represented by mostly empty space because it is impossible to predict exactly where electrons are at any given moment.



Ask: Where are electrons most likely to be? darker areas—closer to the nucleus

Ask: Why do you think the model of an atom above doesn't show the electrons? doesn't show electrons because it is impossible to know both the speed and exact location of an electron at a given moment in time. The cloud represents the likelihood of finding an electron in a given location.

Quarks

Some students may have a difficult time understanding that protons and neutrons are made up of three even smaller particles called quarks.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** Which Key Concept does each image relate to?

Summarize it!

- Early Ideas about Matter
- Dalton's Atomic Model
- The Atom
- Thomson – Discovering Electrons
- Rutherford – Discovering the Nucleus
- Discovering Neutrons
- Bohr's Atomic Model
- The Modern Atomic Model
- Quarks

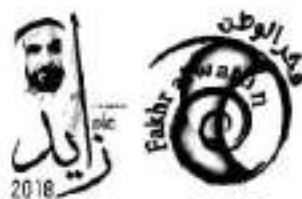
Teacher Toolbox

Fun Fact

Naming the Quark The quark was named by Murray Gell-Mann, an American theoretical physicist and Nobel Prize winner. He selected the name because it sounds like the sound that ducks make. In the novel *Finnegans Wake*, James Joyce, Gell-Mann came across the line “Three for Muster Mark,” and he decided then that the particle would become known as the quark.

Technology Activity

Create a Museum Exhibit Have students use available technology to create an exhibit of the atomic models, principal scientists, and subatomic particles explored in this lesson.



4.1 Review

Discovering Parts of an Atom

Visualize It!



If you were to divide an atom into smaller and smaller pieces, the smallest piece would be an atom.



Atoms are so small that they can be seen only by using very powerful microscopes.



Scientists now know that atoms contain a dense, positive nucleus surrounded by an electron cloud.

Summarize It!

1. What is an atom?

2. How would you describe the size of an atom?

3. How has the atomic model changed over time?

Use Vocabulary

1. The smallest piece of the element gold is a gold _____.

2. Write a sentence that describes the nucleus of an atom.

3. Define electron cloud in your own words.

Understand Key Concepts

4. What is an atom mostly made of?

- A. air C. air atoms
B. empty space D. protons

5. Why have scientists only recently been able to see atoms?

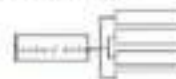
- A. Atoms are too small to see with ordinary microscopes.
B. Early experiments disproved the size of atoms.
C. Scientists didn't know atoms existed.
D. Scientists were not looking for atoms.

6. Draw Thomson's model of the atom, and label the parts of the drawing.

7. Explain: Rutherford's students knew that Thomson's model of the atom needed a change.

Interpret Graphics

8. Contrast the graphic organizer below and use it to contrast the locations of electrons in Thomson's, Rutherford's, Bohr's, and the modern model of the atom.



Critical Thinking

9. Explain why might have happened in Rutherford's experiment if he had used a thin sheet of copper instead of a thin sheet of gold.

Use Vocabulary

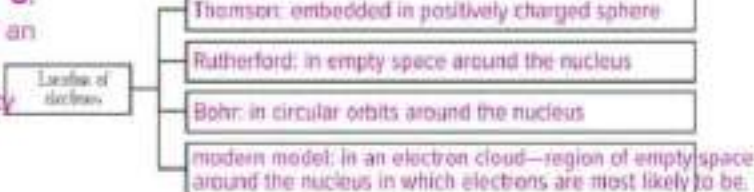
- atom
- Possible answer: The nucleus is the area at the center of an atom that contains both protons and neutrons.
- The electron cloud is made up of the electrons and empty space that surround an atom's nucleus.

Understand Key Concepts

- C empty space
- A Atoms are too small to see with ordinary microscopes.
- Students' drawings should show that Thomson's model had a positively charged sphere with electrons evenly distributed through it.
- They knew this because the alpha particles bounced back when they struck the foil. This meant that the atom contained a dense, positive charge, which was not part of the Thomson atomic model.

Interpret Graphics

8.



Critical Thinking

9. The observations would match those seen with gold, because copper atoms also contain a dense nucleus surrounded by mostly empty space.

4.2 Protons, Neutrons, and Electrons—How Atoms Differ

INQUIRY

Is this glass glowing?

Under natural light, this glass vase is yellow. But when exposed to ultraviolet light, it glows green! That's because it is made of uranium glass, which contains small amounts of uranium, a radioactive element. Under ultraviolet light, the glass emits radiation.

Write your answers in your science notebook.



140 Chapter 4 Understanding the Atom

Explore Activity

How many different things can you make?

Many buildings are made of just a few basic building materials, such as wood, nails, and glass. You can combine these materials in many different ways to make buildings of various shapes and sizes. How many things can you make from these materials?

Procedure

1. Read the procedure and identify the variables before you begin.
2. Use colored building blocks to make as many different objects as you can with the following properties:
 - Each object must have a different substructure.
 - Each object must have a different number of red and blue blocks.
 - Each object must have at least as many yellow blocks as red blocks but can have no more than two extra yellow blocks.
3. As you complete each object, record in your Science Journal the number of each color block used to make it. For example, R1, B0, Y=2.
4. When time is called, compare your objects with others in the class.

Think About This

1. How many different objects did you make? How many different objects did the class make?



Essential Questions

- What happens during nuclear decay?
- How does a neutral atom change when its number of protons, electrons, or neutrons changes?

Vocabulary

- atomic number
- isotope
- mass number
- average atomic mass
- radioactive
- nuclear decay
- ion

INQUIRY

About the Photo **Is this glass glowing?** Uranium glass was first made during the 19th century. It contains a small amount of uranium, which gives the glass a yellow tint. While uranium glass will give a Geiger counter reading, it does not register harmful levels of radiation.

Guiding Questions

- EL** What happens when uranium glass is exposed to ultraviolet light? *It glows green.*
- GL** How could you identify the presence of uranium in a yellow glass vase? *Expose it to ultraviolet light. If it glows a green color, then it is made with uranium.*
- SL** How can you explain, in terms of electron energy levels, why the energy from the ultraviolet light causes the uranium glass to glow? *The ultraviolet light provides energy that causes uranium electrons to move to higher energy levels. When the electrons move back to lower energy levels, energy is released and is seen through our eyes as a green glow.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Prior Knowledge

Students are likely to have heard about some of these terms from previous science classes and others through advertising and popular media.

1. Call on volunteers to share with the class any vocabulary terms they have heard before and anything they may know about it.
2. Start with the term **radioactive**. Point students to the sentence in the lesson opener that uses the word and have them consider context clues.
Ask: What might the word **radioactive** mean?
Answers: an element that is "activated" by some type of energy; matter that emits radiation.
3. Continue with atomic number and average atomic mass. Students should understand that these vocabulary words relate to the properties of atoms.

4. Use this opportunity to gauge student understanding, point out correct responses, and address any misconceptions.

5. Continue through the list. Leave blank words for which students cannot make an educated guess. Revisit this list as students read the lessons in the chapter.

Teacher Notes

ExploreActivity

How many different things can you make?

Prep 10 min Class 15 min

Purpose

To observe how many different objects can be constructed from only three basic parts.

Materials per student:

self-sealing plastic bag containing 40 interlocking building blocks (10 red, 10 blue, 20 yellow)

Before You Begin

Assemble the plastic bags containing the building blocks for each student. Use a common example, such as baking cakes, cookies, or bread, to discuss how many different things can be made from a few basic ingredients (flour, milk or water, eggs). Tell students this investigation will challenge them to make many different objects out of only three materials.

Guide the Investigation

Review the three conditions that each object must satisfy. Do not tell students that the different colors represent protons, neutrons, and electrons. When time is up, have a volunteer list the "composition" of his or her objects on the board. Invite other students to add objects they made with different compositions.

Think About This

Students may not know the answers to all questions. Encourage them to hypothesize.

1. Students should have made at least ten objects. The class may have made 30 different objects if they added one or two yellow blocks to the original ten objects.
2. Answers will vary. Students may say they can make as many different objects as they have red blocks, assuming they have at least an equal number of blue and yellow blocks.
3. **Key Concept** The shape and mass of each object is different.



Journal

Before reading this story, write down what you already know in the first column. In the second column, write down what you want to learn. After you have completed this lesson, write down what you learned in the third column.

What I Know	What I Want to Learn	What I Learned

The Parts of the Atom

If you could see inside any atom, you probably would see the same thing—empty space surrounding a very tiny nucleus. A look inside the nucleus would reveal positively charged protons and neutral neutrons. Negatively charged electrons would be whizzing by in the empty space around the nucleus.

Table 2. Properties of Protons, Neutrons, and Electrons

	Electron	Proton	Neutron
Symbol	e^-	p^+	n
Charge	-1.6×10^{-19} C	$+1.6 \times 10^{-19}$ C	0
Location	outside nucleus	nucleus	nucleus
Relative mass	1/1836	1	1

Table 2 compares the properties of protons, neutrons, and electrons. Protons and neutrons have about the same mass. The mass of electrons is much smaller than the mass of protons or neutrons. That means most of the mass of an atom is found in the nucleus. In this lesson, you will learn that, while all atoms contain protons, neutrons, and electrons, the numbers of these particles are different for different types of atoms.

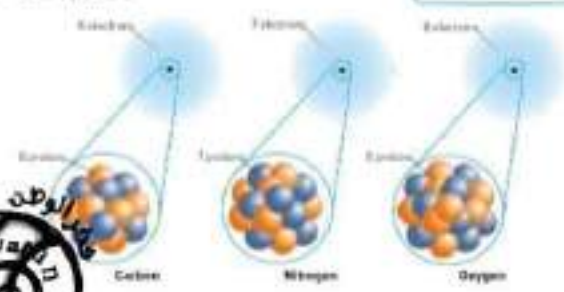
Different Elements—Different Numbers of Protons

Look at the periodic table on the inside back cover of this book. Notice that there are more than 115 different elements. Recall that an element is a substance made from atoms that all have the same number of protons. For example, the element carbon is made from atoms that all have six protons. Likewise, all atoms that have six protons are carbon atoms. The number of protons in an atom of an element is the **atomic number**. The atomic number is the whole number listed with each element on the periodic table.

What makes an atom of one element different from an atom of another element? Atoms of different elements contain different numbers of protons. For example, oxygen atoms contain eight protons, nitrogen atoms contain seven protons. Different elements have different atomic numbers. Figure 11 shows some common elements and their atomic numbers.

Neutral atoms of different elements also have different numbers of electrons. In a neutral atom, the number of electrons equals the number of protons. Therefore, the number of positive charges equals the number of negative charges.

Figure 11 shows that different elements contain different numbers of protons.



FOLDABLES

Create a Foldable book and label it as shown. Use it to organize the ideas you learn about atoms.

Understanding

What two numbers can be used to identify an element?

Visualizing

Explain the difference between an oxygen atom and a carbon atom.



The Parts of the Atom

Use these questions to review the properties and locations of protons, neutrons, and electrons, and to emphasize the relative masses of each.

Guiding Questions

- OL** Which two particles are responsible for the mass of an atom, and which two particles are responsible for the charge of an atom?
The protons and neutrons are responsible for the mass of an atom, and the protons and electrons are responsible for the charge of an atom.
- SL** How does the density of the nucleus compare to the density of the rest of an atom?
The nucleus is denser than the rest of an atom.

Different Elements—Different Numbers of Protons

The number of protons in an atom of an element is the element's atomic number. Atoms of different elements have different atomic numbers, and atoms of the same element have the same atomic number. For a neutral atom, the number of protons (the atomic number) equals the number of electrons. Later in this lesson, students will explore ions, so you may wish to emphasize to students that the number of protons is equal to the number of electrons in a neutral atom only. Use these questions to guide students in understanding these concepts.

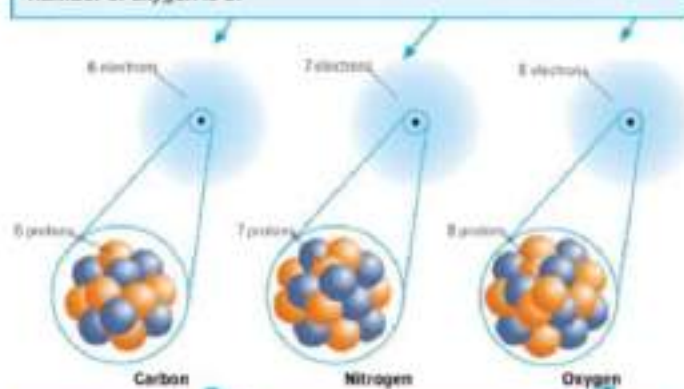
Guiding Questions

- OL** What two numbers can be used to identify an element?
the atomic number and the number of protons
- SL** How is an element's atomic number like a person's fingerprints?
Fingerprints can be used to identify a person. An atomic number can be used to identify an element, because each element has its own unique atomic number.

Visual Literacy: Different Elements

Use this diagram to allow students the opportunity to practice determining the atomic number of an element. Use the questions to emphasize that atoms of different elements have different numbers of protons (in other words, different atomic numbers) and that for a neutral atom the number of protons is equal to the number of electrons.

Ask: What are the atomic numbers of carbon, nitrogen, and oxygen? The atomic number of carbon is 6. The atomic number of nitrogen is 7. The atomic number of oxygen is 8.



Ask: Explain the difference between an oxygen atom and a carbon atom. An oxygen atom has eight protons. A carbon atom has six protons.

Differentiated Instruction

Ask all students in the class to draw the Modern Atomic Model. **Figure 10:** Explain to students that everything they will read in this lesson relates to the inner workings of an atom. Instruct them to keep the visual representation of **Figure 10** in mind as they read.

AL Look Ahead: Have students label their version of **Figure 10's Generic Model of an Atom**. Have them look at **Figure 11** and draw a model of carbon below it and label it **Model of a Carbon Atom**. Ask students to make a list of the specific information they have about the carbon atom. They should be able to point out that they know the number of protons and electrons.

BL Explain to the Class: Ask students to create a poster-size version of the carbon model that will be displayed in the classroom throughout the lesson. Instruct them to label the nucleus with its protons and to label the electron cloud. The poster should include three brief captions, below the appropriate labels, that explain the relative size of the nucleus, where protons are located, and why electrons are represented as a cloud.

LA Hydrogen v. Uranium Model: Ask students to look at the generic model of an atom in **Figure 10**. Tell them that a hydrogen atom contains one electron and one proton. Ask students to draw a representation of a hydrogen atom. Ask students that the uranium atom includes 92 protons and 92 electrons. **Ask:** How would a drawing of the uranium atom be different from the two models we've already drawn? If students can express this idea, help them write a script for a one-minute explanation they can give to the class.

Teacher Toolbox

Real-World Science

Uranium Deposits: Uranium, the same element used to make uranium glass glow, is used for a variety of other purposes, including as an alternative energy resource to replace coal. Uranium is a naturally occurring element in Earth's crust.

Teacher Demo

A Pea-Sized Nucleus Inside an Atom-Sized Stadium

Explain to students that every atom of an element is very small, and each atom's nucleus is exponentially smaller. To demonstrate this concept, bring some peas into class along with a picture of a football stadium cut out of a sports magazine. Hold up one pea and the picture of the stadium. Ask students that the stadium represents each atom, and the pea, each atom's nucleus. Ask students to guess the relative size of a pea inside the stadium. Point out that the nucleus is 100 times smaller than the atom as a whole.

Math Skill

Use Percentages

You can calculate the average atomic mass of an element if you know the percentage of each isotope in the element. Lithium, Li, contains 7.5% ${}^6\text{Li}$ and 92.5% ${}^7\text{Li}$. What is the average atomic mass of Li?

1. Change each percentage to 100 to change to decimal form.

$$7.5\% = 0.075$$

$$92.5\% = 0.925$$

$$0.075 \times 6.015 = 0.451$$

2. Multiply the mass of each isotope by its decimal percentage.

$$6 \times 0.075 = 0.45$$

$$7 \times 0.925 = 6.475$$

3. Add the values together to get the average atomic mass.

$$0.45 + 6.475 = 6.93$$

Practice

Nitrogen-14 contains 99.63% ${}^{14}\text{N}$ and 0.37% ${}^{15}\text{N}$. What is the average atomic mass of nitrogen?

Word Origin

Isotopos is Greek for "equal," and topos means "place."

Visual Link

How do two different isotopes of the same element differ?

Table 3 Naturally Occurring Isotopes of Carbon

Isotope	Carbon-12 Nucleus	Carbon-13 Nucleus	Carbon-14 Nucleus
Abundance	98.93%	1.07%	<0.01%
Protons	6	6	6
Neutrons	6	7	8
Mass Number	12	13	14

Neutrons and Isotopes

You have read that atoms of the same element have the same number of protons. However, atoms of the same element can have different numbers of neutrons. For example, carbon atoms all have six protons, but some carbon atoms have six neutrons, some have seven neutrons, and some have eight neutrons. These three different types of carbon atoms, called isotopes, are atoms of the same element that have different numbers of neutrons. Most elements have several isotopes.

Protons, Neutrons, and Mass Number

The mass number of an atom is the sum of the number of protons and neutrons in an atom. This is shown in the following equation:

Mass number = number of protons + number of neutrons

Any one of these three quantities can be determined if you know the value of the other two quantities. For example, to determine the mass number of an atom, you must know the number of neutrons and the number of protons in the atom.

The mass numbers of the isotopes of carbon are shown in Table 3. This isotope atom is written with the element symbol followed by the mass number. Using this method, the isotopes of carbon are written carbon-12, carbon-13, and carbon-14.



Figure 32 The most common carbon isotope is carbon-12. This isotope has 6 protons and 6 neutrons in the nucleus and 6 electrons.

Guiding Question

What does the term "average atomic mass" mean?

Thinking Time

How many isotopes does carbon have?

Average Atomic Mass

You might have noticed that the periodic table does not list mass numbers or the numbers of neutrons. This is because a given element can have several isotopes. However, you might notice that there is a decimal number listed with most elements, as shown in Figure 32. This decimal number is the average atomic mass of the element. **Average atomic mass** is the average mass of the element's isotopes, weighted according to the abundance of each isotope.

Table 3 shows the three isotopes of carbon. The average atomic mass of carbon is 12.01. Why isn't the average atomic mass 12? After all, the average of the mass numbers 12, 13, and 14 is 13. The average atomic mass is weighted based on each isotope's abundance. Here, most of each isotope is present on Earth. About 99 percent of Earth's carbon is carbon-12. This is why the average atomic mass is close to 12.

Neutrons and Isotopes

Students may need to be reminded that although isotopes of an element have different numbers of neutrons, they have the same number of protons. Use these questions to guide students in understanding these concepts.

Guiding Questions

GL How are isotopes of an element alike? They have the same number of protons.

SL Explain how the number of neutrons affects the mass of an atom. Atoms with more neutrons have more mass than do atoms with fewer neutrons.

Word Origin

Ask: The Greek phrase *isos topos* means "equal (or same) place."

What do you think "place" refers to? Possible response: location on the periodic table.

Ask: Why do you think the Greek phrase *isos topos* is suitable for describing isotopes? Explanation: Isotopes occupy the same place on the periodic table of elements because they have the same number of protons (atomic number).

Protons, Neutrons, and Mass Number

The mass number is the sum of the protons and neutrons in the nucleus of an atom. Isotopes of an element have different mass numbers because they have different numbers of neutrons. These questions provide an opportunity for students to practice calculations involving mass numbers of isotopes.

Guiding Questions

GL How do two different isotopes of the same element differ? Two different isotopes of an element have different numbers of neutrons, but the same number of protons.

SL How many protons, neutrons, and electrons are in neutral atoms of hydrogen-1, hydrogen-2, and hydrogen-3? Hydrogen-1 has 1 proton, 0 neutrons, and 1 electron. Hydrogen-2 has 1 proton, 1 neutron, and 1 electron. Hydrogen-3 has 1 proton, 2 neutrons, and 1 electron.

Math Skill

Use Percentages

Help students conceptualize. Remind them that when they read about percentages, they are seeing numbers that represent parts of a whole.

Practice

$$(0.9963 \times 14) + (0.0037 \times 15) = 14.0037 \text{ average atomic mass for N}$$

Average Atomic Mass

Some students may find it difficult to understand the concept of average atomic mass because they may not have been exposed to weighted averages. Use these questions to help students understand this sometimes confusing concept. Showing students examples of how average atomic mass is calculated is often the best way to reinforce this concept.

Guiding Questions

- AL** Why is it necessary to calculate the average atomic mass? *Because a given element has multiple isotopes.*
- OL** What does the term **weighted average** mean? *Weighted average means that some data points contribute more to the average, or are more abundant, than others.*
- BL** How is the average atomic mass of an element calculated? *The abundance of each isotope is changed into a decimal form. The mass of each isotope is multiplied by its corresponding decimal percentage. All the values are added together to determine the average atomic mass.*

Differentiated Instruction

AL Atomic Number Contest Write the names of 10 elements on the board or on chart paper. Instruct students to record the time it takes for them to locate the element on the periodic table and write down their atomic number. Encourage students to repeat this activity until they are able to cut their original time in half.

BL Write a Children's Book Have students convert the information in **Table 2** into an illustrated children's book about the parts of the atom. Instruct students to write the books in terms that a third or fourth grader could understand.

LA Describing Isotopes Create a sample of "beanium" by mixing several types of dry beans, such as pinto, navy, kidney, and lima. Give each pair of students a handful containing the mixture. Instruct students to pretend that each type of bean is an isotope of a new element called "beanium." Ask them to describe how the isotopes are alike and how they are different.

Teacher Toolbox

Real-World Science

Isotopic Analysis Isotopic analysis involves determining the proportion of the isotopes in a sample. Isotopic analysis is used in various fields such as archaeology, space science, forensics, food science, and medicine. It is used to identify the origins of meteorites, discriminate among bullet types, determine the origins of cotton fiber used to make counterfeit money, detect alterations of food, and to verify the authenticity of organically grown crops.

Teacher Demo

Calculating Grades Compare the method of calculating average atomic mass to the method of calculating grades. On the board or chart paper, show students an example of how grades are calculated, using actual assignment weights from your class. Explain to students that, in the example, assignment weights are analogous to the percentage of each isotope, whereas the average grade for each category is analogous to the mass number.

Reading Strategy

What's the Main Idea? Have each student record the main idea of each section and the two sentences that best support the main idea. Read key sentences in the text and have students raise their hands if they recorded that sentence. Call on individuals to defend their choices.





Figure 13 The black and white photo shows Henri Becquerel's photographic plate. The dark area on the plate was exposed to radiation given off by uranium ore placed over it. The radiation was not exposed to sunlight.

Academic Vocabulary
spontaneous
 occurring without external force or cause

Figure 14 Marie Curie studied radioactivity and discovered that some radioactive elements—uranium and radium.



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Radioactivity

More than 1,000 years ago, people tried to change lead into gold by performing chemical reactions. However, none of these reactions were successful. Why not? Today, scientists know that a chemical reaction does not change the number of protons in an atom's nucleus. If the number of protons does not change, the element does not change. But in the late 1800s, scientists discovered that some elements change into other elements **spontaneously**. How does this happen?

An Accidental Discovery

In 1896, a scientist named Henri Becquerel (1852–1908) studied minerals containing the element uranium. When these materials were exposed to sunlight, they gave off a type of energy that could pass through paper. If Becquerel viewed a photographic plate with black paper, this energy would pass through the paper and expose the film. One day, Becquerel left the mineral next to a wrapped, unexposed plate in a drawer. Later, he removed the drawer, unwrapped the plate, and saw that the plate contained an image of the mineral, as shown in **Figure 13**. The mineral spontaneously created energy, even in the dark! Sunlight was not required. What was this energy?

Radioactivity

Becquerel shared his discovery with fellow scientists Pierre and Marie Curie. Marie Curie (1867–1934) showed **Figure 14**, called elements that spontaneously emit **radioactive** energy. Becquerel and the Curies discovered that the radiation released by uranium was made of energy and particles. This radiation came from the nuclei of the uranium atoms. When it happens, the number of protons in one of the atoms changes. When uranium releases radiation, it changes to a different element.

Types of Decay

Radioactive elements contain unstable nuclei. **Nuclear decay** occurs when an unstable atomic nucleus changes into another more stable nucleus by emitting radiation. Nuclear decay can produce three different types of radiation: alpha particles, beta particles, and gamma rays. **Figure 15** compares the three types of nuclear decay.

Alpha Decay An alpha particle is made of two protons and two neutrons. When an atom releases an alpha particle, its atomic number decreases by two. Uranium-238 decays to thorium-234 through the process of alpha decay.

Beta Decay When beta decay occurs, a neutron in an atom changes into a proton and a high-energy electron called a beta particle. The new proton becomes part of the nucleus, and the beta particle is released. In beta decay, the atomic number of an atom increases by one because it has gained a proton.

Gamma Decay Gamma rays do not contain particles, but they do contain a lot of energy. In fact, gamma rays can pass through thin sheets of lead. Because gamma rays do not contain particles, the release of gamma rays does not change one element into another element.

Uses of Radioactive Isotopes

The energy released by radioactive decay can be both harmful and beneficial to humans. Too much radiation can damage or destroy living cells, making them unable to function properly. Some organisms contain such as cancer cells, that are harmful to humans. Radiation therapy can be used to kill cancer cells by destroying these

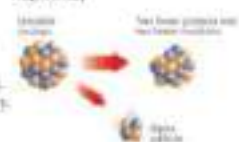
Guiding Questions

1. What happens during radioactive decay?

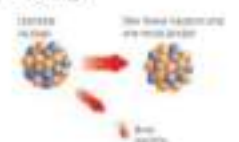
Visual Check

2. Explain the change in atomic number for each type of decay.

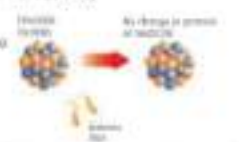
Alpha Decay



Beta Decay



Gamma Decay



Lesson 4.2 Proteins, Neurons, and Electricity—How Atoms Work

Radioactivity

Students need to know that atoms of one element cannot be changed into atoms of another element by ordinary chemical reactions. Yet, some elements change into atoms of other elements spontaneously.

Ask: Why is it not possible to change the number of protons in an atom's nucleus and still have the same element? **Answer:** All atoms of an element have the same number of protons. Only atoms of different elements have different numbers of protons.

Academic Vocabulary

spontaneous

Ask: What do you think the phrase *spontaneous laughter* means? **Answer:** Laughing for no apparent reason or without an external cause.

An Accidental Discovery

Students may not know what photographic plates are. Explain to students that photographic plates are the precursors to photographic film. Many students may not have ever seen photographic film before, so you may want to bring in a sample for students to see. Use these questions to guide students in understanding Becquerel's experiments with uranium-containing minerals.

Ask: What was the difference between the first and second times the image of the mineral appeared on the plate? **Answer:** The first time the minerals were exposed to sunlight. The second time they were exposed in the absence of sunlight.

Radioactivity

Radioactive elements spontaneously emit radiation. When the atoms emit radiation, they are changed into a different element. Use these questions to help students understand this process.

Guiding Questions

AL What happens when an element emits radiation? **Answer:** The number of protons changes, and the element changes into a different element.

BL Predict what the element uranium becomes when it loses two protons. **Answer:** Uranium becomes thorium. Students should be able to determine this answer by looking at the periodic table of elements and finding the element with two less protons than uranium. Students may need reminded that the atomic number is equal to the number of protons in an atom.

Types of Decay

Unstable nuclei become stable by releasing energy through the process of radioactive decay. The energy released is called radiation. Use these questions along with **Figure 15** to guide students in understanding these concepts.

Guiding Questions

- AL** How does an unstable atomic nucleus emit radiation through the process of radioactive decay?
An unstable atomic nucleus changes into another more stable nucleus by emitting radiation.
- OL** What happens during radioactive decay?
Use this opportunity to review that the mass number of an atom is the sum of the protons and neutrons. The mass numbers are conserved.
- BL** How does the sum of the mass numbers of the starting materials compare to the sum of the mass numbers of the products of nuclear decay?

Visual Literacy: Types of Decay

Use **Figure 15** along with the text to guide students in understanding the process of nuclear decay, the types of radiation produced in the process, and the properties of the resulting atoms. Point out to the students that both alpha and beta decay result in the formation of a different element. Have students draw **Figure 15** while you ask these questions.

Ask: Explain the change in atomic number for each type of decay. In alpha decay the atomic number decreases by two. In beta decay the atomic number increases by one. In gamma decay the atomic number remains the same.

Ask: Explain the change in mass number for each type of decay. In alpha decay the mass number decreases by four. In beta decay the mass number remains the same. In gamma decay the mass number remains the same.

Uses of Radioactive Isotopes

Students may have the impression that radioactive isotopes are always harmful to humans. Use this question to guide students in understanding that there are beneficial uses of radioactive isotopes as well.

Guiding Questions

- AL** What is an example of a beneficial use of radioactive isotopes?
Radioactive isotopes are used to destroy cancer cells.
- OL** Why can radiation both improve and hurt the health of humans?
Radiation can damage or destroy cells. This is good if the cells are cancer cells attacking the body, but harmful if they are good cells and too many are killed.

Differentiated Instruction

AL Modeling Radioactive Decay Have students work in groups to model the nuclear decay process shown in **Figure 15**. Instruct students to determine who will be protons and who will be neutrons. Find an open space where students can move around freely. Call out a type of decay (alpha, beta or gamma) and ask students to demonstrate each type of decay.

BL Find "Bad" Science Students are likely to have heard about radioactivity in popular media. Have students bring examples of bad science related to radioactivity from books, including comic books. Have them quote the claim, reference the source, and explain what is wrong.

LA Visual Literacy Have students draw **Figure 15** without the captions, and use their drawings to explain the process of nuclear decay, the types of radiation produced in the process, and the properties of the resulting atoms.

Teacher Toolbox

Reading Strategy

Prepare to Read Before reading, have students write down the headings of the section on types of decay. As they read, instruct students to write notes under the appropriate headings and to include drawing **Figure 15**.

Teacher Demo

Radiation Photographs Self-developing film can be exposed by radioactive items, such as some smoke detectors, gas lantern mantles, and radium-dial watch faces. Cover the film with heavy black paper to prevent visible light from exposing the film, place and secure the radioactive material on the covered photographic film. Leave for at least 4 days.

Real-World Science

Radioactive Products Before the health effects of radiation were known, radioactive products were thought to be good for you. In the early 1900s radioactive isotopes were used in many products including toothpaste, hair tonics, water, cream, blankets, medicines, and candy. Many users later developed skin, mouth and throat, and other cancers.



4.2 Review

Ions—Gaining or Losing Electrons

What happens to a neutral atom if it gains or loses electrons? Recall that a neutral atom has no overall charge. This is because it contains equal numbers of positively charged protons and negatively charged electrons. When electrons are added to or removed from an atom, that atom becomes **charged**. An atom that is no longer neutral because it has gained or lost electrons. An ion can be positively or negatively charged depending on whether it has lost or gained electrons.

Explain It!

1. How does a neutral atom change when its number of protons, electrons, or neutrons changes?

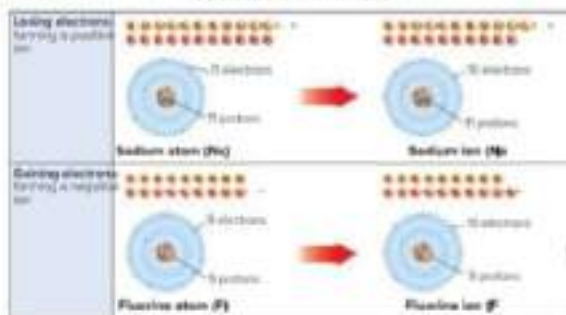
Positive Ions

When a neutral atom loses one or more electrons, it has more protons than electrons. As a result, it has a positive charge. An atom with a positive charge is called a positive ion. A positive ion is represented by the element's symbol followed by a superscript, plus sign for example, Na^+ . Sodium loses one electron. Na^+ becomes a positive sodium ion.

Negative Ions

When a neutral atom gains one or more electrons, it now has more electrons than protons. As a result, the atom has a negative charge. An atom with a negative charge is called a negative ion. A negative ion is represented by the element's symbol followed by a superscript, negative sign, for example, F^- . Fluorine gains one electron. F^- becomes a fluoride ion.

Figure 10 Ion is formed when a neutral atom gains or loses an electron.



Visualize It!



Different elements contain different numbers of protons.



Two isotopes of a given element contain different numbers of neutrons.



When a neutral atom gains or loses an electron, it becomes an ion.

Summarize It!

1. What happens during nuclear identity?

2. How does a neutral atom change when its number of protons, electrons, or neutrons changes?

Ions—Gaining or Losing Electrons

Students often confuse ions and isotopes. Explain to students that an ion has more electrons or fewer electrons than a neutral atom, whereas isotopes differ in the number of neutrons. Use these questions to guide students in understanding ions and isotopes in terms of protons, neutrons, and electrons.

Guiding Questions

- EL** What happens to a neutral atom when it becomes a negative or positive ion? It gains or loses electrons.
- OL** Summarize the difference between isotopes and ions. Isotopes have the same number of protons but different numbers of neutrons. The number of electrons is equal to the number of protons in an isotope. An ion is an atom that has more electrons or fewer electrons than protons. The number of neutrons remains the same in an ion as it was in a neutral atom.
- SL** What is wrong with the statement "an atom has more electrons than protons"? Atoms are neutral. If the particle has more electrons than protons, then it is not an atom; it is an ion.

Positive Ions

Because electrons are negative, loss of an electron from a neutral atom results in an ion with a positive charge. Because they may associate loss with negativity, students often have difficulty understanding how the loss of a particle from an atom can result in it developing a positive charge. You may want to explain this concept using the following analogy: If you have negative friends, you may have a tendency to become a more negative person. If you stop spending time with those negative friends, you may have a tendency to become more positive.

Negative Ions

You may want to review Table 2 and point out to students that protons and electrons are responsible for the charge of an atom or ion, whereas protons and neutrons are mostly responsible for an atom's mass. Use this question to help students understand the ways a neutral atom can change.

Guiding Questions

- OL** How does a neutral atom change when its number of protons, electrons, or neutrons is changed? If the number of protons changes, the atom changes to a new element. If the number of electrons changes, the atom becomes an ion. If the number of neutrons changes, the atom becomes an isotope of the atom.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Task:** Which Key Concept does each image relate to?

Summarize It

- The Parts of an Atom
- Different Elements – Different Numbers of Protons
- Neutrons and Isotopes
- Radioactivity
- Ions – Gaining or Losing Electrons

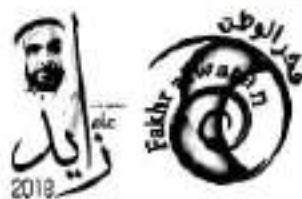
Teacher Tools

Teacher Demo

Plastic Toy Hoop Models: Use plastic toy hoops and construction paper circles to model the concepts in this lesson. Obtain three plastic toy hoops. Cut 45 circles with a diameter of about 10 cm from colored construction paper. Cut 15 circles of each color. Use the plastic toy hoops and colored circles to illustrate that: atoms of a given element contain the same number of protons; atoms of different elements contain different numbers of protons; isotopes are atoms of a given element that contain different numbers of neutrons; and ions are atoms that have more electrons than protons or fewer electrons than protons. Give groups of students materials and have them re-create **Figure 11** (neutral atoms), **Table 3** (isotopes), and **Figure 16** (ions). Have students present their models to the class, identifying numbers of protons, neutrons, and electrons.

Reading Strategy

Compare and Contrast: Have students write a short paragraph to compare and contrast ions and isotopes. They should briefly explain the relationship between the subatomic particles in each.



Play Along

Critical Thinking

9. *Infocampus* (website) also has an article:

- THE JOURNAL OF THE**

E. Show: what happens to the elements of a neutral calcium atom (Ca) when it is charged to form a calcium ion (Ca^{2+})

7. **Contrast** type and fill in the graphic negative to contrast two different elements, images, and text are produced.



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8. There are five instances where the elements would be reversed if the periodic table were arranged by atomic mass. Co and Ni, Ta and I, U and Np, Fm and Es, Md and No

9. All atoms of a given element are isotopes. For example, all oxygen atoms are oxygen-15, oxygen-16, or oxygen-17. The formation of an ion doesn't change the number of neutrons. Therefore, an ion of oxygen will have 15, 16, or 17 neutrons. If all atoms are isotopes, then all ions are isotopes too.

10, abundance of Cu=60%-69.17% 30.83%
 $(0.6917 \times 63) + (0.3083 \times 65) = 63.62$

1. atomic number
2. radiation
3. Two different isotopes of nitrogen have the same numbers of protons but different numbers of neutrons. Two different ions of nitrogen have the same numbers of protons but different numbers of electrons.

4. **B. isotopes**

5. They have the same numbers of protons but different numbers of neutrons.

6. Calcium loses two electrons.

7. How is each produced?

- If protons change, a different element is produced.
- If neutrons change, a different isotope is produced.
- If electrons change, an ion is formed.

4 Study Guide

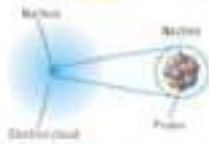
TheBIG Idea

An atom is the smallest unit of an element and is made mostly of empty space. It contains a tiny nucleus surrounded by an electron cloud.

Key Concepts Summary

4.1 Discovering Parts of the Atom

- If you want to divide a pencil into smaller and smaller pieces, the pencil must be **atom**.
- Atoms are so small that they can be seen only by powerful scanning microscopes.
- The first model of the atom was a solid sphere. Now, scientists know that an atom contains a dense **nucleus** surrounded by **electron cloud**.



Vocabulary

atom
electron
nucleus
proton
neutron
electron cloud

4.2 Protons, Neutrons, and Electrons—How Atoms Differ

- Nuclear decay** occurs when an unstable atomic nucleus changes into another more stable nucleus by emitting radiation.
- Different elements contain different numbers of **protons**. The same element contains different numbers of **neutrons**. What a nucleus gains or loses as electrons, it loses **electrons**.



atomic number
isotope
mass number
average atomic mass
radioactive
nuclear decay
ion

Chapter 4 Study Guide

FOLDABLES

Chapter Project

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

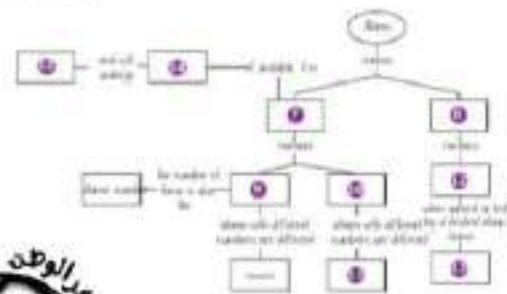


Use Vocabulary

1. An **atom** is a very small particle that is the basic unit of matter.
2. Electrons in an atom move throughout the **electron cloud**.
3. **Atomic mass** is the weighted average mass of all of an element's isotopes.
4. All atoms of a given element have the same number of **protons**.
5. When **radioactive** atoms, an element is changed into another element.
6. Isotopes have the same **atomic number** but different mass numbers.

Link Vocabulary and Key Concepts

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



2018

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Key Concepts Summary



Vocabulary

Study Strategy: Two Truths and a Lie Study Strategy: Self-Assessment

Have students play a review game called "Two Truths and a Lie." **Students** often overestimate the number of vocabulary terms they know. This activity provides a way for students to assess their learning of the vocabulary words explored in this chapter and to learn the meanings of the terms that they may not know.

1. Organize students into groups of four.
2. For each statement in the Key Concepts summary, have students write two true statements and one false statement. Encourage students to write the statements so that it will be very difficult for members of another group to identify the false statement.
3. Have each group of students exchange papers with another group of students.
4. Ask the pairs of groups to take turns attempting to correctly determine which of the three statements is false.
5. Encourage the pairs of groups to discuss what makes each false statement false and how they could change the statement to make it true.

1. Ask students to write a three-column list containing the vocabulary words whose meanings they know, words whose meanings they think they know, and words whose meanings they do not know.
2. Instruct students to define the words they placed in the first two columns.
3. Have students go through the chapter, taking note of their accuracy in defining the words in the first two columns, correcting any incorrect definitions, and defining the words in column three.
4. Encourage students to create flash cards to help them learn the meanings of terms they were not able to correctly define.
5. Finally, have students write a summary of the chapter, underlining all of the vocabulary terms in their summaries.

FOLDABLES Chapter Project

Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables.

Teacher Notes**Use Vocabulary**

1. atom
2. electron cloud
3. average atomic mass
4. protons
5. nuclear decay
6. atomic number

Link Vocabulary and Key Concepts

- | | |
|-------------------|-------------------|
| 7. nucleus | 12. electrons |
| 8. electron cloud | 13. ions |
| 9. protons | 14. radioactive |
| 10. neutrons | 15. nuclear decay |
| 11. isotopes | |



2018



CHAPTER 4 Review

Understand Key Concepts

- Which part of an atom makes up most of its volume?
 - its electron cloud
 - its neutrons
 - its nucleus
 - its protons
- What did Democritus believe an atom was?
 - a solid, indivisible object
 - a tiny particle with a nucleus
 - a nucleus surrounded by an electron cloud
 - a tiny nucleus with electrons surrounding it
- If an ion contains 10 electrons, 12 protons, and 12 neutrons, what is the ion's charge?
 - 2^{-}
 - 1^{-}
 - 2^{+}
 - 3^{+}
- J.J. Thomson's experimental setup is shown below.



- What is happening to the cathode rays?
- They are attracted to the negative plate.
 - They are attracted to the positive plate.
 - They are stopped by the plates.
 - They are unaffected by either plate.

- How many neutrons does lead-208 have?
 - 30
 - 31
 - 79
 - 103
- Why were Rutherford's students surprised by the results of the gold-foil experiment?
 - They didn't expect the alpha particles to bounce back from the foil.
 - They didn't expect the alpha particles to continue in a straight path.
 - They expected only a few alpha particles to bounce back from the foil.
 - They expected the alpha particles to be deflected by electrons.
- Which determines the identity of an element?
 - its mass number
 - the charge of the atom
 - the number of its neutrons
 - the number of its protons
- The figure below shows which of the following?
 - two different elements
 - two different ions
 - two different isotopes
 - two different protons



- How is Bohr's atomic model different from Rutherford's model?
 - Bohr's model has a nucleus.
 - Bohr's model has electrons.
 - Electrons in Bohr's model are located farther from the nucleus.
 - Electrons in Bohr's model are located in circular energy levels.



Chapter Review

Critical Thinking

- Consider what would have happened in the gold foil experiment if Dalton's theory had been correct.
- Contrast how Bohr's model of the atom differs from the present-day atomic model.
- Describe an electron cloud using your own analogy.
- Summarize how radioactive decay can produce new elements.
- Hypothesize what might happen if a negatively charged ion collided with a positively charged ion?
- Interpret why mass number listed with each element on the periodic table?
- Explain how the average atomic mass is calculated?
- Info Oxygen has three stable isotopes.

Isotope	Average Atomic Mass
Oxygen-16	0.01167
Oxygen-17	0.00038
Oxygen-18	0.00019

What can you determine about the average atomic mass of oxygen without calculating?

Write a Story

- Write a story about how the changes in the atomic model provide an example of the scientific process in action.

The BIG Idea

- Describe current model of the atom. Explain the size of atoms. Also explain the charge, the location, and the size of protons, neutrons, and electrons.
- Summarize the Large Hadron Collider, shown below, is continuing the study of matter and energy. Use a set of four drawings to summarize how the model of the atom changed from Thomson to Rutherford to Bohr to the modern model.

Math Skills

Use Percentages

Use the information in the table to answer questions 21 and 22.

Magnesium (Mg) Isotope	Percent Found in Nature
Mg-24	78.9%
Mg-25	9.0%
Mg-26	

- What is the percentage of Mg-26 found in nature?
- What is the average atomic mass of magnesium?

Understand Key Concepts

- A. its electron cloud
- A. a solid, indivisible object
- C. 2^{+}
- B. They are attracted to the positive plate.
- B. 33
- A. They didn't expect the alpha particles to bounce back from the foil.
- D. the number of its protons
- A. two different elements
- D. Electrons in Bohr's model are located in circular energy levels.

Critical Thinking

- If Dalton's theory had been correct, the gold foil would have been made of atoms that were solid spheres. Instead of only a few alpha particles bouncing back, all of the alpha particles would have bounced back from the gold foil.
- In the Bohr model, electrons moved in circular orbits around the nucleus. In the modern model, electrons move in an electron cloud. It is impossible to locate the exact position and speed of an electron in any given moment. Instead, one can only identify the likelihood that an electron will be in a given location.
- Answers will vary. Encourage students to provide an analogy along with how the electron cloud is similar to the analogy and how it differs.
- During radioactive decay, the nucleus of the atom is transmuted. That means that the number of protons, neutrons, and/or electrons is changed. Since the number of protons is changed, that means that the atomic number is changed. A change in atomic number corresponds to a change in the type of element present.
- Negative charges attract positive charges. If the charges are equal in magnitude, the ions would attract each other to create a neutral molecule.

15. A given element can have more than one isotope and each isotope has a unique mass number. It wouldn't make sense to only select one of these mass numbers to list and there isn't enough room to list them all.
16. Average atomic mass is calculated by first multiplying the atomic mass of each isotope by its respective percent isotopic abundance in nature and then adding these sums together.
17. The average atomic mass of oxygen is approximately 16 because oxygen-16 atoms make up over 99.7% of the atoms in nature.

Writing in Science

18. Students' articles should note that scientific models are open to change as new information is discovered. Often, the invention of new technology leads to the discovery of new information. The current model of the atom is also open to modification if information is learned that contradicts or enhances the current model.

Teacher Notes



TheBIG Idea

19. The current model of the atom is a tiny nucleus that contains positively charged protons and neutral neutrons surrounded by an electron cloud that contains negatively charged electrons. Atoms are so small that they can only be seen by special microscopes called Scanning Tunneling Microscopes.
20. The Thomson model should show a sphere of positive charge that contains negatively charged electrons. The Rutherford model should show a positive nucleus surrounded by negatively charged electrons. The Bohr model should show a nucleus with positively charged protons and neutral neutrons surrounded by electrons arranged in circular orbits. The modern model should show a nucleus similar to Bohr's model but surrounded by an electron cloud that is darker near the nucleus and lighter near the edge of the atom.

Math Skill

Use Percentages

21. 11.1% is Mg-26

22. 24.3

Standardized Test Practice

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

Multiple Choice

1. Which best describes an atom?

- A a particle with a single negative charge
- B a particle with a single positive charge
- C the smallest particle that can represent a compound
- D the smallest particle that can represent an element

Use the figure below to answer questions 2 and 3.



2. What is Structure X?

- A an electron
- B a neutron
- C a molecule
- D a proton

3. Which best describes Structure X?

- A most of the atom's mass, neutral charge
- B most of the atom's mass, positive charge
- C very small part of the atom's mass, negative charge
- D very small part of the atom's mass, positive charge

4. Which is true about the size of an atom?

- A It can only be seen using a scanning tunneling microscope.
- B It is about the size of the period at the end of this sentence.
- C It is large enough to be seen using a magnifying lens.
- D It is too small to see with any type of microscope.

Use the figure below to answer question 5.



5. Whose model for the atom is shown?

- A Bohr's
- B Dalton's
- C Rutherford's
- D Thomson's

6. What structure did Rutherford discover?

- A the atom
- B the electron
- C the neutron
- D the nucleus

Use the table below to answer questions 7–10.

Particle	Number of Protons	Number of Neutrons	Number of Electrons
1	4	5	2
2	5	5	5
3	5	0	5
4	5	5	5

Standardized Test Practice

7. What is atomic number of particle 3?

- A 1
- B 3
- C 5
- D 11

8. Which particles are isotopes of the same element?

- A 1 and 2
- B 3 and 5
- C 2 and 4
- D 3 and 4

9. Which particle is an ion?

- A 1
- B 2
- C 3
- D 4

10. Which reaction starts with a neutron and results in the formation of a proton and a high-energy electron?

- A alpha decay
- B beta minus decay
- C the formation of a positive ion
- D the formation of a negative ion

Constructed Response

Use the figure below to answer questions 11 and 12.



11. Identify the atomic model shown in the figure and describe its characteristics.

12. How does this atomic model differ from the modern atomic model?

13. Complete two different nuclear isotopes of the same element. Then compare two different isotopes of the same element. What are all of these particles have in common?

14. How does nuclear decay differ from the formation of ions? What parts of the atom are affected in each type of change?

Handwritten Notes

If You Missed Question...	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Go to Lesson...	1	1	1	1	1	1	2	2	2	2	1	1	2	2

Multiple Choice

- 1 **D—Correct.** describes an electron, B describes a proton, and C describes a molecule.
- 2 **C—Correct.** is found in the cloud that surrounds the nucleus and B and D are particles that make up the nucleus.
- 3 **B—Correct.** correctly describes the mass of a nucleus but incorrectly describes its charge. C describes an electron. D correctly describes the charge of a nucleus but incorrectly describes its size.
- 4 **A—Correct.** and C describe atoms as much too large. D is incorrect because atoms can be imaged with an STM.
- 5 **D—Correct.** (Bohr's model) would show a nucleus with protons and neutrons and electrons traveling in defined paths around it. B (Dalton's model) would describe a particle with no subatomic particles. C (Rutherford's model) would describe a positive nucleus with electrons surrounding it and no neutrons.

- 6 **D—Correct.** was first described by Dalton. B was discovered by Thomson. C was discovered by Chadwick.
- 7 **B—Correct.** is its arbitrary label. C is the number of neutrons. D is its mass number.
- 8 **B—Correct.** and D describe particles with the same number of neutrons. C describes particles that have a neutral charge.
- 9 **A—Correct.** C, and D have the same numbers of protons and electrons and are thus neutral.
- 10 **B—Correct.** names nuclear decay that emits an alpha particle, and C and D involve loss or gain of electrons to produce charged ions.

Constructed Response

- 11** Bohr's atomic model is shown. In the Bohr model, electrons move in circular orbits around the positive nucleus composed of protons and neutrons.
- 12** The Modern Atomic Model has moving electrons within the 3-dimensional space of an electron cloud. They do not move in the set orbits described by Bohr's model.
- 13** Two different neutral isotopes of the same element have different numbers of neutrons and the same numbers of protons and electrons. Two different ions of the same element have different numbers of electrons and the same numbers of protons. All particles of one element have the same number of protons.
- 14** Nuclear decay involves a change in the number of protons and/or neutrons in an atom's nucleus; one element changes to another in nuclear decay. The formation of ions involves a change in the number of electrons (a loss or gain of electrons); the nucleus is not affected and the element does not change to a different element.

Answer Key

Question	Answer
1	D
2	C
3	B
4	A
5	D
6	D
7	B
8	B
9	A
10	B
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.

