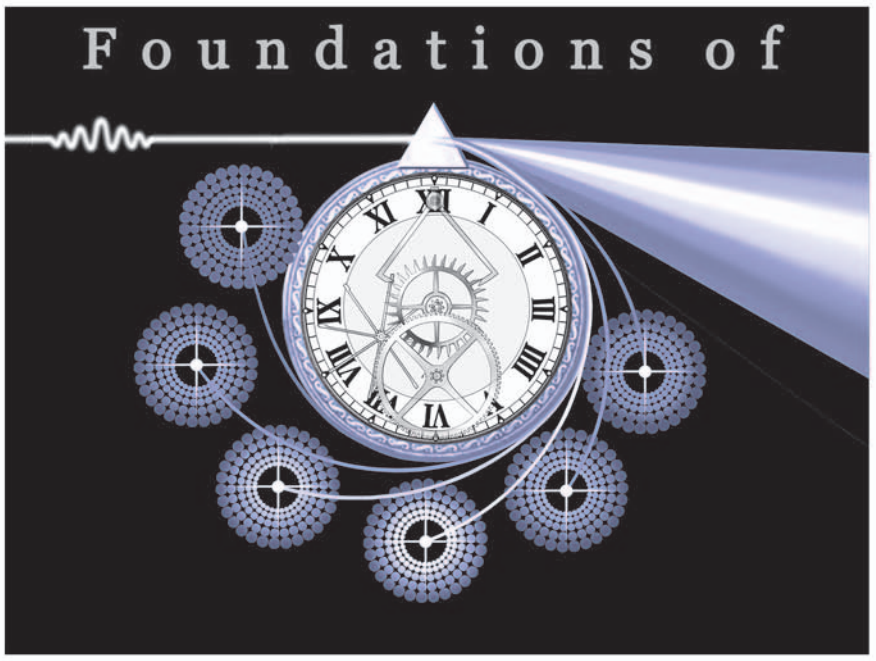

Physical Science

Tom Hsu, Ph.D.

FIRST EDITION
Cambridge Physics Outlet
Peabody, Massachusetts 01960

The cover is an evocative montage of historic scientific achievements that demonstrate the incredible persistence of the human intellect. Around the border, DaVinci's graphics represent the start of an evolving tapestry of conceptual thinking. His fantastical mechanisms become the modern bicycle, a quintessential machine, which rolls into a graphical interpretation of wavelength division multiplexing on a fiber optic. These images follow 500 years of scientific and technological innovation. The Earth and DNA serve to remind us that this technological innovation will always remain deeply connected to the natural world. On the back cover, the elegant geometry of the chambered nautilus folds into a spiral defined by the Golden Rectangle. The interplay of organic and architectural forms represents the balance we seek between the power of technology and the fragility of our lives and our world. I hope this colorful interplay of images will inspire interest and excitement about the discovery of science.

Bruce Holloway - Senior Creative Designer

Foundations of Physical Science

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Science Through Discovery

The universe is like a safe to which there is a combination, but the combination is locked up in the safe.
Peter de Vries

In many learning situations, you are expected to study prescribed materials and come up with correct answers by yourself. Usually, you read the information and then, in a laboratory, you try out the knowledge you acquired. With the CPO program, you will find that science is an opportunity for you to discover and solve problems—though they sometimes seem like mysteries more than "problems"—while working with others as a team.

Working with your fellow students, you will use very accurate equipment to answer key questions, decide if your findings can be backed up with data and facts, and learn how to prove and justify your end results.

What you learn in school should be connected to what you know about the world around you. These connections will contribute to your success in life, sometimes in obvious ways, and many times in quite surprising ways. In today's workplace and in future educational pursuits, you will need to ask insightful questions, plan and organize your work, look for and analyze information, try out your ideas, and then be able to rethink a problem and try again. You must also be able to work on a team, to come up with a system for organizing information, and to feel comfortable about tackling new problems.

The CPO program provides the opportunity for you to practice answering questions, working with others, and finding your own system for solving problems. In the student text, you will find knowledge and skills needed to answer key questions and explore a variety of science topics. Along with each reading, you will complete an investigation activity so that part of your discovery of science is done with others. Some people may think exactly like you, while others might find different ways of approaching the same problem.

Finally, the ability to communicate effectively is one of the most valued skills in the world today. As a result, analyzing and communicating your findings to others in written, verbal or illustration form will be a major part of the learning process throughout the CPO program.

About the Student Text

There are *Nine* Major Science Units covered in the CPO student text. Each Unit contains *Chapters* which are divided into three or four *sections*. The chapters and sections are organized so that you will learn basic skills and then build your knowledge to more complex understanding. You will notice that many of the important science concepts are repeated in different ways throughout the sections. Numerous illustrations, charts, graphs, and data tables support your reading and assist you in grasping its content. Also, there are short subheadings on the left margin of each page to help you study the main ideas and find information quickly.

Student Text Main Components

Main text: In addition to reading about science concepts and skills, you will discover brief stories about important scientists, inventions, real world connections, environmental issues, and interesting facts.

Chapter pages: Each chapter starts with two pages that outline what you will learn in the chapter. These pages provide you with a brief summary, the key questions for each Investigation, vocabulary, and learning goals.

Review questions: After each section, there are review questions that evaluate what you have learned and support you and your teacher in choosing what needs to be reviewed and which concepts to discuss further.

Glossary: The glossary is where you will find the meaning of words that are important science concepts and essential vocabulary. You can also find references to important people who are discussed in your reading.

Index: This section helps you find more specific topic information by giving page numbers that refer to the topic. You can use the index while studying to find information.

Reference Tables: A quick reference guide provides you with safety information, problem solving techniques (dimensional analysis), a conversion chart, table of formulas, and a list of physical constants. The inside back cover of the book is a quick reference periodic table and explanation of how to interpret it.

Student Text Pages

Sidenotes (idea headers): In the left margin of each page you will find phrases, short sentences, and questions to guide you in understanding the most important ideas. These sidenotes will also help you skim the text and quickly find information when you are reviewing and studying for tests.

Illustrations: Use the illustrations, graphs, charts, and data tables to help you understand the reading. These reading tools help most students improve their understanding of the key concepts.

Vocabulary words: The vocabulary words are highlighted in blue. You need to understand their meanings to be successful in science and will find the same vocabulary used in many contexts and repeated throughout the text. The definitions can be found in the glossary.

Data tables: These tables will help you understand complex information, organize numerical data, and provide examples of how to collect and present data.

Figure number/captions: As you are reading, notice the references to the word *Figure* followed by a number. These figures are found on the right side of the page in the form of an illustration, picture, or chart. The figure number indicates which figure goes with the text you are reading and gives you another way to understand the information in the reading.

STUDENT TEXT PAGES

Section number and title

Introduction to section content

Chapter number

Main text including highlighted vocabulary words

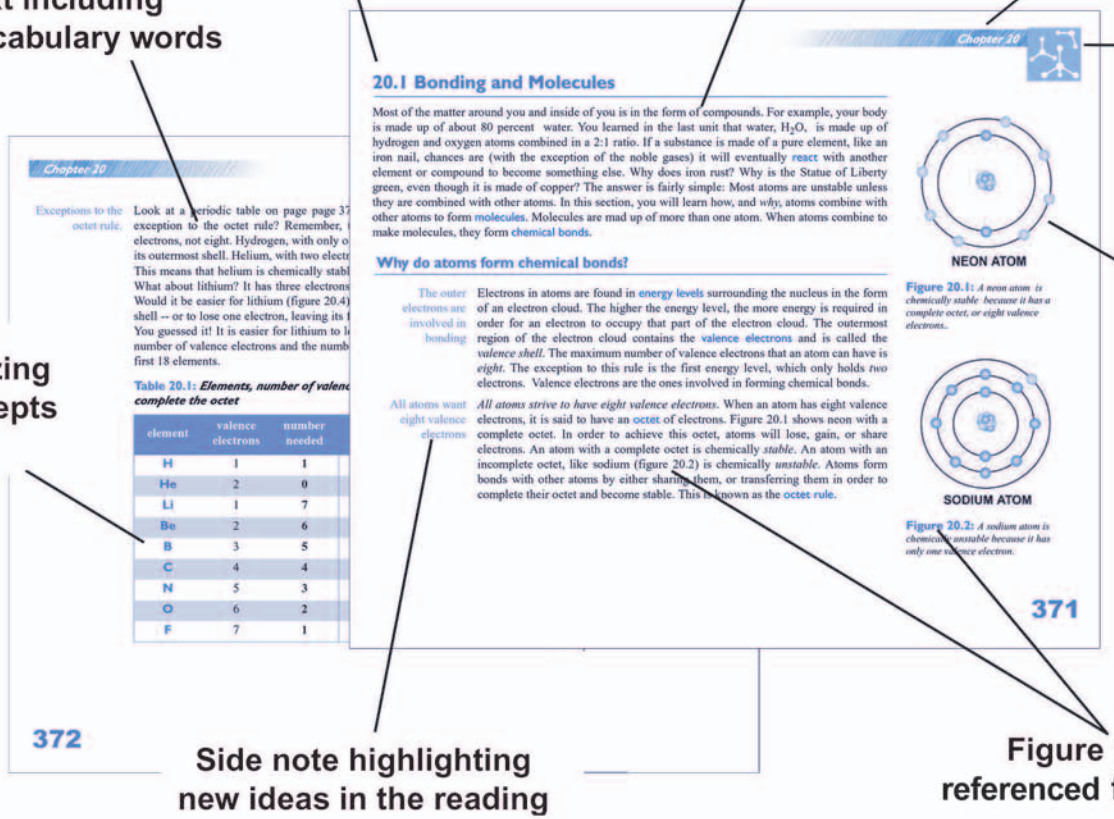
Icon representing unit topic

Illustrations and charts that support content

Table: organizing important concepts and data

Side note highlighting new ideas in the reading

Figure number is referenced from the text



Chapter 20

Exceptions to the octet rule.

Look at a periodic table on page page 37
exception to the octet rule? Remember,
electrons, not eight. Hydrogen, with only o
its outermost shell. Helium, with two electr
This means that helium is chemically stabl
What about lithium? It has three electrons
Would it be easier for lithium (figure 20.4)
shell -- or to lose one electron, leaving its
You guessed it! It is easier for lithium to l
number of valence electrons and the numb
first 18 elements.

Table 20.1: ***Elements, number of valenc
complete the octet***

element	valence electrons	number needed
H	1	1
He	2	0
Li	1	7
Be	2	6
B	3	5
C	4	4
N	5	3
O	6	2
F	7	1

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Chapter 20

20.1 Bonding and Molecules

Most of the matter around you and inside of you is in the form of compounds. For example, your body is made up of about 80 percent water. You learned in the last unit that water, H_2O, is made up of hydrogen and oxygen atoms combined in a 2:1 ratio. If a substance is made of a pure element, like an iron nail, chances are (with the exception of the noble gases) it will eventually react with another element or compound to become something else. Why does iron rust? Why is the Statue of Liberty green, even though it is made of copper? The answer is fairly simple: Most atoms are unstable unless they are combined with other atoms. In this section, you will learn how, and *why*, atoms combine with other atoms to form molecules. Molecules are mad up of more than one atom. When atoms combine to make molecules, they form chemical bonds.

Why do atoms form chemical bonds?

The outer electrons are involved in bonding

Electrons in atoms are found in energy levels surrounding the nucleus in the form of an electron cloud. The higher the energy level, the more energy is required in order for an electron to occupy that part of the electron cloud. The outermost region of the electron cloud contains the valence electrons and is called the *valence shell*. The maximum number of valence electrons that an atom can have is *eight*. The exception to this rule is the first energy level, which only holds *two* electrons. Valence electrons are the ones involved in forming chemical bonds.

All atoms want eight valence electrons

All atoms strive to have eight valence electrons. When an atom has eight valence electrons, it is said to have an octet of electrons. Figure 20.1 shows neon with a complete octet. In order to achieve this octet, atoms will lose, gain, or share electrons. An atom with a complete octet is chemically *stable*. An atom with an incomplete octet, like sodium (figure 20.2) is chemically *unstable*. Atoms form bonds with other atoms by either sharing them, or transferring them in order to complete their octet and become stable. This is known as the octet rule.

NEON ATOM

Figure 20.1: *A neon atom is chemically stable because it has a complete octet, or eight valence electrons.*

SODIUM ATOM

Figure 20.2: *A sodium atom is chemically unstable because it has only one valence electron.*

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Investigation Text

Hear and you forget;see and you remember; do and you understand.
Confucius

Investigations are hands-on activities that accompany the student text. For each section of the text, you will complete a hands-on activity, answer key questions, and find results. The *Investigation Manual* is a softcover book that contains Investigation activities that accompany each section you are reading. Sometimes you will read the student text before doing an Investigation activity, but usually you will complete the Investigations before you read the section.

The Investigations are the heart of the CPO program. We believe that you will learn and remember more if you have many opportunities to explore science through hands-on activities that use equipment to collect data and solve problems. Most of the Investigations rely on the use of CPO equipment to collect accurate data, explore possibilities and answer the key question. The equipment is easy to set up, and your teacher will help you learn how to use the equipment properly.

Features of the Investigation

Key question: Each Investigation starts with a key question that conveys the focus of the lesson. This question tells you what information you need to collect in order to answer the questions at the end of the Investigation.

Data tables: Data tables help you collect and organize your data in a systematic manner.

Learning objectives (goals): At the top of each investigation are the learning goals. These statements will explain what you will have learned and what you be able to do after completing the Investigation.

Brief introduction: This information helps you understand why the exercise is important to complete and, in most cases, how it connects to other sections of your reading.

Icons and section title: The icon is a reminder of the unit that you are studying. The section title corresponds to the reading in your student text.

Numbered steps: The Investigation sequence numbers point out the sequence of steps you will need to follow to successfully complete the Investigation. These steps highlight specific stages of the scientific method such as: following directions, completing hands-on experiments, collecting and analyzing data and presenting the results. The *Applying your Knowledge* step asks you to reflect on what you have learned and to explain your findings.

Illustrations: The illustrations support your understanding of the Investigation procedures.

Fill-in answer sheets: Your teacher will provide you with answer sheets to fill in the data tables and written responses. At times your teacher may collect this data to compile class results. You can also use the sheets to reinforce your reading in your student text.

INVESTIGATION PAGES

Section number referenced from the student text

Section title reference from the student text

Unit topic

Icon representing unit topic

Key question

Major learning objective for the investigation

Explanation of investigation content.

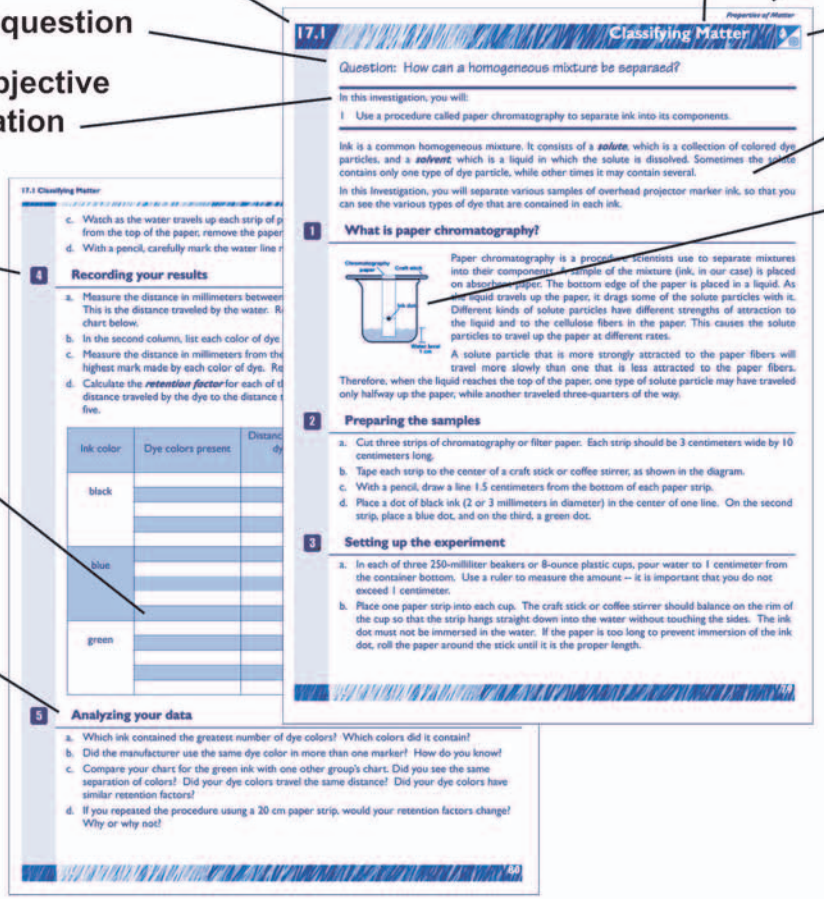
Illustration and charts that support content

Investigation sequence numbers

Example data table *

Thought-provoking question

Detailed explanations of investigation procedures, equipment set up, and data collection



17.1 Classifying Matter

Question: How can a homogeneous mixture be separated?

In this investigation, you will:

1 Use a procedure called paper chromatography to separate ink into its components.

Ink is a common homogeneous mixture. It consists of a ***solute***, which is a collection of colored dye particles, and a ***solvent***, which is a liquid in which the solute is dissolved. Sometimes the solute contains only one type of dye particle, while other times it may contain several.

In this investigation, you will separate various samples of overhead projector marker ink, so that you can see the various types of dye that are contained in each ink.

1 What is paper chromatography?

Paper chromatography is a procedure scientists use to separate mixtures into their components. A sample of the mixture (ink, in our case) is placed on absorbent paper. The bottom edge of the paper is placed in a liquid. As the liquid travels up the paper, it drags some of the solute particles with it. Different kinds of solute particles have different strengths of attraction to the liquid and to the cellulose fibers in the paper. This causes the solute particles to travel up the paper at different rates.

A solute particle that is more strongly attracted to the paper fibers will travel more slowly than one that is less attracted to the paper fibers. Therefore, when the liquid reaches the top of the paper, one type of solute particle may have traveled only halfway up the paper, while another traveled three-quarters of the way.

2 Preparing the samples

a. Cut three strips of chromatography or filter paper. Each strip should be 3 centimeters wide by 10 centimeters long.

b. Tape each strip to the center of a craft stick or coffee stirrer, as shown in the diagram.

c. With a pencil, draw a line 1.5 centimeters from the bottom of each paper strip.

d. Place a dot of black ink (2 or 3 millimeters in diameter) in the center of one line. On the second strip, place a blue dot, and on the third, a green dot.

3 Setting up the experiment

a. In each of three 250-milliliter beakers or 8-ounce plastic cups, pour water to 1 centimeter from the container bottom. Use a ruler to measure the amount -- it is important that you do not exceed 1 centimeter.

b. Place one paper strip into each cup. The craft stick or coffee stirrer should balance on the rim of the cup so that the strip hangs straight down into the water without touching the sides. The ink dot must not be immersed in the water. If the paper is too long to prevent immersion of the ink dot, roll the paper around the stick until it is the proper length.

4 Recording your results

Ink color	Dye colors present	Distanc dy
black		
blue		
green		

5 Analyzing your data

a. Which ink contained the greatest number of dye colors? Which colors did it contain?

b. Did the manufacturer use the same dye color in more than one marker? How do you know?

c. Compare your chart for the green ink with one other group's chart. Did you see the same separation of colors? Did your dye colors travel the same distance? Did your dye colors have similar retention factors?

d. If you repeated the procedure usung a 20 cm paper strip, would your retention factors change? Why or why not?

* Note: All data and answers to questions will be written on a separate fill-in answer sheet.

Student Text Chapter Pages

Each *Unit* has several sections which make up a *Chapter*. *Chapter pages* outline what you will learn in the Chapter and the Investigations (hands-on activities) that complement the readings. The Chapter pages serve as a map that directs you to the major concepts that will be covered. It is important to refer back to these pages to help you focus your learning on the most important ideas introduced in the chapter.

Features of the Chapter Pages

Introduction: The Chapter page introduction summarizes what you will have learned when you finish all the sections and Investigations. Refer back to this summary after you finish the chapter to check your understanding, and use this summary when studying for exams.

Chapter contents and Investigations: This listing with the chapter numbers outlines the key questions and the content of the Investigations that accompany your student readings. When you read the questions and Investigation descriptions, you will be able to see how the Investigations help you understand the skills and concepts introduced in each chapter.

Learning goals: These goals are the major ideas that you will explore throughout the chapter. You should check your learning by going back to this page to make sure you can explain each of these concepts in writing or to another person.

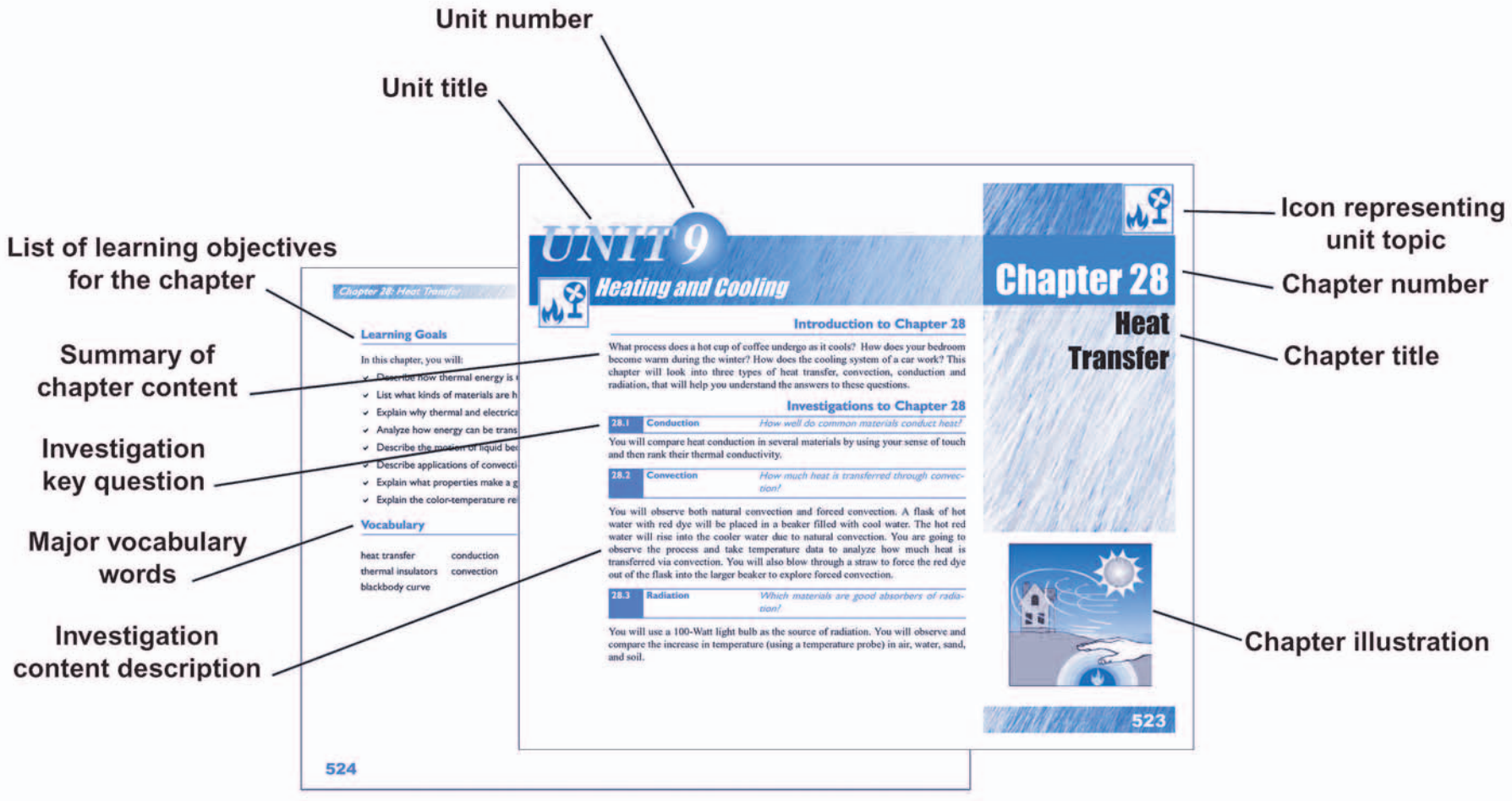
Vocabulary: The list of vocabulary words at the beginning of the chapter will familiarize you with the words in the chapter. Understanding the science vocabulary will help you learn the concepts in the readings. Thinking and guessing about the meaning of the words before reading and then seeing how close you were to the correct meaning is a good learning tool.

Unit Icons Guide

Unit icons are used to identify what unit topic you are studying. You will see these icons on the Chapter and Investigation corners.

	Unit One: Force and Motion		Unit Six: Properties of Matter
	Unit Two: Work and Energy		Unit Seven: Changes in Matter
	Unit Three: Electricity and Magnetism		Unit Eight: Water and Solutions
	Unit Four: Sound and Waves		Unit Nine: Heating and Cooling
	Unit Five: Light and Optics		

CHAPTER PAGES



Using Icons to Locate Information

Icons are small pictures that convey meaning without words. In the CPO program, we use icons to point out things such as safety considerations, real-world connections, and when to find information in the reference pages, complete a writing assignment, or work in a team. The chart below lists the icons that refer to instruction and safety and the meaning of each one:

The mind is not a vessel to be filled but a fire to be kindled
Plutarch

	**Reading:** you need to read for understanding.		**Real-world connections:** you are learning how the information is used in the world today.
	**Hands-on activity:** you will complete a lab or other activity.		**Teamwork:** you will be working in a team to complete the activity.
	**Time:** tells how much time the activity may take.		**Economics:** you are learning how science impacts the economy.
	**Research:** you will need to look up facts and information.		**Formula:** you are reading information about a formula or you will need to use an equation to solve a problem.
	**Setup:** directions for equipment setup are found here.		**Use extreme caution:** follow all instructions carefully to avoid injury to yourself or others.
	**History:** you are reading historical information.		**Electrical hazard:** follow all instructions carefully while using electrical components to avoid injury to yourself or others.
	**Environment:** you are reading information about the environment or how to protect our environment.		**Wear safety goggles:** requires you to protect your eyes from injury.
	**Writing:** you need to reflect and write about what you have learned.		**Wear a lab apron:** requires you to protect your clothing and skin.
	**Project:** you need to complete an assignment that will take longer than one day.		**Wear gloves:** requires you to protect your hands from injury from heat or chemicals.
	**Apply your knowledge:** refers to activities or problems that ask you to use your skills in different ways.		**Clean-up:** includes cleaning and putting away reusable equipment and supplies, and disposing of leftover materials.