

# *Physical Science*

*with Earth and  
Space Science*

*Tom Hsu, Ph.D.*

**FIRST EDITION**  
CPO Science  
Peabody, Massachusetts 01960

**cpo**  
science

The cover colorfully combines illustrations of the forces of nature studied in the various fields of the physical sciences. Here, the "evolving tapestry of conceptual thinking" begins with water. Water droplets dance with the planets including our own watery planet and Saturn with its icy rings. Water reappears in the combustion reaction of methane, as the substance on which plants depend, as pounding waves, and, on the back cover, as the darkening clouds of a coming storm. From this cycle of water, a modern bicycle rolls into a graphical interpretation of white light split into its rainbow of wavelengths and a fiber optic. You may lose yourself in many of these images which represent hundreds of years of scientific and technological innovation. Nevertheless, that our innovations are inextricably woven into and from the natural world is illustrated by the images of Earth and the spiral connection between the DNA helix and a bicyclist ever-moving forward. On the back cover, images from physics, chemistry, and earth and space science move around a chambered nautilus seen through the windows of the Golden Rectangle. We at CPO Science with Bruce Holloway, the spirited illustrator of the cover, hope these images will inspire your interest and excitement about the discovery of science.

*The CPO Science Development Team*

Foundations of Physical Science with Earth and Space Science

Teacher's Guide Series

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# The CPO Science Program

One of the great scientists in history, Albert Einstein stated, “The whole of science is nothing more than a refinement of everyday thinking.” This great thinker and theorist explained that science is not just the memorization of complex facts or the rote learning of complicated ideas but a process by which we discover and explore the things, concepts, and mysteries we see around us.

The CPO Foundations of Physical Science with Earth and Space Science Program is created from the premise that science is an exploration and discovery of ideas about the universe, and that ideas and knowledge connect and enhance our lives. The program is presented and sequenced in a way that moves the student through an inquiry-based learning approach. Each chapter and Investigation begin with key questions that form the foundation for the learning. In many sections, student complete experiments and hands-on activities before conceptualizing ideas in the student readings. Threaded throughout all the instruction are probing questions that students answer through exploration, posing new questions, finding data to prove theories, and expressing their findings to others.

## Scope and sequence

Unlike other textbooks that match content to National Science Education Standards, the CPO Science Program was written directly to your state standards. The standards form the benchmark criteria from which each science topic, specific content requirement, and science process was developed. The program provides numerous opportunities for students, teachers, and schools to meet the standards and state testing program. Matching the standards to CPO Unit topics ensures that students will receive the highest quality in science instruction to the depth and breadth necessary to meet your teaching needs.

If requested, CPO Science staff will send your state correlation index. This document demonstrates the alignment between the your standards and the CPO Science Program. The index lists specific page numbers from the CPO Student Edition and Investigation Lab Manual where examples of correlations are found. The CPO Scope and Sequence found in this reference guide demonstrates the careful consideration and detail of content match between the Student Edition and accompanying Investigations. These charts can be reviewed as a quick reference to the teaching and learning objectives covered in this program.

## Meeting all students’ needs

Learning science is an active process allowing students to gain abstract, conceptual knowledge through discovery. Most students learn best when reading is enhanced by doing. The CPO Science Program combines strong, in-depth coverage of physics and chemistry content with abundant hands-on learning activities to meet the variety of learning styles. Real-world examples and historical perspectives provide students the authenticity that validates their connection to the content and topics. Teaching tips are found in the teacher’s guide as suggestions for remediation and skill development practice with challenge problems for students who are prepared to tackle more difficult concepts.

*“The whole of science is nothing more than a refinement of everyday thinking.”*

*Albert Einstein*

## The Multilevel Classroom of Today

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Classrooms are composed of learners who are at different instructional levels and who process information through multiple learning styles. The CPO Science Program has been designed to meet the challenge of bringing in-depth, accurate science to all students. To teach in-depth science concepts and skills, the design of the Student Edition reflects instructional aids and strategies to meet that diversity of student needs. Careful consideration has been taken to include reading, math, and learning techniques to help all students grasp science concepts and skills.

### Reading and concept-learning strategies

**Main idea indicators** — Main idea indicators appear in the left margin of each paragraph in the Student Edition to help students find information and understand the main concepts in the instruction. Students can use the indicators in the following ways:

- Read all the main idea indicators before reading the section as a pre-reading activity.
- List the major points of the section.
- Create outlines and concept maps.
- Find answers to questions by skimming and scanning the indicators for a quick review.

**Highlighted vocabulary** — As in any discipline or occupation, people must understand the subject's terminology and know how to use it correctly. Terms, units of measurement, and concepts are highlighted in blue for students to easily identify key words as reading clues and for vocabulary development.

**Bold highlighted points** — Major scientific concepts, vocabulary, and laws appear in large print and blue type. These statements identify the major learning points and what to review when studying.

### Building problem-solving skills by using key questions

Asking questions before starting an activity focuses students on what they will learn during the experiment or reading. Each Investigation begins with a key question that students need to answer after the activity. Students build problem-solving and critical thinking skills as they tackle each Investigation question. The following is a suggested sequence to use when deciphering questions:

- Have the student reread the question.
- Underline the action words and explain what is being asked.
- Identify the important words (usually vocabulary words).
- Have the students rewrite the question in their own words.
- Help students decide what they will need to know in order to answer the question.

## Reading illustration and graphics for science concepts

Some students learn best through visual clues and illustrations. Others need the dual support of text and visual clues in order to comprehend science concepts and theories. Our student text and Investigations manual have numerous content-rich illustrations, charts, tables, and graphics. Suggestions for using the visual clues include:

- Give students enough time to analyze the graphics and illustrations. Decoding the meaning of a visual is like reading text.
- Ask the students to verbally explain what they see in the graphic and what is being demonstrated.
- Teach students to read data tables and graphs so that they understand how to organize and represent data. Numerous examples and questions requiring completion of tables are presented with explanations.
- In teams, have students illustrate a concept or create graphics for the section. Other team members decide which concept or section is being illustrated.

## Reading, understanding, and using math formulas

Formulas help students describe relationships between quantities. After students understand the basis for formulas and how they represent relationships, they can use them as tools for solving problems or predicting outcomes. We emphasize understanding relationships rather than simply memorizing formulas.

- Math formulas are connected to the data collection process during hands-on activities. The formulas are all in the context of the Investigation, and as a result, students apply math formulas to actual science experiences.

Important math formulas are highlighted, written in large print, and also explained in the text.

- Example problems illustrate how to use the formula and how it can be applied to the most common situations. Students' learning of the formulas is reinforced throughout the Student Edition and in the assessment sections.
- Only the most relevant math formulas are presented in the text and explained in depth.
- A reference section in the Student Edition contains an easy-to-read table of all the formulas in the program.

## Expressing learning in a variety of ways

Students learn differently and use various avenues for expressing their knowledge. In the review questions in the Student Edition, students are asked to answer *Applying Your Knowledge* questions. These questions allow students to express their knowledge and demonstrate learning in several modalities. Examples include designing an experiment, researching information, building a model, writing an essay, checking appliances in their homes, preparing a pamphlet or brochure, discussing ideas, creating sketches, forming a committee to develop plans, interviewing someone, creating a handout for young children, and using the Internet.

## Evaluation and Assessment

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The CPO Science Program is committed to presenting material in a variety of ways to meet the diversity of student learning styles. Students learn in a combination of modalities and demonstrate understanding through a variety of modes. A combination of evaluation methods is available to ensure multilevel and diverse opportunities. A variety of methods is necessary in order for students to demonstrate science content knowledge, application skills, performance abilities, and scientific process and problem-solving skills to the best of their ability. Below are descriptions of the different evaluation and assessment instruments.

*“Anyone who has never made a mistake has never tried anything new.”*

*Albert Einstein*

### Evaluating with review questions — formative assessment

Review questions are found at the end of each chapter to evaluate student progress and reflect on key chapter objectives. These questions provide opportunities to test and practice vocabulary, concept knowledge, skill understanding, computational ability, problem solving, and application. Many questions require a written response in order to better evaluate the student’s abstract understanding. The review questions are a useful teaching tool to benchmark individual progress and to aid class discussions that review and reflect on chapter objectives.

### Assessing broader knowledge with assessment questions — summative assessment

The assessment questions have been carefully designed to test all the important topics covered in a unit. The assessment questions evaluate the student’s knowledge that correlates with the unit. Included in the questions are examples of graphs, charts, and computational information needed to answer questions and demonstrate application skills. The assessment questions are on the ExamView CD and consist of multiple choice and multi-format questions that cover computation, skill attainment, and concept understanding. These questions are designed to reflect typical standardized test questions. Exposure and practice in answering multiple-choice type questions has proved helpful to students in states using formal standardized testing. There are over 900 questions on the ExamView CD.

### Learning and applying skills — performance assessment

Being able to justify conclusions based on active experimentation and data collection is a powerful skill in today’s technological world. Performance assessment measures how well a student can solve problems and demonstrate understanding through application. The CPO Science Program builds the self-confidence that students need to tackle problems in a thoughtful and sequenced manner.

An Investigation is completed with each teacher’s guide section and includes questions and activities that allow teachers to observe the students’ ability to think and demonstrate understanding. Most Investigations rely on team participation and hands-on learning. Students are continuously exposed to a systematic problem-solving method that encourages students to discover, observe, collect data and justify findings. A sample observation evaluation form is provided in the *Teaching Tools* section of the Reference Guide to help determine the students’ progress with performance tasks. A student reflection form can also be found in the *Teaching Tools* section.

## Organization of the Program

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The program is composed of four components: Student Edition, Investigations, Teacher’s Guides, and Equipment. These components reflect the connections between inquiry-based learning, hands-on discovery, and grasping science concepts through reading. Abstract concepts and skill development opportunities are presented in a variety of ways to address diverse and multiple learning styles. Enhancing the instruction are clear, precise illustrations that reinforce the learning of abstract concepts. By the end of each section, students have completed a hands-on activity or experiment, answered essential questions, and mastered science skills and content through reading.

The Teacher’s Guide and support materials have been divided into six volumes: one reference and five content topic guides. The Reference Guide contains: the glossary, index, assessment questions and answers, review answer keys, teaching tools, and other reference tables. The five content topic teacher’s guides provide sample lessons that demonstrate how to teach each lesson with accompanying Investigation sheets and answers. Teaching tips, challenge questions, and student reinforcement of skills are also present.

*“Hear and you forget; see and you remember; do and you understand.”*

*Confucius*

## Student Edition

The basic organizational structure of the Student Edition is the unit. There are nine units that are broken down into topic chapters containing three to five content-specific sections. The unit themes covered in the CPO Foundations of Physical Science with Earth and Space Science Program were chosen because of their relevance to CPO’s commitment to in-depth coverage of science concepts. The glossary and index have been designed so students can quickly skim for page numbers and definitions. Each student section contains pertinent content and skills-development reading with numerous illustrations for reading support. Each chapter contains an extensive review question section that evaluates the student’s progress in areas such as: vocabulary development, concept understanding, computation skills, and application. Special features of the Student Edition:

- **Chapter pages:** These introductory pages present the major components of the student reading, including Investigation descriptions, what the student will learn from the section, and the pertinent vocabulary.
- **Side heading outlines:** Developing literacy skills in math and reading is stressed throughout the instruction. Left-margin side headings highlight the main ideas in the text and help the student grasp reading concepts through skimming, scanning, and key word identification.
- **Highlighted vocabulary:** Science vocabulary mastery is paramount for science concept understanding. Science vocabulary can be highly technical and abundant. Vocabulary words are highlighted for easy identification and defined in a variety of ways.
- **Numerous visual teaching tools:** The Student Edition contains graphics, charts, illustrations, and data tables supporting abstract conceptual learning. These teaching tools reinforce instruction and aid in visual representation of material necessary for addressing multiple learning styles. The visuals are precise in content and presentation and reflect CPO’s commitment to accuracy, science content excellence, and inquiry-based instruction.

### Investigations

The Investigations are the heart of the CPO Science Program. We believe that most students learn best and are motivated to learn through direct experience and exploration activities. Key questions focus the student on the main point of the learning and what they should be able to answer after the experiment. There is at least one Investigation for each student reading section. The student reading and Investigation closely compliment the science instruction and reinforce the same principles.

Each Investigation is introduced with a key question that the students will be able to answer after completing the hands-on activity. Students are also given learning goals for each Investigation and a short informational piece to get them thinking about the content of the Investigation. Student answer pages are found in the teacher's blackline master notebook. The teacher can duplicate the forms for students to complete and answer the questions.

Each Investigation begins with a key question and uses leading questions to aid in skill development, reflection, and application. An observation form is found in the *Teaching Tools* section of the Reference Guide to aid the teacher in evaluating Investigations as performance-based tasks.

Investigations are usually completed before the accompanying student reading section. The CPO philosophy is based on the premise that through discovery, the students will begin to understand foundation skills and concepts. The student readings strengthen the students' knowledge of theory and aid in their understanding. For certain Investigations, the student reading must be read first so that students have the basic knowledge necessary to complete the Investigation. Whether a section should be read before or after an Investigation is explained under the reading synopsis heading in the teacher's guide pages for each section.

### Special Features

- **Data collection, graphing skills and the scientific process:** These skills are emphasized and reinforced throughout the program and students are frequently encouraged to practice these skills as self-learners.
- **Lesson planning page:** The information you need to know to teach and conduct the Investigation is available in the teacher's guide section pages. The learning goals and questions, equipment setup requirements, consumable materials list, teaching sequence, and a synopsis of the student reading are all in found on the lesson introduction pages.
- **Icons:** Throughout the Investigations, icons are used to point out safety requirements and to reference important information for the students. A reference sheet of the icons and the meaning of each is found in the Student Edition and the teacher's guides.
- **Equipment:** Specialized equipment has been designed to accompany the teaching of the Investigations. The equipment is durable and provides consistent accurate results.

*“The greatest tragedy of Science: the slaying of a beautiful hypothesis by an ugly fact.”*

*Thomas Huxley*

## Teacher's guides

The teacher's guides are constructed around the same premise as the student instructional materials: inquiry-based learning. The guides include a sample demonstration lesson for each Investigation written as a dialogue between the teacher and the class. These samples demonstrate how to teach the Investigation using inquiry-based teaching and student group discovery. The sample demonstration is only one example of teaching the Investigation with possible student responses. Teaching tips, the accompanying student section synopsis, projects, and teaching strategies are also included.

The first two pages of each teacher's guide section contain a clear, concise overview of the Investigation. It is our belief that a quick guide is useful in outlining the learning objectives, setting up the Investigation, and mapping the sequence of the Investigation procedures. These pages contain a brief synopsis of the student reading, review of the leading question, learning objectives, and a clear equipment and consumable materials list. The equipment setup instructions are identified with an equipment icon and are found in this volume under the *Equipment Setup* section.

The Investigation lesson pages present a sample teaching scenario written as a dialogue between the teacher and class. The dialogues present actual lessons taught from the teacher's point of view, as well as possible student responses. The dialogues provide excellent support for teachers who are new to the subject area, as they identify possible student misconceptions and highlight important learning content. The dialogues provide teaching tips such as:

- What to put on the chalkboard.
- How to teach by questioning.
- What reactions the students may have and how to respond.
- Interesting stories to make connections between key concepts and everyday life.
- Computational information.

## Organization of the teacher's guides

The teacher's guides are divided into five unit volumes and the reference volume. The volumes have been divided according to similar objectives, content coverage, and specific equipment needs. The lightweight topic volumes are easy to carry and content is focused on one to three units. You will only need one volume and the reference section when planning a lesson. The teacher's guides contain the Student Edition text and all the information you need to teach and evaluate each unit. The reference volume includes: assessment questions and answers, quick reference charts, teaching information, the glossary and index. The unit contents for the teacher's guides are:

**Volume 1:** Reference Guide

**Volume 2:** Force and Motion, Work and Energy

**Volume 3:** Electricity and Magnetism

**Volume 4:** Sound and Waves, Light and Optics

**Volume 5:** Properties of Matter, Changes in Matter, Water and the Environment

**Volume 6:** Energy in the Earth System, Earth Science, Astronomy

*“The most important thing in science is not so much to obtain new facts as to discover new ways to think about them.”*

*William Bragg*

## Equipment

CPO products are high-quality, accurate, and long-lasting. These characteristics are found in all the equipment used to teach the concepts in the CPO Science Program. Equipment has been especially designed and tailored to the course goals and tested to ensure precise data and repeatable findings.

You can use the CPO Science Program to its fullest potential by taking advantage of all the benefits of using hands-on equipment. There is a section in this book that presents all the equipment and how to set up and use each piece. Information is presented in the Investigations that also explains how to set up the equipment and how it will be used throughout the experiments.

The table below outlines the equipment pieces and units where the equipment is needed.

*“The strongest arguments prove nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences and the goal of all speculation.”*

*Roger Bacon*

Equipment Name	Units Equipment is Needed	Concepts
Car and ramp	Unit 1, 2	motion, speed, acceleration, Newton’s laws
Rollercoaster	Unit 2	energy conservation, transformation, potential and kinetic energy
Gears and levers	Unit 2	simple machines, input and output force, mechanical advantage
Ropes and pulleys	Unit 2	simple machines, work, energy
Electric circuits and motor	Unit 3	voltage, current, resistance, series circuits, parallel circuits
Pendulum	Unit 4	harmonic motion, time, frequency, period, cycle, amplitude
Sound and waves	Unit 4	sound, music, frequency, period, wavelength
Spectrometer	Unit 5,6,11	wavelength, light, color, astronomy
Light and optics	Unit 5	light, color, optics, reflection, refraction, lasers
Periodic table tiles	Unit 6,7	the periodic table, chemical formulas, balancing chemical equations
Displacement tank	Unit 6	buoyancy, force, weight, mass, displacement
Atom Building Game SE	Unit 6,7	atomic structure, electrons and bonding, atoms, ions, isotopes
Earth and Space Science Kit	Unit 9, 10, 11	weather, geology, oceanography, astronomy

**\*The Timer and the Physics Stand are used with Force and Motion, Work and Energy, and Sound and Waves.**

The equipment is available in suggested packages depending on the needs of the school or district. Districts will receive an equipment voucher that can be used to receive the appropriate equipment package to fit teaching needs. The equipment quantity included in the voucher will depend upon the number of textbooks a district purchases for its students from the adoption process.

## Sharing Equipment

Many schools share lab equipment among science teachers. The CPO Science Program has been designed to meet this need with alternative sequences for teaching the units. The sequences outlined in the chart below allow three teachers to simultaneously teach different units of the program and share one classroom set of equipment. If the time for each rotation is followed, there is no overlap for any piece of equipment used in the program.

Each teaching sequence allows for a suggested teaching time period and a week for review and evaluation. The teacher's guides have been divided into volumes so that every teacher in the rotation can use the volume they need for the units they are teaching.

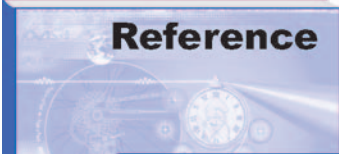


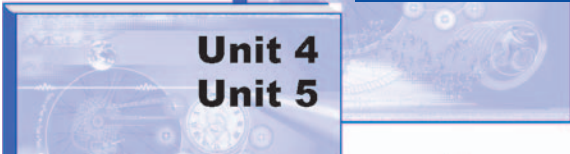

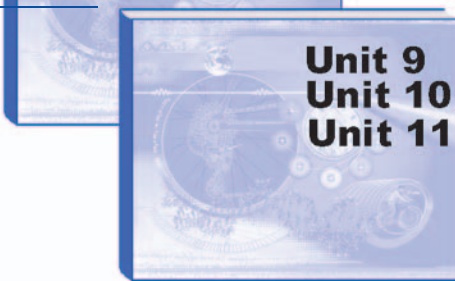
Other equipment rotation suggestions include: creating a designated space as a science lab with multiple sets of equipment, and portable equipment science labs that can be moved from classroom to classroom.

### Suggested Teaching Sequence and Rotation of Equipment for Three Teachers

<b>Teacher One</b>	Unit 1: Forces and Motion Unit 2: Work and Energy	Unit 3: Electricity	Unit 9: Energy in the Earth System Unit 10: Earth Science Unit 11: Astronomy	Unit 4: Sound and Waves Unit 5: Light and Optics	Unit 6: Properties of Matter Unit 7: Changes in Matter Unit 8: Water and the Environment
	<i>8 teaching weeks</i>	<i>4 teaching weeks</i>	<i>10 teaching weeks</i>	<i>4 teaching weeks</i>	<i>10 teaching weeks</i>
<b>Teacher Two</b>	Unit 3: Electricity	Unit 4: Sound and Waves Unit 5: Light and Optics	Unit 6: Properties of Matter Unit 7: Changes in Matter Unit 8: Water and the Environment	Unit 1: Forces and Motion Unit 2: Work and Energy	Unit 9: Energy in the Earth System Unit 10: Earth Science Unit 11: Astronomy
	<i>4 teaching weeks</i>	<i>4 teaching weeks</i>	<i>10 teaching weeks</i>	<i>8 teaching weeks</i>	<i>10 teaching weeks</i>
<b>Teacher Three</b>	Unit 6: Properties of Matter Unit 7: Changes in Matter Unit 8: Water and the Environment	Unit 1: Forces and Motion Unit 2: Work and Energy	Unit 3: Electricity	Unit 9: Energy in the Earth System Unit 10: Earth Science Unit 11: Astronomy	Unit 4: Sound and Waves Unit 5: Light and Optics
	<i>10 teaching weeks</i>	<i>8 teaching weeks</i>	<i>4 teaching weeks</i>	<i>10 teaching weeks</i>	<i>4 teaching weeks</i>

## How the Volumes Are Organized

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<b>Volume 1</b>	 <b>Reference</b>	Contains introduction, scope and sequence, answer keys to review questions, teaching tools, equipment setup, and the glossary and index from the Student Edition.
<b>Volume 2</b>	 <b>Unit 1</b> <b>Unit 2</b>	<b>Forces and Motion / Work and Energy</b> Teacher's guides (white pages) and Student Edition (cream color pages)
<b>Volume 3</b>	 <b>Unit 3</b>	<b>Electricity and Magnetism</b> Teacher's guide (white pages) and Student Edition (cream color pages)
<b>Volume 4</b>	 <b>Unit 4</b> <b>Unit 5</b>	<b>Sound and Waves / Light and Optics</b> Teacher's guides (white pages) and Student Edition (cream color pages)
<b>Volume 5</b>	 <b>Unit 6</b> <b>Unit 7</b> <b>Unit 8</b>	<b>Properties of Matter / Changes in Matter / Water and the Environment</b> Teacher's guides (white pages) and Student Edition (cream color pages)
<b>Volume 6</b>	 <b>Unit 9</b> <b>Unit 10</b> <b>Unit 11</b>	<b>Energy in the Earth System, Earth Science, Astronomy</b> Teacher's guide (white pages) and Student Edition (cream color pages)

## The Teacher's Guide Investigation Overview Pages

The teacher's guide for each Investigation begins with the overview pages. The overview pages correspond to each section of the Student Edition and each Investigation in the CPO Science Program. These pages review the instructional components, beginning with a summary of what the students will learn in the Investigation. Included are a synopsis of the reading, pertinent vocabulary from the Investigation, learning goals, and the key and leading questions that students will be able to answer after completing the Investigation. It is important to note that below the heading for the reading synopsis, there is a suggested sequence for teaching the student section and the Investigation. The student reading section frequently follows the completion of the hands-on Investigation. In some sections, the student reading must be completed first in order for students to assimilate the skills and concepts required to complete the Investigations.

The second page outlines the equipment and material needed, teacher's guide section considerations, and the sequence of teaching steps.

**Investigation and section title**

**Summary of the Investigation**

**Sequence for teaching the entire lesson**

**Brief summary of student reading**

**Unit title**

**Explanation of how to prepare for teaching the Investigation**

**Questions students will be able to answer after completing the Investigation**

**Important vocabulary students will use in the Investigation**

**Key information about the structure of the lesson**

**Icons to identify the type of task**

**Sequenced outline for teaching the Investigation**

**19.3 Comparing Molecules**

**68**

## Teacher's Guide Demonstration Lessons

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Each teacher's guide demonstration lesson contains an outline of the lesson, a "sample dialogue," and teaching strategies and tips. These pages also include the Investigation and sample answers to the activity. In the facing-page format, you can review the sample dialogue between the teacher and students, the Investigation page, and sample data and answers. All the information you will need to teach the Investigation is easily skimmed in this format.

Below are the features of the dialogue, Investigation answer page, and sidebar teacher notes.

**Outline:** This section contains an at-a-glance sequence of steps that a teacher can skim. It is a quick guide to what is taught in the Investigation and notes on the Investigation.

**Inv.:** In this column the teacher will find a reference number that matches the parts of the Investigation page. These corresponding numbers guide you to the part that is discussed in the dialogue.

**Dialogue:** This section is presented as an exchange between the teacher and the class. This sample lesson outlines what the teacher would actually say to the class and typical responses from the students. Helpful teaching ideas and tips such as: "Students will need access to water," "Group supervision is important at this point" are included. The teacher's directions and comments to the students are printed in black, and responses and directions are in blue text. It is our hope that teachers will review the dialogue before presenting the Investigations to the class, as a supportive tool and to help clarify the goals and important points of each Investigation.

**Investigation:** This is a miniaturized Investigation page that is referenced in the dialogue. The Investigation page includes answers to data tables and written responses. The teacher can refer to the numbers at the left of the Investigation page and match them to the opposite page as numbers under the column "Inv." These numbers indicate what section of the Investigation the dialogue is referring to. The data and some of the reflective answers are only examples of data and responses that can be given by the students.

**Reinforcement and Enrichment:** This section includes teaching tips, challenge questions, and more reinforcement ideas for students who may need extra time learning concepts. Ideas for future study and short interesting pieces are also found in this right-hand margin area.

**Outline and notes for teaching the Investigation**

**Reviewing chemical formulas**

**Inv. Biology**

**gen trioxide**

**For name binary covalent... These are named... than binary ionic compounds.**

**nitrogen oxide**

$\text{NO}_2$  = nitrogen dioxide  
 $\text{NO}$  = nitrogen monoxide  
 $\text{N}_2\text{O}_5$  = nitrogen pentoxide

**Reference number corresponds with parts of the Investigation**

**Introducing the Investigation**

**1**

**2**

**Demonstration lesson and teaching notes**

In the last Investigation, you learned what the symbols and numbers in a chemical formula tell you. Can you now tell us what the numbers in this chemical formula mean?

Write the chemical formula for barium chloride on your board ( $\text{BaCl}_2$ ). Students should know that the formula means that there is a 1:2 ratio of barium ions to chloride ions in one molecule of the compound. At this point, you may wish to review ionic compounds, ions and oxidation numbers.

Remember from the readings that not all compounds are ionic. What is a covalent compound?

Students should know from the reading that a covalent compound is one in which electrons are shared instead of transferred. Ions are not involved in covalent compounds.

Can you now give us an example of a covalent compound?

Compounds made from elements that can neither gain or lose electrons in order to complete their octet are usually involved in covalent bonds. For example, most compounds that contain carbon are covalent such as carbon dioxide ( $\text{CO}_2$ ).

What is the difference between these two compounds,  $\text{CO}$  and  $\text{CO}_2$ ?

The first one is carbon monoxide, with a 1:1 ratio of carbon atoms to oxygen atoms. The second is carbon dioxide with a 1:2 ratio of carbon atoms to oxygen atoms. Emphasize the prefix, mono- and di- in front of the -oxide as the indicators of the number of oxygen atoms. Have the students refer to figure 19.25 on page 330 of the student book for the rest of the Greek prefixes used in naming these compounds.

Covalent compounds that are made up of only two types of atoms are known as binary covalent compounds.

Use the example of compounds that are made out of nitrogen and oxygen, to illustrate how to name binary covalent compounds:

$\text{NO}$  = nitrogen monoxide  
 $\text{NO}_2$  = nitrogen dioxide  
 $\text{NO}_3$  = nitrogen trioxide  
 $\text{N}_2\text{O}_5$  = nitrogen pentoxide

In today's Investigation, you will use dots and crosses to represent two types of atoms. Let's assume that two represent atoms of the element Na while white represent atoms of the element Bo. Imagine that two elements can combine in any ratio to make different binary covalent compounds. What are the chemical formulas of some different compounds that these two elements can make?

There are a variety of answers possible. A few include:

$\text{Na}_2\text{Bo}$ ,  $\text{Na}_3\text{Bo}$ ,  $\text{Na}_2\text{Bo}_2$ ,  $\text{Na}_3\text{Bo}_2$ ,  $\text{Na}_4\text{Bo}_3$

In your groups, complete the first two activities on your Investigation sheet.

Make sure the students are doing the calculations in activity 2 on the investigation properly. Some students may need a quick review on calculating percentages and ratios.

After students have completed this part of the investigation, have groups share the chemical formulas of their molecules and the ratios of Na to Bo for each formula.

Do you see a relationship between the chemical formula and the ratio of Na to Bo for each of your compounds?

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**Outline**

**Inv. Biology**

**Determining empirical and molecular formulas**

**Empirical formula - simplest whole number ratio of elements in a compound**

**Molecular formula - actual ratio of elements in a compound**

**Example  $\text{H}_2\text{O}$  = molecular formula**  
 $\text{H}_2\text{O}$  = empirical formula

**Suggested teaching tip**

**What is the empirical formula and number of molecules of the compound in this box?**

**Discussing formula mass**

**Forma mass of  $\text{H}_2\text{O}$**

mass of  $\text{H}_2$  =  $2.0 \text{ g}$   
 mass of  $\text{O}$  =  $16.0 \text{ g}$   
 mass of  $\text{H}_2\text{O}$  =  $2.0 \text{ g} + 16.0 \text{ g} = 18.0 \text{ g}$

**Formula mass of  $\text{H}_2\text{O}$**

mass of  $\text{H}$  atom =  $1.0 \text{ amu}$   
 mass of  $\text{O}$  atom =  $16.0 \text{ amu}$   
 $2(1.0 \text{ amu}) + (1 \times 16.0 \text{ amu}) = 18.0 \text{ amu}$

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**Unit 7: Changes in Matter**

**Suggested chalkboard information to aid students in understanding important concepts in the Investigation**

**Investigation page**

**Investigation**

**19.3 Comparing Molecules**

**Question: What is the meaning of a chemical formula?**

**1** Use mass and volume to find different combinations of atoms to form compounds.

**2** Determine the percent composition of the compounds made out of atoms of the box.

**3** Determine the chemical formula of the compounds based on percent composition of atoms and bolts.

**4** Use the balanced red atoms combine in different ratios to form chemical compounds. In fact, the same two elements may form several different compounds by combining in different ratios. Chemical formulas show the ratio in which atoms combine to form a compound. To find the empirical formula, the ratio is reduced to the simplest form.

**5** Find the mass of the individual atoms

Your teacher has given you a set of nuts and bolts. Let's assume that the mass represents atoms of the element Na. Its equivalent atoms of the element Bo. Find the mass of one Na atom and the mass of one Bo atom and record below.

**6** How many different compounds can you make?

Build four different molecules out of nuts and bolts. You must use any combination you wish. Write the chemical formula for each molecule and then calculate the mass of each molecule. Next, calculate the percent composition of each element in the molecule by using the following procedure. For the calculation, use the mass of the atoms and the ratio of the atoms in the molecule using the following procedure:

chemical formula	mass of 1 molecule	% Na	% Bo	ratio of Na	ratio of Bo
$\text{Na}_2\text{Bo}$	$2 \times 10 + 10 = 30 \text{ g}$	$\frac{20}{30} = 66.7\%$	$\frac{10}{30} = 33.3\%$	$\frac{2}{1}$	$\frac{1}{1}$
$\text{Na}_3\text{Bo}$	$3 \times 10 + 10 = 40 \text{ g}$	$\frac{30}{40} = 75\%$	$\frac{10}{40} = 25\%$	$\frac{3}{1}$	$\frac{1}{1}$
$\text{Na}_2\text{Bo}_2$	$2 \times 10 + 2 \times 10 = 40 \text{ g}$	$\frac{20}{40} = 50\%$	$\frac{20}{40} = 50\%$	$\frac{2}{2}$	$\frac{2}{2}$
$\text{Na}_3\text{Bo}_2$	$3 \times 10 + 2 \times 10 = 50 \text{ g}$	$\frac{30}{50} = 60\%$	$\frac{20}{50} = 40\%$	$\frac{3}{2}$	$\frac{2}{2}$

**19.3**

**Investigation**

**19.3 Determining the empirical formula of your compounds**

As you have learned, elements can combine in many different whole number ratios to form different compounds. The simplest whole number ratio which elements combine in is known as the empirical formula. The empirical formula of a compound is the simplest whole number ratio of the atoms in the compound. For example,  $\text{C}_2\text{H}_4$  is the molecular formula for ethane. The empirical formula for ethane is  $\text{CH}_2$ . Determine the empirical formula for each of your compounds using the following activity.

Think the larger of the two values of Na and Bo to be the smaller one. And divide the smaller one by itself to get 1. The result will be the ratio of Na to Bo. What the empirical formula for each of your compounds in the table below. If you have an odd whole number, convert that to a whole number. For example,  $\text{Na}_2\text{Bo}_1.5$  would become  $\text{Na}_4\text{Bo}_3$ . Finally, write the empirical formula of the compound you made.

ratio of Na	ratio of Bo	empirical formula	molecular formula
2:1	1:1	$\text{Na}_2\text{Bo}$	$\text{Na}_2\text{Bo}$
3:1	1:1	$\text{Na}_3\text{Bo}$	$\text{Na}_3\text{Bo}$
2:2	2:2	$\text{Na}_2\text{Bo}_2$	$\text{Na}_2\text{Bo}_2$
3:2	2:2	$\text{Na}_3\text{Bo}_2$	$\text{Na}_3\text{Bo}_2$
3:1	1:1	$\text{Na}_3\text{Bo}$	$\text{Na}_3\text{Bo}$
2:1	1:1	$\text{Na}_2\text{Bo}$	$\text{Na}_2\text{Bo}$

**Challenge!**

What is the empirical formula of the compound in this box?

This molecule has a total mass of 119.4 g. The number of molecules of  $\text{Na}_2\text{Bo}$  and  $\text{Na}_3\text{Bo}_2$  in the box is 100. Find the empirical formula of the compound in the box.

mass of  $\text{Na}_2\text{Bo}$  =  $30 \text{ g}$   
 mass of  $\text{Na}_3\text{Bo}_2$  =  $50 \text{ g}$   
 mass of  $\text{Na}_2\text{Bo}$  =  $100 \times 30 \text{ g} = 3000 \text{ g}$   
 mass of  $\text{Na}_3\text{Bo}_2$  =  $100 \times 50 \text{ g} = 5000 \text{ g}$   
 mass of  $\text{Na}_2\text{Bo}$  and  $\text{Na}_3\text{Bo}_2$  =  $3000 \text{ g} + 5000 \text{ g} = 8000 \text{ g}$

**Investigation part number**

**Investigation part number**

**Data table and answers**

**Data table and answers**

**Answers to written and computational problems**

**Example Answers**

**1** The mass of the box with molecules is 109.2 g. The mass of the molecules is 109.2 g.  $109.2 \text{ g} = 109.2 \text{ g}$ . To find the empirical formula of the mystery compound, first find the ratios of Na and Bo:

Ratio of Na =  $\frac{30}{109.2} = \frac{30}{109.2} = 0.275$   
 mass of 1 Na = 10.0 g  
 Ratio of Bo =  $\frac{10}{109.2} = \frac{10}{109.2} = 0.091$   
 mass of 1 Bo = 10.0 g

Next, find the empirical formula by dividing the largest ratio by the smallest ratio and the smallest ratio by the smallest ratio:

ratio Na =  $\frac{0.275}{0.091} = 3$   
 ratio Bo =  $\frac{0.091}{0.091} = 1$

The empirical formula is  $\text{Na}_3\text{Bo}$ .

**2** To find out the number of molecules in the box:

number of molecules =  $\frac{\text{mass of molecules in box}}{\text{mass of 1 molecule}}$

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**Investigation 19.3 Comparing Molecules**

**Reinforcement & Enrichment**

**Air Pollutants**

There are two families of air pollutants that are byproducts of the combustion of fossil fuels.

$\text{NO}_x$  are the nitrogen oxides. These products are formed when nitrogen in the air (the air is 78% nitrogen) combines with oxygen due to the extreme amount of heat generated during the combustion of fossil fuels. These compounds react with water during combustion to form acid rain.

$\text{SO}_2$  are the sulfur dioxide. Sulfur is present in fossil fuels. When sulfur reacts with water, it forms sulfuric acid, another combustion product. Students will learn about acid rain in a later investigation. However, it is a good idea to introduce the compounds while students are learning how to name them.

**Plastics and chemical formulas**

Students read about plastics in 19.1 Bonding and Molecules. This would be a good point to reintroduce polymer and discuss them in terms of empirical and molecular formulas. The basic building block of plastics is ethylene,  $\text{C}_2\text{H}_4$ . Plastics are polyethylenes, with a formula of  $(\text{C}_2\text{H}_4)_n$ .

**Teaching tips**

**Title of the Investigation procedure**

**Number and Investigation title**

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## Safety

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Safety is highlighted throughout the CPO Science Program by the use of safety icons and safety tips in the Investigations. The Investigations activities and experiments have been written to reduce safety concerns in the laboratory. The equipment that is used for physics is very stable and easy to use and manage. All the chemistry Investigations use supplies and chemicals that can be purchased readily in a grocery or hardware store. Although this does not mean that these supplies are non-toxic, you will be able to dispose easily of most of these chemicals. In cases where you are concerned about safety and proper use or disposal, we strongly recommend that you obtain the Materials Safety Data Sheets (MSDS) for the chemicals. These are easily obtained by calling the manufacturer of the product.

The CPO Science Program introduces students to safety through an information Safety Skill Sheet. In addition to this sheet, we have provided a quiz as an evaluation tool to be administered to the students after you have covered safety in the laboratory. We recommend devoting an entire lesson to safety in the classroom and laboratory and responsibilities for maintaining a safe environment. Use the Safety Skill Sheet as a guide for your lesson and fill in any information and guidelines that are particular to your classroom and school. In the skill sheet section of this book you will find a student safety contact. Safety is such a crucial concern when working in a laboratory environment that having students sign a contract may emphasize that safety in the science lab is everyone's responsibility.

## Units and Measurement

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The CPO Science Program was designed to prepare students to be successful in any career, not just academia. Students need to be fluent with scientific skills in any system of units prevalent in the workplace. Virtually all engineering and industrial careers require proficiency in both English and metric units. Even metric measures are not standardized. Research scientists use two varieties of metric: meter-kilogram-second (MKS) for physics and centimeter-gram-second (CGS) for chemistry. Ocean and air transportation industries use nautical miles. Medicine uses both Fahrenheit and Celsius temperature scales. Astronomers use light-years. The message to take from this diversity is that students need to learn and practice science in several systems of units because they will encounter different systems outside the classroom.

You will find that the text, examples, and questions gradually transition from mixed English/metric to all metric by the end of Unit 2. Because of their extensive practical use, the Student Edition and Investigations include both English and metric (MKS) units in Unit 1 (Force and Motion). This was done to connect the student's common experience and also to provide a bridge between the systems. For subsequent units, almost all concepts are presented in metric units, with an occasional reference to other systems when appropriate. All of the assessments use only metric units, which is common practice for standardized tests. The chemistry units (6-8) switch from MKS to CGS to mirror research, medical, and industrial chemistry, which is measured predominantly in grams and milliliters instead of kilograms and cubic meters. It is our opinion that a basic high school science education should be focused on developing practical quantitative reasoning, problem solving, and observational skills. By presenting a mixture of units as they occur in the real world, we help prepare students for success in any endeavor that requires scientific thinking, such as business, industry, or education, as well as for further study in science.