FOSS ® CHEMICAL INTERACTIONS
TEACHER PREPARATION VIDEO TRANSCRIPT

<An Introduction to FOSS Middle School>
Larry Malone: Hi I'm Larry Malone.

Linda De Lucchi: And I'm Linda De Lucchi.

Larry: We're the co-directors of the Full Option Science System or simply FOSS.

Linda: The FOSS Middle School Program developed at the Lawrence Hall of Science with funding from the National Science Foundation includes 9 courses for grades 6 through 8. The courses are organized into 3 strands: Earth and Space Science, Life Science, and Physical Science and Technology.

Larry: Each course includes 8 to10 sequential investigations and lasts 9 to 12 weeks. The 9 courses can form a complete 3 year science curriculum. Three topics to a year or individual 9 to 12 week courses can be integrated into an existing program.

Linda: With FOSS, students learn science by doing science. They develop deep durable understanding of science concepts and principles through authentic investigations, analysis, and reflection.

Larry: The FOSS middle school activities are informed by cognitive research about how adolescents think and learn and field tested in middle school classes around the country. The result is a program that reliably teaches important science content and critical scientific thinking processes such as logical analysis and database decision making.

Linda: Students engage the FOSS course content in 4 ways: active investigation, reading, multimedia, and assessment. These 4 learning modalities are seamlessly integrated to maximize every student's opportunity to learn. Experiences in the 4 learning modalities build on and reinforce one another resulting in comprehensive understanding of science concepts.

Larry: Students in FOSS middle school classrooms are engaged and thoughtful. They love to study science in collaborative learning groups with their peers using real scientific equipment. And FOSS makes science fun for you too. It's easy to maintain interest and motivate learning with FOSS. Welcome to the FOSS family. You and your students are about to embark on a wonderful science learning adventure.

<Assessment>
Linda: The FOSS Middle School Assessment materials are designed to be used throughout the course. They can be used to monitor progress during the investigations and as evaluation tools at the end of the course. There are three overarching goals for the program: Science Content, Conducting Investigations, and Building Explanations.

On the first page of each investigation, these goals are listed with the objectives for each. Science Content is the facts and concepts of science that students learn throughout the course. Conducting Investigations includes designing experiments and the skills needed for successfully engaging in scientific inquiry. Building Explanations includes the discussion students have, their ability to articulate concepts developed during the investigations, and to use evidence to support ideas and conclusions.

Unlike many curriculums that treat assessment as a separate component only related to giving grades, FOSS Assessments are integrated into the instruction throughout the course. Assessment activities in FOSS provide teachers with immediate feedback about student understanding and give students the opportunity to reflect on their own learning.

In each investigation you'll find suggestions for Embedded Assessments in the Getting Ready section as well as in the Conducting the Investigation section.

There are two kinds of Assessments in the FOSS curriculum: Formative and Summative Assessment. Read through the Overview and Assessment chapters of your teacher guide for complete information about the two types of FOSS Assessment. There are scoring guides for both Formative and Summative Assessments in the Teacher Answer Masters and Assessment chapters of your teacher guide.

Formative Assessments are embedded throughout the course to provide diagnostic information. This information will help you make decisions about instruction for individual students and for the class. In general, FOSS suggests that these Formative Assessments not be graded. Although you might score them with a check, plus, or minus to keep a record of student's progress.

Formative Assessment Strategies include: informal notes, teacher observation, student sheets, quick writes, response sheets, self assessments, and group projects. Additional information about using each of the Formative Assessment Strategies can be found in the Assessment chapter of your Teacher Guide.

It's important to remember that all Formative Assessments are intended to give you greater insight into student's thinking and guide your instructional decisions. Formative Assessment is an important part of each day's lesson. It may be a look at a notebook sheet or a response sheet to look for content understanding, or an observation in which you look over student's shoulder to see if they're developing inquiry skills. In any case, Embedded Assessment is integrated into instruction so your students may not even realize that assessment is part of the activity.

FOSS provides a Mid-Summative Exam for most investigations and a Final Exam for the course. The Mid-summative exams are short tests presented in a number of formats including: multiple choice, short answer, and narrative questions. The Mid-summative Exams serve as checkpoints for student learning. Even though these are considered Summative Assessments they can be used formatively.

If you notice particular areas where students seem to have developed a misunderstanding you can make a note to yourself and come back to that idea during the next investigation. Remember to give students an opportunity to gather and process the information from the course before you have them take the Mid-summative Exams.

Understanding the big ideas of science requires that students construct relationships among many different pieces of evidence. It's important that students have time to build these higher levels of understanding before they are assessed. A final exam for the course is included it can also be used as a pretest or survey before students begin the course.

<Course Introduction>
Narrator/Ann Moriarty: Hello my name is Ann Moriarty. In this video we will lead you through the investigations in the FOSS Chemical Interactions middle school course.

This video is not a replacement for the teacher guide, so you want to make sure that you do spend time going through the teacher guide for all the details and the specifics of the course.

This course explores the amazing incredible, absolutely astounding world of chemistry. Students come face to face with the nature of matter and the energy dynamics that go along with matter transformations.

They learn about elements and the periodic table. They interact with the concept that all matter is made of particles that are later defined as atoms and their various combinations. This 12-week course comes in four boxes, with enough consumable equipment for five classes of 32 students each.

In addition to the boxes of equipment, the course comes with a detailed Teacher Guide, a lab notebook containing the student sheets and organizers for students to use while they engage in the investigations, 32 Resources books containing data and readings that are used throughout the course, and 5 CD-ROMs for use as a whole-class demonstration tool as well as an individual or small-group interactive instructional tool.

Both the lab notebook masters and the multimedia are also available online at FOSSweb.com. Before you start, check with your district regarding safety contracts, goggles and any other safety guidelines that may already be in place. For more information, check the Safety section of this video and the Overview chapter of the teacher guide.

<Teacher Guide Overview>
Narrator: The teacher guide is the heart and soul of the curriculum, so let's take a little time and look through it.

You'll notice that the guide is subdivided into tabbed chapters: Overview, Materials, Investigation Chapters, Transparency Masters, Special Teacher Masters, Teacher Answer Masters, Assessment, Assessment Masters, Multimedia User Guide, and References. See page 20 for more info on how to use the teacher guide.

Be sure to read the Overview chapter before you begin teaching the module. It contains many helpful suggestions for getting started. In it you will find:

- The National Science Education Standards that are addressed in this course
- A complete description of the Program Components
- Chemical Interactions in Context
- Why Study Chemical Interactions?
- Can I teach this? I'm not a Chemist
- Using FOSS Technology. Note the symbol in the right hand margin. You will see these same symbols in the Investigation chapters of the Teacher Guide. Look for other symbols in the margins.
- Instructional Methods for All Students

- Assessing Progress
- Reading and Writing in Science
- Encouraging Discourse
- Management Strategies, and
- Safety in the classroom. Notice the safety symbol in the margin. As I discuss each investigation, I'll point out specific safety issues you should consider.

You can download the Materials Safety Data Sheets by looking under the Course Notes section of the Chemical Interactions course at FOSSweb.

The Course Matrix gives a quick overview of the course, including a synopsis of each investigation, how many class sessions it will take to complete the investigation, the science concepts, thinking processes, the media used in that investigation, and readings from the student resources book.

In the Materials chapter there's an inventory of the equipment provided in the kit and directions for its preparation and maintenance.

An inventory sheet is also enclosed in drawer one of the kit, and each drawer has an inventory list on the outside of the drawer, listing the equipment contained.

Starred items indicate consumable items. You can order replacement parts for all FOSS modules and courses at the Delta Education website, or by calling this number, 800-258-1302.

Some items for this course need to be supplied by the teacher. Most of these are common items found in science classrooms. You should look over this list before beginning to teach the course to identify items that might need to be collected or ordered.

For example, you will need to collect consumer product labels for Investigation 2 and 500 mL plastic water bottles for Investigation 3.

The Preparation section provides guidance for preparing a new kit, which is done only once by the first user, preparation tasks that will need to be done each time that the kit is used, reminders for when to reserve computer time, and how to best organize the materials for sequential classes.

The next section addresses safety issues in Chemical Interactions. Be sure to read through this section carefully as there is information about each investigation. Look at the Safety Section of this video for detailed information.

Next come the Investigation chapters that are the heart of the course. These will be described in detail in this video. The first page of each chapter lists the Goals and Objectives for each Investigation.

The At a Glance chart summarizes the Investigation and helps you plan for assessing, preparing, and executing each part of the investigation.

Next you'll find background information specific to the investigation, including a section explaining why this investigation is important for middle school students. Common student misconceptions are listed in this section.

Each Investigation has several parts. For each part you'll find a Materials List, a Getting Ready section, and step by step directions for conducting the activity with your students.

After the investigation chapters, you will find the Transparency Masters. The actual transparencies are in drawer one of the kit, but the masters are provided in case you need to replace one.

The Special Teacher Masters chapter contains an atom-tile inventory and sample safety contract. The Teacher Answer Masters chapter has answers for most of the student lab notebook sheets.

There are many ways to assess your students' learning as they progress through the course. Read through the Assessment chapter for more information about formative and summative assessment. This chapter contains the scoring rubrics for formative assessments, and scoring guides for the summative assessments. These will assist you in evaluating student progress throughout the course.

After the assessment chapter, you'll find the Assessment Masters. Assessment charts can be used to record individual student progress. These are followed by masters for the summative exams for each Investigation and a final exam for the entire course.

Another helpful chapter is the Multimedia User Guide. The multimedia is an integral part of the course. Students can use it to interact with simulations, images, and text that can enhance their understanding of concepts.

System requirements, program basics, and specific navigation tips are included. The References chapter has an annotated list of print and web-based materials for both the teacher and student.

<Multimedia Overview>
Narrator: The multimedia is an essential part of every FOSS middle school course. It is not optional. Give your students time to interact with the various simulations, images and text. This gives them the opportunity to further develop their understanding of the concepts in each course.

Five identical CD-ROMS come with each kit and you can also access the multimedia online at www.fossweb.com. To use the multimedia online, you can get a username and password which you can share with your students.

Go to the multimedia chapter of the teacher guide to view the necessary system requirements for Macs and PCs.

The browsers that are compatible with the FOSS multimedia are listed in this chapter. In the same spot you can find which plug-ins are needed to run the simulations. Technical troubleshooting suggestions and ideas for getting the best view of the multimedia in a classroom setting are included.

Before using the multimedia with your students, make sure that you have prepared your computers. Dedicate some time to cruising around the different components so that you are comfortable.

The multimedia in each course has a unique welcome screen, also called the main menu. Follow the basic instructions in the multimedia chapter of the teacher guide to access the program. Here are a few hints: if you click on the button, “Enter the Program” you have access to all of the simulations and activities. Click on a title to go to a specific activity. From here you can also access the teacher guide resources by clicking the title.

From the welcome screen you could also choose to “Enter the Teacher Guide.” Here you will find a convenient way to access the multimedia in each investigation. Click on an investigation title. Once you are in an investigation, you can access the PDFs of the lab notebook sheets and transparencies. If an investigation part has any simulations or activities, they will be listed and you can click on them to go directly there. On the bottom of the screen you can return to the investigation list. Your last choice from the Welcome Screen is a link to check your browser. This makes sure that your web browser is properly configured to run the program.

Here is how you access the multimedia and other resources using FOSSweb.com. From the front page, click on the Middle School Button and then choose your course. Click on it and you are given several options.

On the top left, you can click on the Multimedia button and go to the Welcome Screen as described earlier. Other options for students include: updated websites, books, and a glossary.

For parents and teachers, you will find: a summary of the course, information on plant and animal care, when appropriate, a link to the PDF duplication masters for the lab notebook, a list of references, and course notes—with important information about corrections, ordering, and the link to the material safety data sheets.

Accessing the lab notebook file takes a separate password from the one you give the students to access the multimedia. This user name and password should not be given to students.

In the teacher guide, more details about each multimedia option are given in the Investigation chapters. Look for the CD-ROM icon in the margin.

<Safety Considerations>
Narrator: During Chemical Interactions, it is important that you and your students practice lab safety. Before you start, check with your district to see if there are specific lab contracts or considerations that you will want to go over with your students.

Use the Chemical Interactions Safety contract found in the Teacher Master Chapter of your teacher guide with your students if your district does not have a standard contract.

Refer to the overview chapter, and the materials chapter of your teacher guide for complete safety information. In addition, each investigation has safety reminders in the Getting Ready section, and in the Conducting sections.

Look for this safety icon throughout the teacher guide. There is a safety poster in your kit. Put it up in your classroom. Be sure to go over the rules on the poster.

The FOSSweb.com website has copies of the Materials Safety Data sheets for each substance used during the course. You can print these out to keep in a binder in your classroom for easy reference.

You will see a warning label on a number of lab notebook sheets. The label is required by the United States Consumer Product Safety Commission whenever students work with chemicals or hazardous materials. The labels should act as a reminder to you and students to exercise particular safety precautions when working with materials in the investigations where the sheets are used.

Students should wear goggles anytime there is a risk of something getting in their eye and any time you instruct them to wear them.

In Investigation 7, students use m and m's to explore melting and dissolving. Be sure to remind students never to eat anything during science class.

In addition, students use a candle flame to melt wax and sugar. Be sure that students have removed all flammable materials from their desks and that they are wearing goggles. Long hair should be tied back. Be aware that when students melt the wax, if it continues heating, the gases released can flash. Tell students simply to drop the spoon until the flame goes out.

In several investigations, students will use hot water. Tell them to be very careful. Students should always behave responsibly during science investigations.

Remember; always refer to your teacher guide for important safety information. Be sure you look ahead for any safety information before you begin an Investigation.

<Investigation 1, Introduction>
Narrator: Investigation 1 is a hook to catch students' interest and introduce them to the world of substances and chemistry. They are confronted with a mystery mixture which is made of two unknown white substances. Their job is to figure out what they are. They do this by investigating known white substances and comparing those to the ones in the mystery mixture.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about substances, particles, molecules and atoms, and chemical reactions.

The Why Do I Have to Learn This? section reminds us of students' beliefs about the study of chemistry and how we can work to generate a whole new vision of chemical interactions.

<Investigation 1, Part 1>
Narrator: In this part, students examine a mystery mixture of two white, solid substances. They add water and observe what happens.

This is what you need from the kit: for each group of four students, you need 1 cup, 2 hand lenses, a cup with a small amount of water, and 2 pipettes. You may also want to provide a craft stick from the kit for stirring.

For the class you will need the safety poster, citric acid, and sodium bicarbonate to make the mystery mixture, 1 yellow 25-mL spoon, 1 blue 5-mL spoon, 1 stirring stick, self-stick notes, and one ½ liter container and its lid.

You will need to supply dark-colored paper, a pitcher for water, paper towels, goggles, and an overhead projector and pens.

Make copies of the special teacher master "Chemical Interactions Safety Contract" to use if your district does not have its own. The Chemical Interactions Resources book has a list of safe lab practices to discuss with your students. Also, check out the Safety Section of this video for more information.

Make copies of Lab notebook page 5, Mystery Mixture for each student.

Find transparency no. 1, Mystery Mixture. All of the transparencies for the course are in a white envelope at the very bottom of drawer one. PDFs of all transparencies are also located on FOSSweb. Please see the Multimedia Section of this video for more information on how to access them.

The assessment chart can be found in the assessment master chapter of the Teacher Guide. Make one copy for each class. Please see the assessment section of this video for more information on using these charts in your classroom.

Before you get ready for Part 1, look ahead to Part 2 and start preparing the vials and white substances. This may take you awhile! To make a supply of mystery mixture for one class, first put some baking soda into a jar. Use the yellow 25 mL scoop to measure the baking soda into a ½ liter container, and then take 25 mL of citric acid which you can also pour into a jar and put it in the container. Stir it up with the stirring stick, label it "Mystery Mixture," and snap a lid on. You need about 50 mL of the mystery mixture for each class. Multiply the recipe by the number of classes you teach. The mixture tends to clump, so make only enough for one day.

Do not let students see the stock containers of citric acid and sodium bicarbonate!

Decide if you are going to use the provided lab sheet – Mystery Mixture, or if you want students to use a more open form of recording by using a blank piece of paper or a blank page in their science notebooks.

If you are using the assessment charts, have them ready on a clipboard. The charts might be easier to use if you list students' names by group rather than in alphabetical order.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide!

Introduce students to the course and tell them that over the next few weeks they will be investigating the composition, properties, and interactions of substances. This is the study of CHEMISTRY!

Stress to students that they must follow the safety guidelines that you establish with them according to your district guidelines. Use the safe lab practices page of the Resources book as support if needed.

Show students the container of mystery mixture. Tell them that you were given this mixture and you don't know what it is, only that it is a safe mixture of two substances. How can they figure out what those substances are? Ask for student ideas.

The idea of observing the mystery mixture more closely is a good one. Scientists rely on making careful precise observations.

Getters from each group go to the Materials Station, label a cup and measure one level 5 mL spoon of the mixture into it.

Another student can get two hand lenses, darkly colored paper for contrast, and goggles for their group.

Pour some of the mixture onto the paper to look at more closely.

One hint about using the hand lens is to tell students to bring it up to their eyes like a jeweler's loupe and then bring the substance up until it is in focus.

Remind students that though the substances are safe, they are not to taste or touch with their hands.

After a few minutes of free observation, students record what they notice on part one of lab notebook sheet 5. Encourage them to share observations between groups and then share out as a class.

Many times students suggest adding water to the Mystery mixture to see if that will help them identify the substances. Do so now. Project transparency no. 1, Mystery Mixture and go over the procedure in Part 2.

Show them how to use a pipette: Squeeze the pipette, put the tip in liquid, and release the bulb to draw liquid up. This is "one pipette" of liquid. Students add one pipette of water to the mystery mixture. Tell them not to stir with the pipette; instead, they can use a craft stick. Remind them to make and record precise observations.

Students keep adding pipettes of water until there is no more fizzing. Once students have completed their observations, discuss what happened as they added pipettes of water. Did the mixture keep fizzing?

Clean up by returning the materials to the materials station. The mixture is safe to dump down the sink or into a tub.

<Investigation 1, Part 2>
Narrator: In Part 2, students investigate nine white solid substances trying to figure out which 2 are part of the mystery mixture. They conduct mini tests using a well tray, dropper, and the substances to see what makes up the mystery mixture.

This is what you will need from the kit: for each group of four students, you will need a FOSS vial holder, one set of nine substances in vials, 1 vial of the mystery mixture, and 10 green minispoons, one in each vial.

You also need 2 well trays, 2 dropper bottles of water, a one-liter waste container, 2 hand lenses and labels for the dropper bottles.

If you choose to do the large scale reaction, you also need 3 white 2-mL spoons, 3 cups, 1 pipette, 3 self-stick notes, water, scratch paper and dark paper for each group.

You also need to get out the sodium bicarbonate, the sodium carbonate, the citric acid, the jars, and adhesive labels.

For the class, open the drawer that has the substances in it and pull out these substances. You need to provide sucrose. To help prepare the vials and dropper bottles, get out a 35-mL syringe, a blue 5-mL scoop, and a funnel stand.

You will need to provide paper towels, goggles, and an overhead projector and pens.

Students will need the Chemical Interactions Resources books and Lab notebook page numbers 1, Chemistry Glossary, 7, White substance information, 9, Mystery-Mixture Analysis and 11 Mystery-Mixture Summary.

Get out the transparencies no. 2, Substance Labels and no. 3, Two-Substance Reactions.

You will also need to prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

Finally, get out the Assessment chart to make informal notes on students' lab practice.

To prepare the water dropper bottles, remove the screw cap, and pop off the dropper tip. Use a syringe and pull in 15-20 mL of water. Put that into the bottle. Pop the top back on, screw the cap on and apply the water label. If you can't get the tip on, just screw on the cap and it will pop in.

Each group will share a set of 10 substance vials. Nine vials will have different pure white substances and the 10^{th} will be a sample of the mystery mixture. The vials will be placed in a vial holder and used throughout the day.

To fill the vials, it is easiest to group all vials for one substance together and get out the supply of that particular substance. The vials are silk screened with a substance label and a matching cap is labeled with only the chemical formula of that substance.

To fill the vials, put a Vial under a dry funnel. Take a 5-mL scoop of your substance. Put it into the funnel. Add a green minispoon and cap the vial with the matching cap. Do the same for all the vials of the same substance.

Here’s a hint. Prepare the calcium carbonate vials last. The calcium carbonate sticks to the sides of the funnel and to the scoop. This makes them difficult to clean.

Next, make a fresh supply of the mystery mixture as you did for Part 1. Transfer a 5-mL scoopful into a vial labeled “Mystery Mixture” for each group.

Snap a vial of each substance into place. Put two dropper bottles in and you’re ready to go.

If you decide to do the large-scale reaction, transfer sodium bicarbonate, sodium carbonate, and citric acid to labeled 250-mL jars. Put a white 2-mL white spoon with each substance. If you choose to have groups do this, make sure that there are jars of each substance for each group.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide. Start Part 2 off by reviewing with students their observations of the mystery mixture from the previous class.

Introduce the white substances in their vials. Tell students that a substance is a form of matter and each pure substance is different from every other substance. First what they are going to do is observe the properties of each white substance.

There are three kinds of information on the vials. Project transparency no. 2, Substance Labels, and explain. The first entry is the substance’s chemical name. This substance is called calcium carbonate. The second entry is in parentheses. This is the common name of the substance. The common name for calcium carbonate is chalk. The third entry is the chemical formula for the substance, a kind of code name that describes what the substance is made of. They will learn more about chemical formulas later. Tell students that they may remove the vials from the vial holder to examine the contents more closely, but they may not open the vials.

Students use lab notebook sheet no. 7, *White Substance Information* to record information about the substances.

Information about the common uses of the different white substances can be found in the Resources Book.

After the students have completed the notebook sheets, discuss their observations and the various uses of the substances. Think about the question at the bottom. Have they noticed any patterns? For instance, any chemical name that includes “carbonate” has CO3 in its code.

This is a good time for a break.

Ask students if they have any idea what 2 substances might make up the mystery mixture. What could they do to get more information? Most students will suggest adding water as they did to the mystery mixture in the cup. Give groups a few minutes to develop their plans. Record possible steps on the board, something like: Mix two substances and add water, watch what happens, compare to the mystery mixture, and try other combinations.

Each pair of students will use a well tray. The well tray is numbered, 1,2,3,4 all the way to 12. The mystery mixtures goes in depression 1 and then they try different rxn.s For example, they might take sodium carbonate, put in one level green minispoon. Make sure they put the spoon back into the correct vial. Students should not mix them up. They might then choose ascorbic acid, put in a level spoonful. Then add 10 drops of water.

Students record their observations on lab notebook page no. 9, Mystery-Mixture Analysis. Everyone should start with two spoonfuls of mystery mixture and 10 drops of water in well no. 1.

Make sure that students wear goggles. Once they have their materials, let the testing begin. Make sure they record their observations! Depending upon how quickly your students work, this process may take several class periods. If students use all the wells in their tray, they need to clean it out before continuing. If students announce that they have "solved the mystery," do not confirm or refute their conclusions. You might want to tell them confidentially that there may be many more combinations that produce fizzing and bubbling. Encourage them to find them all to compare to the mystery mixture.

Instead of using a faucet to clean out the well trays, dump the liquid out into a sink or a tub, rinse the tray, and wipe out the wells with a piece of wet paper towel. Make sure they are clean and dry for the next class!

Have students make sure that all of the minispoons are in the proper vials, the vials are snapped into place and the caps are screwed on tightly. Don't forget to check the tops of the dropper bottles.

This is a good place for a break.

Ask students which two substances they now think make up the mystery mixture. Ask them for their evidence. List on the board all reported combinations of substances that produced bubbles. Your class list may look something like this.

Introduce students to the idea of a chemical reaction by asking them first to consider the bubbles produced when water was added to the mystery mixture. Ask them if the gas was always there or if it formed when water was added. Where did the gas come from?

Tell students that the gas formed as a result of a chemical reaction. Give them the information that during a reaction, starting substances change into new substances. Ask them if the two substances in the mystery mixture reacted when water was added. Again, ask them for their evidence.

Ask what other changes might be indicators of a chemical reaction.

If students mention a simple change from solid to liquid like ice melting, ask them if liquid water and solid water are both water. Don't spend too much time here, but confirm that phase change is not evidence of a chemical reaction.

Project transparency no. 3, Two-substance Reactions, a complete list of seven combinations of the white substances that react.

Students will use lab notebook sheet no. 11, Mystery-Mixture Summary, to test each of these combinations in the well tray to confirm which combination is the mystery mixture. Make sure they do each reaction in the corresponding well number.

Students will most likely narrow their possibilities to well nos. 2, 6 and 7. To compare the results, they can find out what happens if they leave the trays out to evaporate the liquid out of the wells. Please note that only your first period class will provide evaporation results for all of your classes because you do not have enough trays. All other classes will wash and dry their well trays as before.

This is a good time to break so that the liquid in the trays has time to evaporate. This should take no longer than a day.

When the well trays are ready, have students observe the residues. They should look but not touch as students in other classes will be looking at them too. Instruct students to compare the residues to that left in well no. 8, which was used to evaporate the mystery mixture.

Students eliminate ascorbic acid because its residue is orange.

After observing, students write which substances they now think make up the mystery mixture.

At this time, introduce the multimedia program. Go through the main entrance page to the Two-substance reaction multimedia and have students choose which combinations to compare. They may want to do more combinations just to see them.

You may also choose to use the version of the reaction multimedia that is accessible only through the teacher guide, Investigation 1, Part 2. This is a modified, quicker version of the same media.

Save the well trays for use by the next class.

After the last class has viewed the evaporation results, the well trays can be cleaned. You may want to soak them first.

If there is still disagreement about the players in the mystery mixture, students can conduct the optional large-scale reaction as described in the teacher guide.

You have your choice here—you can either reveal that the substances in the mystery mixture are citric acid and sodium bicarbonate or you can continue to refer the students back to their evidence.

Make glossary entries. Summarize the big ideas from Investigation 1.

<Investigation 2, Introduction>
Narrator: Investigation 2 introduces students to the world of elements. They investigate the names and symbols of the 90 naturally occurring elements by looking at the periodic table of the elements. Then, they go ahead and look at the lists on consumer product labels.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about elements, the history of our understanding of them, and the development of the periodic table of the elements.

The Why Do I Have to Learn This? section reminds us of students' common misconceptions elements. We want them to come away with the understanding that elements make up all matter in the universe.

<Investigation 2, Part 1>
Narrator: In this part, students identify the elements in the substances they used in Investigation 1, learn what elements are, and use the periodic table of the elements as a tool.

This is what you need from the kit: for the class you will need the poster called Periodic Table of the Elements. Students need their resources books and you need to make copies of Lab notebook sheets 13, Mystery-Mixture Elements and 15, Elements Questions for each student.

Prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

The Investigation 2 assessment chart can be found in the assessment master chapter of the Teacher Guide. Make one copy for each class.

Find a spot in your room to post the periodic table poster. Preview the multimedia Periodic Table of Elements. Make sure you can identify all of the features. Click on an element to view basic information. Click on the basic information box to see more extensive information. In the upper right hand corner of the Periodic Table, click on the "Find an Element" function to see an alphabetical list of all the elements. Click on the yellow arrow by the Lanthanides to insert them into the table. Familiarize yourself with the property groupings, top ten displays including the pie charts, the dates of discovery, and standard state data.

Start collecting consumer product labels and packages for students to analyze in Part 2. You will need at least one per student. Ask students to collect empty packages or labels to add to a class set. You can also collect packages and labels yourself.

If you are using the assessment charts, have them ready on a clipboard.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Point out the poster of the periodic table on the wall and ask students to turn to the periodic table in their Resource books. Tell them that the periodic table is a display of fundamental or basic substances called elements. Ask them how many names of the elements they recognize and call on them until all familiar elements have been shared. This may go on for a while but is a fun exercise.

Tell them a bit more: elements are the basic building materials of matter. Everything on Earth that has mass and occupies space is made of combinations of these elements. All substances are made of elements. Point out that each element has a name and is represented by a symbol.

Introduce lab notebook sheet no. 13, *Mystery-Mixture Elements* that lists the substances from Investigation 1. Ask students to use their periodic tables to identify and record the elements found in each substance in the right-hand column. They should also answer the questions at the bottom of the sheet.

When students are done, ask them to discuss their answers in their groups and then report out in class.

Use the multimedia to continue exploring elements. Use Iron (element no. 26) as an example and follow the guide on this page of the teacher guide to identify metals and other groups. Show students the various information available in the multimedia periodic table. If you have access to multiple computers, give students time to investigate on their own.

Assign the article *Elements* in the Resources Book. Use lab notebook sheet no. 15, Elements Questions, to analyze the reading.

Don't forget to remind students to bring in labels or empty packages from home!

<Investigation 2, Part 2>
Narrator: In Part 2, students study the lists of ingredients in consumer products to discover what elements are present. The class then takes this information, posts it on the Periodic Table Poster using self-stick notes and analyzes what they have found.

This is what you need from the kit: for the class, you need the poster, Periodic Table of the Elements, and the small self-stick notes. You may choose to have the large 3 × 3 self-stick notes available for an optional activity.

You need to provide marking pens, colored pens or pencils and for the extension, scissors, tape, and scratch paper. You'll also need chart paper if you decide to do the extension.

Make sure you have your supply of product labels ready. Don't forget you might need to provide some yourself!

Students need their resources books and you need to make copies of Lab notebook sheets nos. 16, Elements in Products, 17, Periodic Table and 21, Elements in the Universe Questions.

Prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

Get out the Assessment chart to make informal notes on students' work. And finally, make copies of Lab notebook sheet number 19, *Response Sheet – Elements* and *Mid-summative Exam 1-2* to use as assessment.

Preview the element identification games on the multimedia periodic table. There are 2 games. Game 1 provides the element's name and students click on the correct location on the periodic table.

Game 2 focuses on information about specific elements. Students locate an element based on hints. The Periodic Table in the background can be used as a resource.

The games are most effective when students have extended time to work in pairs. If possible, arrange to use a computer lab or multiple computers.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Show students a consumer product label. Remind them that all matter is made of elements and that some of those elements might be found on that ingredients list. These elements might be listed by their name or by their symbol.

Challenge students to work with a partner and find out how many different elements they can identify in products. They should record the name of the product and the list of elements on lab notebook sheet, no. 16.

They may know what elements are in certain substances, like carbon, hydrogen, and oxygen in sugar.

Students can use the multimedia Periodic Table to help them tell if certain ingredients are elements. For instance, they can use the alphabetical listing of elements to look for "carbohydrate."

This page of teacher guide will give you suggestions on how to use the periodic table poster to tally and record the elements students discovered. The poster will end up covered with self-stick notes.

Pass out lab notebook sheet no. 17, *Periodic Table*. Students can mark the elements the class found by using a colored pen or pencil to put a dot next to those element numbers.

Encourage students to keep looking for additional elements at home, bringing their findings in to add to the class list.

To prepare for the next class, remove the element tags and stick them to a sheet of chart paper in order by number.

Students now consider lab notebook sheet no. 19, *Response Sheet—Elements*. They should work on their own and you can use this as assessment.

This is a good time for a break.

The next day, review the element search and challenge students to use the multimedia Periodic Table to find out which elements are most abundant, by mass, in the universe, in stars, on Earth, in the ocean, in the air, and in humans.

Assign the article *Elements in the Universe*, in the Resources book. Students use lab notebook sheet no. 21, *Elements in the UniverseQquestions* to think about the reading.

Give students time to play the element identification games on the multimedia Periodic Table

Summarize the big ideas of Investigation 2 with students.

When they are ready, give them the *Mid-summative 1–2 Exam*.

Take a look at the Extension idea on this page of the teacher guide. You can engage students further, challenging them to find uses of many of the elements and building your own class periodic table.

<Investigation 3, Introduction>
Narrator: In Investigation 3, students investigate the properties of gas and develop a particulate model to explain the behaviors that they observe.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages and The Why Do I Have to Learn This? section for information about gases, representing gas particles, how to develop this very abstract understanding in students, and what notions students bring to the table.

<Investigation 3, Part 1>
Narrator: In this part, students observe a balloon filling with the gaseous product of the citric acid and sodium bicarbonate reaction. They then undertake to measure more precisely how much gas is produced from a measured amount of reactants.

This is what you need from the kit: for each group of four students, you need 1 jar each of citric acid and sodium bicarbonate, two white 2-mL spoons, one ½ liter container of water, one 1-liter container for waste, 1 cup, a small self-stick note, a stirring stick, two glass, 8-dram bottles, two #1 1-hole stoppers, and two 35-mL syringes. You may want to use the plastic trays to organize materials for each group. They are provided in the kit. Use them throughout the course when appropriate and convenient.

For the class you need 1 plastic 120-mL bottle, 2 blue 5-mL spoons, 3 cups, 1 35-mL syringe, 1 jar of citric acid, 1 jar of sodium bicarbonate, 1 #3 2-hole stopper, 1 balloon, 1 container for water and one for waste, and 1 plastic tray.

You need to provide ¼ sheets of plain paper, goggles, an overhead projector, and overhead markers.

Make copies of Lab notebook sheets 22 and 23, *How Much Gas? A and B* for each student.

The Investigation 3 assessment chart can be found in the assessment master chapter of the Teacher Guide. Make one copy for each class.

Gather the materials and get ready for the demonstration at the beginning of this part, a review of the citric acid, sodium bicarbonate reaction from Investigation 1. Read the steps on this page of the teacher guide for more help.

If you did not prepare the plastic 250-mL jars of citric acid and sodium bicarbonate for Investigation 1, do so now. See the teacher guide for instructions.

Each group will make a funnel to transfer baking soda to the glass bottle. Practice making one. Take the ¼ sheet of paper, fold it into quarters, get a couple pieces of tape. Open it up and put one piece of tape here and the other down at the bottom so that it opens up like this. Take the bottom and snip. This fits into the top of the glass bottle.

Get the materials ready for the balloon demonstration. Stretch the balloon over the top of the stopper.

If you are using the assessment charts, have them ready on a clipboard.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide! As a review, put one 2-mL spoon of sodium bicarbonate into an empty cup. Ask students what might happen if you add water. They may say bubbles will form, but hopefully, most will say that no reaction will occur. Pull up 10 mL of water and add it to the cup. No bubbles! How disappointing!

Repeat this with citric acid. Ask what might happen if you put a scoop of citric acid in a cup and add water. Pull up 10 mL of water and add it to the cup! No bubbles—oh well. Now ask what will happen if you pour the mixture of citric acid and water into the cup with the mixture of sodium bicarbonate and water. Big fizz—we had our reaction! Ask where the gas went and ask for ideas about how they could capture the gas to figure out how much was formed.

Bring out your bottle-and-balloon system. Tell students what you are doing as you go through the steps. Put one spoonful of citric acid in a cup. Add about 10 mL of water. Dissolve the citric acid. Pour this mixture into the bottle. Get one spoonful of sodium bicarbonate. Be ready to put on your stopper and balloon as soon as you add the sodium bicarbonate. The balloon traps the gas. Ask students how this system adds to their knowledge of the gas and what its limitations are.

Ask them how you could find out exactly how much gas is formed and then pass out lab notebook sheet no. 22, *How Much Gas, A*. Read through the procedure and then give them a few details.

First, define what a stock solution is. Tell students to be very precise in making their citric acid stock solution. Make sure everyone has their goggles!

They first label a cup, citric acid stock solution. Then they measure one spoon of citric acid, using a craft stick to level it. Add it to the cup.

Show them how to draw in and read the volume of liquid in a syringe. Always start with the plunger pushed all the way to the bottom. Pull in the water. Read the amount by looking right at the bottom of the rubber plunger. Then put the water in the cup. Remind them that the syringes are only 35 mL and they will need 100 mL of water for their stock solution.

Show them how to make the paper funnel. Measure an exact spoonful of sodium bicarbonate, using the craft stick. Use the funnel to put it into the bottle. Put the stopper firmly into the bottle. Draw up exactly 5 mL of the citric acid stock solution, place the syringe tip into the stopper and push the solution in. The syringe traps the gas! Do not remove the syringe until the reaction is complete! Students conduct three trials, record their results on lab notebook sheet no. 22 and find the average volume of gas made.

Between trials, students can dump the reaction product into their waste containers. As sodium bicarbonate is in excess, they do not need to rinse between trials.

Visit the groups as they work and make notes on your assessment chart. This will give you an informal record of how your students follow procedures, if they are measuring accurately and how well they work together.

When students complete the three trials, they should clean up. The left-over citric acid solution can be dumped down the sink and the cup, syringes and bottles rinsed for the next class. This is a good time for a break.

Groups transfer the average volume of gas produced on transparency no. 4, *How Much Gas*. You can have them calculate the class average and record. The class average should be in the 25–30 mL range.

Now is a good time to discuss experimental error with your students. Ask them why there is a range of results and discuss their ideas.

You may also choose to have students go through the exercise of calculating how much citric acid was in the 5-mL sample of citric acid solution. Follow the steps on this page of the teacher guide and you will end up with 0.1 mL of citric acid in each 5 mL sample of solution.

Have students complete the questions on Lab notebook sheet no. 23, *How Much Gas, B*. Students have not yet had any experience with limiting factors, so the last two questions are included simply to probe their ideas.

<Investigation 3, Part 2>
Narrator: This is what you need from the kit: for each group of four students, you need 4 syringes, 4 pieces of flexible 10-cm long plastic tubing, 4 small binder clips, and 4 bubble cells. You'll cut the bubbles from the sheet of bubble wrap.

For the class you need the 7" rubber playground ball, the air pump with inflation pin, a cup for weighing the ball, and a container for storing the bubble cells.

Pins are stored in the pump handle. You need to provide a metal fork, scissors, an electronic balance with 0.1-gram accuracy, and an overhead projector and pens.

Students need their resources books and you need to make copies of lab notebook sheets nos. 24, *What's in the Bubbles*, 25, *Discuss Air as Particles,* 26 and 27, *Air in a Syringe A and B,* and 29 *Particles Questions.*

Make sure you have these transparencies ready: no. 5, *Properties of a Gas,* no. 6, *Push and Pull on Air,* no. 7 *Discuss Air as Particles,* and no. 8 *Air in a Syringe A*.

If you are using the assessment charts, have them ready on a clipboard.

Students will use syringes in a variety of ways to experience how compressible gases are. They will add in plastic bubbles, and in part three, closed cell foam and open cell foam cubes to observe what happens to air.

The tube can be hard to get off without breaking the tip of the syringe, so students can use a metal fork to lever it off.

Cut the bubble wrap right down a line of bubbles, sacrificing a couple of lines. Then carefully cut out the individuals, one per student. Some of the bubbles might already be popped. Just throw them out. Make sure you cut extras as they can break or disappear! Store them in a jar or bag.

Practice using the pump and inflation pin to slightly inflate the ball. Remember to moisten the pin before putting it in the ball.

To make sure that the air pressure inside the ball is about the same as the air pressure outside the ball, use a pin to release any extra air. You'll know the air pressure is equalized when no more air flows out.

Remove the pin, zero the balance with the cup and weigh the ball using the plastic cup to keep it from rolling off the pan of the balance. Now pump up the ball until it is very firm. Remove the pin and reweigh the ball. It should be a half to 1 gram heavier.

Now use the pin to release any extra air to prepare it for your classes.

Preview the transparencies and think about how you will use them in the course of working with your classes to think about the particle theory of matter.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide!

Ask students to think about the reaction between citric acid and sodium bicarbonate. Recall that it produced a gas. The challenge is to think about what that gas could be. Remind students of the periodic table and elements. The gas that was formed must be made of the elements that made up the reactants.

Pass out lab notebook sheet no. 24, *What's in the Bubbles?,* and have students work on the questions. Then discuss their ideas. As a class, list the gases that students have heard about. Ask a few students to share their definitions of gas but don't worry if they are not complete at this point.

Ask students what elements could be in the gas bubbles from the reaction between citric acid and sodium bicarbonate.

If they think only of these elements, what could the gas be? Students should list hydrogen, oxygen, water vapor, and possibly carbon dioxide as possibilities. Confirm that carbon dioxide is the gas.

Discuss carbon dioxide as a product of respiration and combustion as well as a natural part of Earth's atmosphere. Then ask students what air is.

Shift to the more general idea of gases, using transparency no. 5, *Properties of Gas.* Ask students how they could demonstrate that gas is matter and remind them that matter takes up space and has mass.

Show students the small, inflated playground ball, the inflation pin and the pump. Tell them that the ball is hollow and has air in it. Ask them how they could find out if the air in the ball has mass. Listen to their suggestions and conduct the demonstration as you practiced.

Ask students what caused the mass of the ball system to change. They should come to the conclusion that air has mass.

Ask if air takes up space in the ball and how do they know. Air is matter. It has mass and takes up space. This might be a good place for a break.

Introduce the syringe, tubing, and binder clip as tools to explore how air takes up space. Set the ground rules: the syringes may not be used to annoy anyone. They may use the clip to clamp the tube. Tell them that they may work alone or with a partner and may work with or without air in the syringe.

Show students how to use the fork to remove the tube from the tip of a syringe and designate a place where they can find the fork. Put the plastic tube on the tip of a syringe. Pull the plunger out a bit. Fold the tube and clamp it. Practice pushing and pulling the plunger.

Connect two syringes with the tube, push and pull and see what happens. Remember that two students will share this system.

After students have experienced the resistance of trapped air in a couple of ways, project transparency no. 6, *Push and Pull on Air,* and follow the questions. The idea is for students to show evidence that air takes up space and that amount of space can change.

Air that is forced into a smaller space is called compressed air. When the force holding air in a smaller space is removed, the air expands. When matter expands, it takes up more space.

You can record the new vocabulary on chart paper.

Introduce students to the idea that air, like all matter, is composed of tiny particles too small to see. The particles are constantly moving and there is space between them. They bounce off of one another and the sides of their containers as they careen around.

Tell students to imagine that they can see these air particles as they continue to push and pull on the syringes. Encourage them to come up with an explanation for what they think is happening to the air particles as they compress and expand the air inside the syringes.

After a few minutes, show students the bubble wrap. Show them how to drop a single bubble into the syringe, insert the plunger halfway and then clamp the tubing to make a closed system.

As they push and pull on the plunger, they should think about what is happening to the air in the syringe and the air in the bubble. Give them several minutes to work with the syringe-and-bubble systems.

Collect the materials and discuss the results of the syringe-and-bubble investigation. Follow the questions on page 106 of the teacher guide.

Pass out lab notebook sheet no. 25, *Discuss Air as Particles,* and ask students to work in their groups to write short, precise answers to the questions.

When they are done, project transparency no. 7, *Discuss Air as Particles,* and discuss the questions one at a time. Listen very carefully to students. Make sure that the model they are developing for compression involves particles getting closer together, not smaller. The opposite is true for expansion. The distance between the particles is getting larger; the size of the particles themselves is not increasing. Pass out lab notebook sheets no. 26 and 27, *Air in a Syringe A* and *B.* Project transparency no. 8, *Air in a Syringe A,* and make sure the students understand that illustrations B through E represent a sequence of events. Students are to draw the air particles in syringes B through E based on what they see in syringe A. Give them 10 minutes to complete the drawings and write their rationales before collecting the sheets to review.

Summarize the big ideas with students. There is nothing between particles of gas except space. During compression and expansion, the number and size of particles in a sample of gas do not change; only the space between the particles changes.

Read the article *Particles* in the Resources book and answer the questions on lab notebook sheet no. 29, *Particles Questions.*

<Investigation 3, Part 3>
Narrator: This is what you need from the kit: for each group of four students, you need 4 syringes, 4 pieces of flexible 10-cm long plastic tubing, 4 small binder clips, 4 blue closed-cell foam cubes, and 4 gray open-cell foam cubes.

You need to provide colored pens or pencils, an overhead, and overhead pens.

Students need their resources books and you need to make copies of lab notebook sheet no. 31, *Three Phases of Matter Questions.*

Prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

Make sure you have these transparencies ready: no. 8 *Air in a Syringe A*, no. 9, *Foam Cube Discussion,* and no. 10, *Foam Cubes*.

If you are using the assessment charts, have them ready on a clipboard and make copies of Mid-summative Exam 3.

Preview the Gas in a Syringe multimedia and revisit the Periodic Table to review the elements that are gases at standard temperature and pressure.

Start to collect empty half-liter plastic water bottles with caps for Investigation 4. Make sure the #4 rubber stoppers fit into the mouths securely. You will need one bottle per pair of students and a few extras in case they are ruined.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide!

Return the *Air in a Syringe* sheets to students and project transparency no. 8, *Air in a Syringe A* as you review their conceptions of a particulate model of air.

Use the discussion on this page of the teacher guide to help you.

Here are some things to look out for: first, there should be 20 particles of air in each syringe. The only thing that changes is the distance between the particles. In syringe D, the particles are closer together and in syringe E, the particles are farther apart.

Introduce the blue closed-cell foam cube. Explain that it is filled with thousands of little bubbles that are each sealed and separated from each other.

Introduce the gray open-cell foam. Explain that it is filled with bubbles that are all connected to one another.

Show students how to drop both cubes into the syringe, push the plunger halfway down, and close the system with a clip, just like they did with the bubble wrap. Give students a few minutes to observe the behavior of the two cubes.

Use transparency no. 9, *Foam Cube Discussion;* and discuss what happened to the foam cubes.

Ask for a volunteer to use the board to illustrate what he or she thinks happens in the blue closed-cell cube before and after the air around it is compressed. Continue the discussion and have another volunteer illustrate before and after particles in the gray open-celled cube.

Summarize the cube investigation with transparency no. 10. You may choose to cover over the "after" cubes and have students describe what is happening in the "before" illustrations first. Then reveal the "after" illustrations and continue the discussion.

Put away materials and wrap up the discussion with a mini-lecture about gases found on this page of the teacher guide.

Project the multimedia simulation, *Gas in a Syringe,* to help illustrate the principles involved. Give students time to operate the Gas in a Syringe multimedia, narrating the actions as they go.

Navigate to the Periodic Table multimedia and highlight the elements that are gases at standard temperature and pressure.

Have students read the article, *Three Phases of Matter* and answer the questions on lab notebook sheet no. 31, *Three Phases of Matter questions.* Pay particular attention to the diagrams.

Summarize the big ideas from Investigation 3. When students are ready, give them *Mid-summative Exam 3.*

<Investigation 4, Introduction>
Narrator: In Investigation 4, students continue their investigation of particles. They observe the expansion and contraction of gases, liquids, and solids and explain what happens in terms of kinetic theory, particle motion.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about kinetic energy, its relationship to heat and the kinetic model of matter. The Why Do I Have to Learn This? section addresses the notions students bring to the table and how we can help them form good models for very difficult and abstract ideas.

<Investigation 4, Part 1>
Narrator: In this part, students work with half-liter plastic water bottles to find out what happens to air when it is heated and cooled. The kinetic particulate model is introduced and students use it to explain expansion and contraction.

This is what you need from the kit: for each group of four students, you need 2 insulated foam cups, 4 large, 500 mL plastic cups, one #4 1-hole rubber stopper, one 45-cm long flexible plastic tube, one round balloon and a cup for the bubble solution. For the class you need 2 metal-backed thermometers.

You will need to provide two half-liter plastic water bottles and caps per group, liquid dishwashing soap, a supply of water heated to 65-70º Celsius, and a supply of cold water at about 5º Celsius. Make copies of Lab notebook sheets 32 and 33 *Heating and Cooling Air A and B* for each student.

Make a copy of the Investigation 4 assessment chart for each class.

Make sure you have enough empty half-liter plastic water bottles with caps. Test that the #4 1-hole rubber stoppers fit into the mouths securely. You will need one bottle per pair of students and a few spares.

Prepare bubble solution by mixing about 25 mL of liquid dishwashing soap with 250 mL of water. For each group, pour enough bubble solution into a cup to just cover the bottom. Oops – I'll pour a little back! Students don't need much!

Put one end of the long tubing into the hole on the top side of the stopper. If you can't get it in, use a little bit of water to get the end of the tube wet and try again. Don't push it through to the other side of the stopper.

In this investigation, pairs of students use about 150 mL of 65–70ºC hot water at a time and will need to refresh it to keep it hot. You may need about 6–7 liters of hot water per class.

It is easiest to use a large coffee urn with a tap at the bottom. You can also use a hot plate or other source, but make sure that the supply can keep up with the demand.

If you have a cooler, you can put hot water in gallon jugs, put the jugs in the cooler, and surround them with newspapers to keep them warm.

Check the temperature of the water to make sure that it is not too hot. The water will melt the plastic cups if it is hotter than 70º Celsius. This water is 88º Celsius—too hot!

Prepare cold water as well. Adding ice to tap water is sufficient, but check the temperature to make sure is stays cold. Pairs of students will use 150 mL of cold water at a time, so you may need about 5–6 liters per class. You can use pitchers or large basins to prepare the cold water. Just add ice!

Make sure you have the Assessment charts for Investigation 4 ready to go.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide!

Ask students to recall the properties, behaviors, and characteristics of gases.

Tell students that they are going to further investigate air using several tools. One tool is an empty water bottle. Ask them what is inside. They should reply that air is inside.

Set a challenge by asking the students to imagine they are going to have to show a class of fourth graders what happens to air when it is heated and cooled. Show them the tools that are available.

Each pair of students will have a bottle and cap, 2 large plastic cups, and 1 foam cup. Each group will share one balloon, one stopper and tube, one cup with a small bit of bubble solution, and one tote tray.

Lay down the rules…nothing goes inside the bottle, no bubble solution, no water, nothing.

Do not crush, fold, or otherwise modify the bottle.

No hoarding the group materials. You need to share! Everyone should try several ways to demonstrate what happens when air is heated and cooled.

Preview lab notebook sheet no. 32 with the students and describe the logistics of the work.

Advise working in the trays to contain any spills or splashes.

Point out the water-level line on the large plastic cups. This is how high they will fill the cups with hot or cold water. When they push the water bottle into the cup, the water won't overflow.

The following is one possible way students might work with the materials.

Students might put the balloon over the mouth of the bottle and move it back and forth between warm and cold water.

See what else your students come up with as long as they don't put anything into the bottles! Check these pages of the teacher guide for more of what to anticipate.

Instruct students to clean up and then gather together to share results. As groups share, focus on observations by asking them what they did and what happened.

In the last investigation, we used syringes to push and pull on air. This time, we used heat and cold. When a volume of gas gets hot, its volume increases. We call this expansion.

When a volume of gas gets cold, its volume decreases and we call this contraction (not compression).

Develop these concepts as suggested on these pages of the teacher guide.

Give students time to complete lab notebook sheet no. 32, *Heating and Cooling Air A*. They need to use the words expand, expansion, contract, and contraction to explain to the fourth graders what happened.

When students have completed the lab notebook sheet, introduce kinetic energy as the energy of motion. Relate kinetic energy to the motion of particles and heat, following the suggestions in the teacher guide. Ask students to complete lab notebook sheet no. 33, *Heating and Cooling Air B,* using the concepts of kinetic energy, expansion, and contraction. Encourage them to use illustrations of particles if it helps. Collect their work when done to assess if students understand the fundamental relationship between heat and gas expansion and contraction.

<Investigation 4, Part 2>
Narrator: In this part, students explore the expansion of liquids using a water thermometer that they construct. They apply their understanding of kinetic theory to explain what happens.

This is what you need from the kit: for each group of four students, you need 2 glass bottles, two #1 1-hole rubber stoppers, 2 10-cm rigid plastic pipes, 2 index card pieces cut from a single card, 4 large 500 mL cups, 2 glass thermometers, 2 syringes, 2 pipettes, and transparent tape.

For the class you need two syringes, 2 pieces of the10-cm flexible plastic tubing, 2 small binder clips, and the blue food coloring. You need to provide hot 60ºC water, cold water at 5°C, 1.5 liters of blue room-temperature water, paper towels, an optional washcloth, and an overhead projector and pens.

Students need their resources books and you need to make copies of lab notebook sheets nos. 34 and 35, *Heating and Cooling Water A* and *B*, and no. 37, *Particles in Motion Questions*.

Make sure you have transparency no. 11, *Kinetic Definitions* ready. If you are using the assessment charts, have them ready on a clipboard. Also, make copies of notebook sheet no. 39, *Response Sheet—Kinetic Energy,* to use for assessment.

Students will work in pairs.

To make the glass bottle thermometer, take the short plastic pipe, and put it in the large end of the stopper. You don't need to push it all the way through. Set it aside and then take the syringe that has 35 mL of colored water, and carefully push it into the bottle. Tell your students to do it slowly, and it should fill it up. Next, carefully take the stopper and insert in the top. Water will come out around the stopper, and it also may come out at the top. To get the level of water in the middle of the tube, what you need to do is just move the stopper just a little bit until its right in the middle.

Another way you can adjust the water level in the pipe, is to use a pipette. Simply squeeze the pipette, hold, insert in the pipe, and slowly release the bulb as you move down in the water, until it's in the middle.

Once you have adjusted the water level in the pipe and you've dried off the bottle, take a 1 × 3 piece of index card, and attach a small piece of tape to it. Take the card, and go ahead and put the card right up next to the tube, wrap the tape around, and then label the water level. Draw a line right at the level and write the letter "R" right next to it.

For the demonstration in Step 2, you will need one syringe half-full of air and a second one, half-full of water. Prepare the air syringe as you have in the past. Prepare the water syringe, following the directions in the teacher guide. Make sure there are no air bubbles in the system.

Prepare room-temperature water by leaving out several containers the day before. To color it, 25 drops of the blue food coloring per liter of water gives a good tint. Each class needs about half a liter, so make enough for all of your classes.

Set up one materials station with the glass bottles, a few syringes, and the blue water. Put a half-liter container of the blue water into a basin so that students can easily transfer 35 mL of water into their bottles.

Cut index cards into 1 inch by 3 inch strips. You need two per group for all of your classes.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide!

Start this part off by comparing how students compressed a volume of air by pushing it in a syringe and how students caused a volume of air to contract by transferring heat energy away from the particles.

Bring out the two syringe systems you prepared, and show that you can easily decrease the volume of air by pushing in the plunger on the air-filled syringe. You can also increase the volume of air by pulling out the plunger. Can a volume of water can be changed in the same way? Show that you can neither compress nor expand the water by pushing or pulling the plunger. If you choose to let students try, be careful to warn them not to use excessive force!

Give students a minute in their groups to think about why water can't be compressed.

Show the students the bottle system you prepared. Tell them that the other day they put a plastic bottle of air into hot and cold water and observed what happened. This time they will try the same thing with water.

Pass out Lab notebook sheets 34 and 35. Show them how to set up the bottle system like you practiced. Tell them where to get the blue water and tell them to work in trays to catch any water overflow. Make sure they fill the water cups no higher than the water line like they did before.

Show the students the glass thermometers and tell them to be very careful with them as they can break. The plastic triangles will keep the thermometers from rolling. The thermometers are stored in a special rack.

Finally, they should measure, record the temperature, and put the bottle in the cold water first. If they start with the hot water, the colored water may overflow the pipe and there might not be enough time for the water to cool below the starting temperature. Give students 15–25 minutes to complete the measuring and recording.

When they are done, have them clean up according to your instructions. The card should be removed from the pipe and taped onto one partner's lab notebook sheet.

Students should now consider the questions on lab notebook sheets 34 and 35. When they have completed the questions, remind them that they could not use a syringe to compress or expand the water. Ask them why they think that water can't be compressed. Take some time with this question before telling them that in a liquid the particles are already touching and they can't be pushed closer together. If students suggest that the colored water went up the pipe because heat rises, take a hot washcloth and first ask them what will happen if you turn the bottle upside down. Nothing! But, if you surround the bottle with the hot washcloth what will happen to the water in the pipe. The water you see dripping is just water from the washcloth. As you see, the water moves down the pipe. This should prove to students that the water is expanding, not rising.

Continue your discussion of the notebook sheet and focus on question 5. Make sure that students do not think the water expanded because the particles themselves expanded. Instead, heat energy was transferred to the water particles in the bottle. The particles moved faster and pushed each other apart, resulting in expansion.

Summarize the kinetic model of water expansion with a careful lecture. Use the teacher guide to help you.

Remind students of the thermometer they used to measure the temperatures of the hot and cold water. Ask them to develop an explanation for what happens when you put a thermometer in hot water. Give them a few minutes in their groups and then share out as a class. See various examples of student explanations in the teacher guide. Compare the bottle system to a thermometer.

Finally, use transparency no. 11 to add vocabulary to student notebook glossaries.

Have students read the article *Particles in Motion* and answer the questions on lab notebook sheet no. 37, *Particles in Motion Questions.* Pay particular attention to the diagrams.

After discussing student responses, have students a copy of lab notebook sheet 39, *Response Sheet—Kinetic Energy*, and remind them to use the ideas of particles and kinetic energy in their explanations.

<Investigation 4, Part 3>
Narrator: In Part 3, students explore the expansion of solids by observing a brass sphere and ring demonstration. They apply their understanding of kinetic theory to explain what happens.

This is what you need from the kit: for the class, you need the brass sphere and ring set and the sodium chloride. You need to provide a gas burner or electric hot plate and ice water.

Students need their resources books and you need to make copies of lab notebook sheet no. 41, *Expansion and Contraction Questions.*

Prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

If you are using the assessment charts, have them ready on a clipboard and make copies of Mid-summative Exam 4.

The third part of Investigation 4 uses a brass ring and sphere. When the sphere and ring are at the same temperature the sphere passes easily through the ring. When the sphere is heated and the ring cooled, the sphere won't pass through the ring anymore.

To get the ring cold enough you need to put it in an ice water and salt bath. To make the bath, add three scoops or 15 mL of salt to approximately 250 mL of ice water. Stir it up and soon the temperature should drop below 0°C. Put the ring in and let it sit for several minutes.

At the same time you need to heat up the sphere. Turn on a lab hot plate above 200°C or you could just use a regular hot plate from home. Lay the sphere on the plate and prop it if you need to. It will need to rest for several minutes. After a few minutes, take out the ring, remove the sphere, and try and push them through. It's difficult until the ring heats up enough to allow the sphere to pass through.

And here's a safety note: the sphere is still very hot, even after cooling off enough to pass through the ring. Cool it off in a tub of water before touching it or returning it to the kit.

Preview the multimedia titled *Particles in a Solid, Liquid, or Gas*.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Take a few minutes to review the expansion and contraction of gases and liquids. Make sure that the students are developing a model that includes the amount of space between particles changing due to a changing kinetic energy. After reviewing, ask students if they thing solid materials like glass, rock and metal also expand and contract. How could we find out?

After students share their thoughts, bring out the ring and sphere. Conduct the demonstration as you practiced. Ask students what they think is happening to the brass particles at each stage and have them predict what will happen after the sphere is heated and the ring cooled.

Discuss what they observed and confirm that though the particles in solids are not free to move around, they vibrate more and move farther apart when heated and the volume of the solid increases.

Review the big ideas that students interacted with during Investigation 4 and spend some time with the multimedia.

Have students read the article, *Expansion and Contraction* and answer the questions on lab notebook sheet no. 41, *Expansion and Contraction Questions.*

When students are ready, give them *Mid-summative Exam 4.*

<Investigation 5, Introduction>
Narrator: In Investigation 5, students learn to conceptualize energy transfer as changes in the kinetic energy of particles resulting from particle collisions. They learn that the calorie is the unit of heat.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about kinetic energy transfer, heat and temperature. The Why Do I Have to Learn This? section addresses the notions of "hot" and "cold" that students bring to the table and how we can help them move to a model of energy levels and how energy moves.

<Investigation 5, Part 1>
Narrator: In this part, students predict what the final temperature of a mixture of hot and cold water will be. After predicting, they carry out the experiment.

This is what you need from the kit: for each group of four students, 3 foam cups, one large 500 mL plastic cup, two accurate 50-mL graduated cylinders, 2 pipettes, and 2 of the glass thermometers.

For the class you need 2 foam cups. You will need to provide a supply of water heated to about 60ºC, and a supply of 5ºC cold water and an overhead projector and pens.

Make copies of Lab notebook sheet 43 *Mixing Water* for each student. Make sure you have transparency no. 12, *Mixing Water Results* ready. Make one copy of the Investigation 5 assessment chart for each class.

Prepare the hot and cold water. Students working in groups of four will mix samples of hot and cold water that are close to 50ºC and 10ºC respectively.

If you heat water to approximately 60ºC, by the time students transfer it to a container and use it at their tables, the temperature should drop to about 50ºC.

If you have a batch of 5ºC cold ice water, you can raise the temperature by adding tap water just before class.

Find the correct graduated cylinders. These are 50-mL hard plastic ones and are much more accurate than the black and yellow cylinders that will be used in Investigation 10. Be prepared to show students how to use the pipette to adjust the volume of water in the cylinder to exactly 50 mL.

Students will use the glass thermometers. Make sure that they can read them accurately.

Make sure you have the Assessment charts for Investigation 5 ready to go.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review what students have learned about particles and kinetic energy in the past investigation. Ask them to describe what happens at the particle level to cause expansion and contraction in solids, liquids and gases. Give them a few minutes in their groups to consider and then share out as a class.

Hold up a cup of hot water and a cup of cold water. Tell students that the cups have equal amounts of water. If you mix the two samples of water, can they predict the final temperature?

Pass out lab notebook sheet no. 43, *Mixing Water* and ask students to work together to predict the final temperature of a mixture of equal volumes of 50ºC hot water and 10ºC cold water. They also need to write their reasoning. Give them a few minutes and then discuss their predictions.

At this point, do not confirm or refute their ideas, but record them on the board. They might say 60ºC which reflects an additive model. They might say 40ºC, a subtractive model: high minus low temperature. They might say 30ºC, the average model: the sum of the temperatures divided by 2. Or they might not be able to choose a specific temperature, but state that the final temperature will be somewhere between 10 and 50ºC.

Show students the equipment that is available and ask them to sketch out a draft plan for checking their prediction. They can use scratch paper or the blank lab notebook page 42. When groups have come up with some beginning thoughts, call on several groups to share. Refine the procedures until they have included the elements found on this page of the teacher guide.

Give students a few minutes to write their final procedure on their notebook sheets and provide a few suggestions. Use one foam cup to get cold water and another foam cup to get hot water from the supply station. Make sure that they do not have any ice in their cold water. Use a pipette to get the water in the two graduated cylinders exactly even and remember to record the volumes! Put the third foam cup into the large plastic cup so it doesn't get knocked over.

Pour your 50 mL of hot water into a foam cup, put the thermometer in, pour your 50 mL of cold water into another foam cup put the thermometer in, read the temperatures—in our example, the hot is 55ºC. The temperature of the cold is 13ºC. The third foam cup is in the large cup so it doesn't fall over when you put the thermometer in. Predict the end temperature and pour both waters into the third cup. As soon as the alcohol in the thermometer stops moving, measure the temperature. The final temperature here is 34ºC. Compare it to the prediction.

When students are done, and have cleaned up their materials, ask a recorder from each group to write their data on a class chart. You can use transparency no. 12, *Mixing Water Results,* or create a chart on the board.

Discuss the results. Ask students to compare their predictions to the final results and to look at other groups' results. Which groups had accurate predictions? Do they notice any patterns between the starting temperatures and the predicted final temperatures?

They should notice that the average of the two starting temperatures is equal to the predicted final temperature, though the actual final temperature might not be perfectly accurate due to heat loss.

Work with students to derive the equation for calculating the final temperature when two (or more) equal volumes of water are mixed.

Let's say the capital T with a subscript h means the temperature of hot water. And T subscript c means the temperature of cold water. Finally, T subscript f means the final temperature of the mixture.

We can write the equation for the average like this. This is for two samples of water. We do the same thing if there are more samples but can use a number to represent each sample. Like this. The letter "n" stands for the number of samples. Tell students to write these equations at the bottom of their notebook sheets.

Summarize the investigation together, starting with the idea that when mixed, the hot water got cooler and the cold water got warmer. Then ask what happened to the kinetic energy of the particles in the hot and cold water when they mixed. In the next investigation we will try to figure out how the kinetic energy of particles changes!

<Investigation 5, Part 2>

Narrator: In this part, students grapple with the concept of energy transfer as a consequence of collisions between particles. They are introduced to temperature as the average kinetic energy of particles in a substance and study how a thermometer works.

Students need their resources books and you need to make copies of lab notebook sheets no. 45, *Energy on the Move Questions.*

Prepare to use the FOSS Chemical Interactions multimedia, either online or from the CD.

If you are using the assessment charts, have them ready on a clipboard. Also, make copies of lab notebook sheet no. 47, *Response Sheet—Energy Transfer,* to use for assessment.

The concepts in this part are difficult and abstract. Follow the progression of ideas in the teacher guide especially carefully this time.

Preview the multimedia. You will use four different animations: Energy Transfer by Collision, Mixing Hot and Cold Water, Thermometer, and Energy Flow.

Plan on having students read the article, *Energy on the Move*, in class so that you can guide students carefully and stop when needed.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review what students did the other day: mixing water of equal volumes and different temperatures.

Ask students if the final temperature of the water was hotter than the hot water, colder than the cold water or somewhere in between. Ask if the final temperature was closer to the hot water or closer to the cold water.

Now, the important question: *What do you they think happened to make the final temperature different than the starting temperatures?*

Give groups a few minutes to think about this and then share out as a class. Follow the prompts on this page of the teacher guide to get to this point. The hot water particles lost kinetic energy when they were mixed with the cold water particles. And the cold water particles gained kinetic energy when they were mixed with the hot water particles.

Tell students that this movement of energy from one place to another is called energy transfer.

Change of temperature is evidence of energy transfer. Give students time to consider the following questions in their groups: did the energy transfer from the hot water to the cold water, from the cold water to the hot water, or in both directions?

After a time, call on groups to share their ideas. Then, confirm these Important Ideas: Important Idea no. 1: The level of kinetic energy of the particles in a sample of matter determines how hot it is. Kinetic energy = Heat. Heat = Kinetic energy.

Important Idea no. 2: Energy transfers between particles when they hit each other. When a fast-moving particle hits a slow-moving particle, the one that was going fast, slows down and the one that was going slow, speeds up.

Important Idea no. 3: Though energy is not a liquid, we can think of energy transfer as energy flow. Energy always flows downhill. What we mean by that is energy always moves from higher energy (hot) to lower energy (cold). Always!

Students should record these important ideas in their notebooks.

Now view the multimedia as a class. Navigate to the Energy Transfer by Collision animation and tell students that this animation shows how energy transfers during collisions. The animation is thousands of times slower than reality!

Next go to the Mixing Hot and Cold Water animation. This represents what happens when equal volumes of hot and cold water are mixed. The water particles are different colors so that we can observe what happens to the ones that start in the hot water and what happens to the ones that start in the cold water.

Allow the students time to interact with the animations and explain what is happening.

Now remind the students of the bottle system thermometers they built several days ago. The Celsius thermometers we use work in the same way. Follow the description in the teacher guide and define temperature as the average kinetic energy of the particles in a substance.

Show the thermometer animation on the multimedia. Both you and the students need a mental break right now, take one.

As a class, read the article *Energy on the Move*. There is a suggested method on this page of the teacher guide, but use a process that works for you. It is important to vary strategies and go slowly so that the ideas have time to sink in.

Pass out lab notebook sheet 45, *Energy on the Move questions,* and give students time to work on the questions on their own.

Now is a good time to use the *Energy Flow* multimedia. This is an interactive experience, so if possible, introduce the multimedia and then give students time to work in groups or pairs on single computers.

When students are done, give them lab notebook sheet no. 47, *Response Sheet—Energy Transfer,* as an assessment.

<Investigation 5, Part 3>
Narrator: In Part 3, students conduct another water-mixing experiment, except this time they quantify the amount of heat transferred and use the calorie, the unit we use to measure heat.

This is what you need from the kit: for each group of four students, you need 3 foam cups, 1 large 500 mL plastic cup, two accurate 50 mL graduated cylinders, 2 pipettes, and 2 glass thermometers.

For the class, you need 1 accurate 50 mL graduated cylinder and 1 pipette. You need to provide hot 60ºC water and cold 5ºC water, calculators, one or two electronic balances, an overhead projector and pens.

You need to make copies of lab notebook sheets nos. 48 and 49, *Calculating Heat in Calories A* and *B,* no. 51, *Heat Transfer,* and nos. 52–53, *Heat Practice A* and *B.*

Have transparencies no. 13, *Calories* and no. 14, *Energy Vocabulary* ready.

If you are using the assessment charts, have them ready on a clipboard and make copies of Mid-summative Exam 5.

Use 50 mL of water to show students that 1 mL of water has a mass of 1 g. To do this, first zero the balance using an empty 50 mL graduated cylinder. Then find the mass of the 50 mL of water. The balance should read exactly 50 g. If the balance doesn't read exactly 50 g, try another graduated cylinder. Once students understand this relationship, they can determine the mass of a sample of water either by measuring the volume or by weighing it.

Plan for hot and cold water. Pairs of students will use up to 50 mL of each. The beginning temperature of the water is not critical at this time. The hot water can be between 50 and 60ºC. The cold water can be a broad range from ice water to cold tap water.

Spend some time with the notebook sheets to anticipate where students might have trouble and plan for the mid-summative assessment.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Use lab notebook sheet no. 48, *Calculating Heat in Calories A* and transparency no. 13, *Calories* to introduce the concept that heat and temperature are not the same thing and are not measured using the same units.

We use the degree Celsius to measure temperature. We use a unit called the calorie to measure heat. You might want to ask them where they have heard that word before and when they mention food, affirm the response but tell them that food calories are actually Kilocalories, 1000 times a calorie.

Read together the definition of a calorie. One calorie is the amount of heat needed to raise the temperature of 1 g of water 1ºC.

Work together as a class to answer no. 1 a through d and then give students a few minutes to finish e through h. Make calculators available if needed.

When students have completed e-h, go over the answers together. Ask students how they figured out the number of calories used in each item. What is the equation for calculating the amount of heat needed to heat up or cool down a mass of water? Calories of heat = mass of water times the change in temperature.

Students should complete question no. 2 and continue on lab notebook sheet, no. 49, *Calculating Heat in Calories B.* When they are done, take a few minutes to discuss their answers. This page of the teacher guide gives you some more information on each question.

Now might be a good time to take a break.

The next day, students find out how much heat is transferred from the hot water and how much heat is transferred to the cold water when the water is mixed.

Pass out lab notebook sheet no. 51, *Heat Transfer.* Go over the table with them, pointing out the information they need to include.

If students already know that 1 mL, or 1 cm3 of water has a mass of 1 gram, move on. If they don't, show them using the balance and graduated cylinder as you practiced. Emphasize that this is true only for water!

Review the instructions. Encourage students to decide who is going to do what in the group so that they can work quickly and efficiently.

Students follow the exact same procedure as in Part 2, but this time the masses of water do not need to be perfectly identical.

Measure and record starting masses and temperatures of the hot and cold water, mix them and record.

When they have recorded the final temperatures, they calculate the change in temperature. They calculate the number of calories transferred from the hot water and the number of calories transferred to the cold water and compare.

Ask students what happened and what caused the kinetic energy to change. Did the energy transfer from the hot water or from the cold water?

In comparing the number of calories transferred from the hot water to the number of calories transferred to the cold water, students should notice that they are close if not equal. Any difference reflects a loss to the environment. Ask them what the equality tells them about energy transfer.

After listening to their responses, confirm that the energy transferred from someplace is equal to the amount of energy transferred to another place. We say that energy is conserved. That means that the amount of energy in a system is always the same—no energy is ever created, and no energy is ever destroyed. It can, however, be moved or transferred. When we mixed hot water with a lot of kinetic energy with cold water that didn't have as much kinetic energy, we got medium temperature water with a medium amount of kinetic energy. The total amount of energy did not change.

Refer to the discussion in the teacher guide to introduce the concept of equilibrium.

Revisit all of the multimedia if students need more time to develop the idea of particle kinetic energy, energy transfer, energy flow, and heat.

Project transparency no. 14, *Energy Vocabulary*, to ensure that students have all the words and definitions in their notebook glossaries.

Pass out lab notebook sheets 52 and 53, *Heat Practice A* and *B,* and have students work on their own to solve the problems. You may choose, after a time, to let them work with a partner or their groups.

Review the big ideas from Investigation 5. When students are ready, give them the *Mid-summative Exam 5*.

<Investigation 6, Introduction>
Narrator: Investigation 6 explores some difficult questions. Energy transfers to ice but the ice doesn't warm up. Why not? Isn't energy supposed to be conserved? The answer requires advanced proportional reasoning that may be beyond the ability of younger students. The idea that it takes energy simply to melt ice is complex.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about the heat of fusion and what happens to energy during phase change.

<Investigation 6, Part 1>
Narrator: This is what you need from the kit: for each group, you need 4 foam cups, 2 glass thermometers, and 2 stirring sticks.

For the class you need 1 glass thermometer and 1 large 500 mL cup for a demonstration and bulb pipettes.

You need to provide a supply of ice cubes for the groups. Each group will need about 30–40 g of ice. You also need ice water at 0ºC and water heated to about 75 or 80ºC. You need a cooler, 1 or 2 electronic balances, and an overhead projector and pens.

Students will need their Resource books and you need to make copies of Lab notebook sheet nos. 54 and 55, *Ice Water and Hot Water A* and *B,* sheet nos. 56 and 57, *Heat of Fusion A* through *D,* and sheet no. 59, *Heat of Fusion Questions* for each student.

Make sure you have transparency no. 15, *Ice Water/Hot Water,* no. 16, *Ice Water/Hot Water Results,* and no. 17, *Temperature of Melted Ice* ready.

Make a copy of the Investigation 6 assessment chart for each class. Also make copies of Mid-Summative 6 for each student.

Prepare the demonstration for the classes. Fill one of the large plastic cups about one third full with water. Put the glass thermometer in the water and set the system in a freezer.

When you pull the cup and ice out of the freezer, the temperature of the ice will be lower than 0ºC because the temperature of a freezer is below 0ºC. After sitting at room temperature for a few minutes, the temperature should rise to 0ºC.

You need ice both for the students and to make ice water. You need lots of ice. Lots. Plan on about 1 kilogram per class. This is generous, but you will need more in the coming days. So make sure you're ready!

Each pair of students needs an ice cube with a mass of 30–40 g. A standard ice-cube tray makes this size of cube. So if you start making the ice cubes a few days in advance and transferring them to plastic bags for each class, you should be fine. You can also purchase bags of ice cubes, but you may want to check the size of the cubes and put them in class-size bags ahead of time. One more thing about the ice. If you store your ice in the freezer, remember that the temperature of freezers are below zero. Surround the ice cubes with newspapers and put them in a cooler to warm them up.

Prepare hot and cold water. This time the hot water needs to be hotter than before, between 75 and 80ºC so that it will melt the ice quickly before losing heat to the environment. This is a safety issue so be sure to warn students to be careful.

You need ice water at 0ºC, which you can prepare using a lot of ice compared to water. Keep a large quantity in the cooler and keep adding ice.

Set up two weighing stations so that students can weigh ice, ice water and hot water to an accuracy of 0.1g. Electronic balances are best, but triple beams will work.

Plan for the reading again, the content is challenging and you might want to walk students through it instead of having them read on their own.

Use both lab notebook sheet nos. 54 and 55 and the mid-summative, for assessment.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review what students have learned about particles, energy, energy transfer and equilibrium in the past investigations.

Remind students that the last time they mixed hot water and regular cold water and found the final temperature. This time they are going to mix hot water with water and ice and see if we can discover the final or equilibrium temperature.

First ask them what the temperature of ice is. They should answer 0ºC and to confirm, bring out the thermometer frozen in the cup of ice. Have a few students read the temperature and leave the cup throughout the period (and throughout the day) so that the temperature can be read.

Use transparency no. 15, *Ice Water/Hot Water* and lab notebook sheet no. 54, *Ice Water and Hot Water A* to read through the procedure carefully.

Show students how to zero the balance using the foam cup. Then add between 30 and 40 g of ice. We have 32.9 g. Add ice water. Students will have to go back and forth using a pipette until the balance reads 60.0 g exactly. This may take awhile.

Warn students to be careful with the hot water. Zero the balance. Add hot water. Use the pipette until the balance reads exactly 60.0 g.

Remove the hot water cup from the balance and measure its temperature. Bring in the ice and water mixture and measure its temperature. Remind students to predict the equilibrium temperature and then pour the hot water into the cold water. Stir it up. Right as the last ice melts, students record the final temperature.

After students have recorded the final temperature, give them time to calculate the energy transfers and answer the first four questions on lab notebook sheet no. 55, *Ice Water and Hot Water B*. If they are thinking at all, students should be scratching their heads and looking at each others' data to try to explain why their predictions and results are so different!

Depending upon the starting temperatures, students usually predict about 30ºC as a final temperature. The actual final temperature will most likely be between 5 and 15 ºC.

Again, depending upon the starting temperatures, the calories transferred from the hot water should fall somewhere between 2500 and 3500 calories. In contrast, the calories that apparently transferred to the cold water and ice mixture will fall somewhere between 300 and 900 calories.

Question 4 is the crux of the matter. The number of calories transferred from the hot water does not equal the number of calories transferred to the cold water. In fact, the difference is huge! So, where did the calories go?

Perhaps the students made experimental errors? Perhaps something went wrong? Have the partners average their data in each group and then gather class data on transparency no. 16, *Ice Water/Hot Water Results.*

Calculate the class average and ask students if experimental error might explain the missing calories. As everyone had similar data, there must be some other explanation. Remind students that energy is conserved during energy transfers; no energy is created or destroyed. So, where did those calories that transferred from the hot water go?

Some students may suggest that the calories were used to melt the ice rather than heat it up. Focus on this idea for a time. Project transparency no. 17, *Temperature of Melted Ice* and carefully go through the questions checking for understanding. This transparency focuses specifically on the ice and the ice/water mixture. Record the answers on the transparency or board as you go.

1. What was the temperature of the ice in the ice/water mixture at the start of the experiment? 0ºC
2. What was the temperature of the water in the ice/water mixture at the start of the experiment? Usually between 0-2ºC
3. At the moment the ice melted, what was the temperature of the water it turned into? 0ºC
4. What was the total mass of water at 0ºC just as the ice melted? 60g
5. How much energy did it take to raise the 60g of ice water at 0ºC to the equilibrium temperature? (the energy transferred to the ice water from the class average data)
6. How much energy is unaccounted for? (the difference in energy transfer from the class average data)

It is time to either confirm or introduce the idea that energy was needed to change water from solid ice to liquid water. Refer to teacher guide to bring out the following points:

The particles of water in solid ice are held together by attractive forces called bonds. Energy is needed to break those bonds and allow the particles to break apart from each other and move around. That's where the missing energy went. We call the energy needed to change solid water or ice at 0ºC to liquid water at 0ºC the heat of fusion. The heat of fusion of any solid material is the amount of heat needed to melt 1 g of that material and turn it into liquid.

The question you need to answer with your students is: how many calories of heat does it take to melt 1 g of ice? Now, let's do an example with your students. First of all, lets' say that they had 35 g of ice. They will have between 30 and 40 but 35 is an, an example. And let's say that their heat imbalance was 350 calories.

Now, the way to figure it out how many calories per gram would be to take the missing calories, 350, and divide it by the mass of the sample, 35 grams. Do the division and you find out that it takes 10 calories of heat to melt 1 g of ice? So, for your students, their job, the heat of fusion, is their missing calories divided by their mass of ice.

Students add the results to transparency no. 16. Average the class data.

If students worked efficiently and calculated correctly, their data for the heat of fusion should be a number in the 70s. The actual heat of fusion of water is 80 cal/gram, and much of the difference in experimental results is due to the heat lost in our imperfect foam cup system.

Summarize the heat of fusion as directed in the teacher guide. Stress that as the ice is melting, the temperature of the mixture of ice and water is not changing. All of the heat energy from the hot water is going to change the ice to liquid water. Once the ice is totally melted, the temperature of the water will go up if heat energy is added.

Have students record the general definition for heat of fusion in their notebooks. Ask students to complete the questions on Lab notebook sheet 55 and collect them to assess their understanding.

Have students read the article *Heat of Fusion* in the Resources book and have them answer the review questions on lab notebook sheet no. 59, H*eat of Fusion Questions.*

The next day or after a break, review the heat of fusion with students and then introduce lab notebook sheet no. 56 and 57, *Heat of Fusion.* These scenarios describe different alien materials and ask students to determine the heat of fusion of each one.

Review the big ideas from Investigation 6. When students are ready, give them the *Mid-summative Exam number 6*.

<Investigation 7, Introduction>

Narrator: In Investigation 7, students explore the three common phases or states of matter, solid, liquid and gas and how particles are related in each phase. They investigate conditions that cause substances to change from one phase to another.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book. There are five parts in this investigation.

Be sure to read through the Scientific and Historical background pages for information about the phases of matter we encounter on Earth. The relationships between phases, particles, energy and phase changes are addressed. The Why Do I Have to Learn This? section looks at how students sometimes confuse dissolving and melting, and introduces the big ideas they will explore in this investigation.

<Investigation 7, Part 1>
Narrator: In this part, students first express their understanding of dissolving and melting. They then compare what happens to M&M candies in four different environments, refining their ideas of dissolving and melting based on their observations.

This is what you need from the kit: for each group of four students, 4 plastic 250 mL cups, 4 squares of aluminum foil, cut to 4” × 4”, 4 small paper cups, and a 1-liter container for waste. You will need to provide enough M&Ms for each pair to have 4 of the same color, a supply of water heated to about 60ºC, a supply of cold water for the groups, scissors or a paper cutter and a ruler to prepare the aluminum foil squares, paper towels, and an overhead projector and pens.

Have transparency no. 18, *Foil Cup Assembly* ready. You need one copy of Investigation 7 assessment chart for each class.

Prepare your water supplies as before. Students working in pairs will need approximately 150 mL of hot 60ºC water and 150 mL of cold but not necessarily freezing water. Consider keeping the cold water in the fridge.

Each pair of students will need two 4”× 4” squares of aluminum foil to make their cups. Cut these in advance. A 25 foot roll of 12”-wide foil can be cut into a lot of squares. Make sure you calculate the necessary number and then make some extras. A paper cutter makes things go faster, but the cut edges can get squished together. You can slip a ruler between the squares and use it like a letter opener to free the edges.

In Investigation 7, Part 1, each pair of students will make two aluminum foil cups. Be prepared to help students make the cups. They need to make them with no holes as they’re going to be floating in a cup of water.

This is how your students will make the foil cups. First, take one of the paper cups and put it inside a 4×4 square of aluminum foil. Beginning with the corner, fold it up around the cup, and keep folding as you go. Place the foil wrapped cup inside the second paper cup. Push it gently, but firmly, straight down. Be sure to tell students not to twist the cup because this could make holes. You pull out the cup right here; you’re ready to go.

Make sure you have the Assessment charts for Investigation 7 ready to go.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Students may not be clear on how solids turn into liquids. Ask them to respond on paper or on an index card to these two questions.

Collect these quick writes and discuss the questions. Ask students how melting and dissolving are alike and how they are different. At this point, just gather their ideas.

Suggest investigating the melt-and-dissolve question using M&Ms.

Project transparency no. 18 *Foil Cup Assembly* and show students how to make the cups as you practiced. Be sure to warn them not to twist the cups as they might put holes in the aluminum.

Pass out lab notebook sheet nos. 60 and 61, *Dissolve or Melt A* and *B.*

Review the procedure. Students will first make two little foil cups. Then they get the rest of their materials and one goes in each foil cup. One goes in each cup of water. Float the foil cups. Instruct students to record their observations in the table.

As students work, check in with them. Various questions can help them focus: What happens to the colored coating in water? What is under the colored coating? What happens to the chocolate in the water? What happens to the candies that are not in water?

After the candies have been in the water for about 5 minutes, put the candies on a paper towel, squish them and record observations. The candy from the hot water squishes easily and the one from the cold doesn't at all! Make sure that students squish the candies that were in the water as well.

After cleanup, discuss melting and dissolving using the observations students made during the investigation.

Introduce that when a solid is placed in liquid and the solid disappears, we say that the solid dissolved.

Next, focus on melting. When heat energy is added to a material and it changes from solid to liquid, it is called melting.

Once students have the beginning definitions under their belts, compare dissolving and melting. Follow the discussion in the teacher guide. You want to get them to thinking about how dissolving and melting are different at the particulate level.

Heat was added to the chocolate, giving it more energy. The kinetic energy of the particles increased and as the motion of the particles increased, they began to move around and past one another. The chocolate melted.

When a solid substance is placed in water, or another liquid, particles of the solid substance break away and move into the liquid. The solid substance dissolves. Investigation 8 is devoted to dissolving and solutions, so a more precise definition is not yet needed.

Students now complete the last two questions on lab notebook sheet no. 61, *Dissolve or Melt B.*

Collect these sheets to use as an assessment of how well they are beginning to understand the processes of dissolving and melting.

<Investigation 7, Part 2>

Narrator: In this part, students place margarine, wax, and sugar in small cups and float them in hot water. They make observations and work on a mental model to explain what happens at the particle level when a substance changes state from solid to liquid.

From the kit you will need: for each group of four students, two half-liter containers, 6 small paper cups, 1 metal-backed thermometer, and 2 cut pieces of paraffin wax.

For the class you need 2 white midi-spoons, 1 plastic 250 mL cup, and toothpicks. You need to provide granulated sugar, and margarine, a knife to cut the paraffin and margarine, colored pens or pencils, ice if you choose to do the margarine melting-temperature extension, 60ºC hot water, and an overhead projector and pens.

Make copies of lab notebook sheet no. 63, *Melt Three Materials* for each student. Have transparency no. 19, *Melting Experiment* ready to go.

Prepare cubes of margarine and wax. To cut the margarine, make sure you have a cold stick that you can cut in to ½ cm cubes. Put the cubes in a cup and keep them in the fridge or a container of ice to stay cold until needed. Place a few toothpicks nearby for students to use to get the cubes.

To prepare the wax, it is easiest if you put the entire slab in a bowl of warm water. Let it soften for about 10 minutes and it will be easier to cut into ½ cm cubes. Cut enough for each group to use two cubes and then cut more to use in Part 3. Keep the paraffin cubes in a separate cup or small plastic bag.

You need to provide granulated sugar. Put a small amount in a plastic cup and put two of the small white midispoons in the cup.

You will use the metal-backed thermometers in this investigation. The metal-backed thermometers are more durable even though they aren't as precise as the glass thermometers.

Make sure you have glanced at the students' quick writes from Part 1. At the end of this part, give students about 10 minutes to revise their original ideas about melting and dissolving using different-colored pens or pencils.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review what the students did with the M&Ms. In this investigation; students are going to observe what happens when heat is added to three materials: margarine, wax, and sugar.

Project transparency no. 19, *Melting Experiment.* Ask students to work in their groups to design an experimental procedure using the suggested materials to find out if margarine, wax, and sugar will melt.

If students suggest putting the materials directly into water, ask them what will probably happen to sugar if they put it right into the warm water. Remind them that this is about melting, not dissolving!

You may want to work together as a class to refine a plan or this time, let groups move ahead, record their plan on lab notebook sheet no. 63, *Melt Three Materials,* and go for it. The table is provided to help students organize their observations. Make sure the students predict which materials they think will melt! Get to it!

After students have cleaned up, discuss their results. Ask them which materials melted. The paraffin simply softened. Nothing happened to the sugar. The margarine is completely melted. Ask what the temperature of the water was and if the melting temperature of each substance is higher or lower than the temperature of the water.

An optional extension here is to discover the actual melting temperature of the margarine. See this page of the teacher guide for more guidance.

Return to the three materials and discuss with students what happened at the particulate level for each material as it melted.

Return students’ quick writes for revision as suggested in the Getting Ready section.

<Investigation 7, Part 3>
Narrator: In Part 3, students investigate what happens if they add more heat to the wax and sugar using a candle and then take the heat away. They use these experiences to extend their understanding of melting and to reinforce the idea that different substances have different melting points.

This is what you need from the kit: for each group of four students, you need 1 piece of wax, two 2” × 4” foil rectangles, one 4× 4 square of foil, 1 candle, 1 2 × 5 cm piece of match-striking surface, cut from the sheet you’ll find in your kit, and 1 vial and cap.

For the class you need 2 cups with the prepared wax pieces and 2 midispoons for the sugar. You need to provide wooden safety matches, sugar, scissors or a paper cutter and a ruler to prepare the foil, goggles, and an overhead projector and pens.

Students need their resources books and you need to make copies of lab notebook sheets no. 64, *Wax and Sugar Questions,* and no. 65, *Rock Solid Questions.* You might want to make just enough copies of no. 64 for each group to have one.

Have transparencies no. 20, *Aluminum Foil Spoon* and no. 21, *Wax and Sugar Melting* ready.

If you are using the assessment charts, have them ready on a clipboard. You also need to make copies of lab notebook sheet no. 67, *Response Sheet—Phase Change,* to use for assessment.

Cut the aluminum foil in 2 sizes – 2 × 4 rectangles and 4 × 4 squares. The 2 × 4 rectangles are used to make aluminum foil spoons, one per pair of students. Each group gets a 4 × 4 square to wrap around the candle.

In Investigation 7, Part 3 your students will make an aluminum foil spoon. They’ll use this spoon to melt a piece of wax. In order to make this spoon, take a 2×4 piece of rectangular foil, fold the sides up on one end to make the handle, then crumple the other end around your finger tip, so that it makes a nice depression. Then you can place the piece of wax inside.

Make sure that you have enough cubes of wax. Each group will need one. You can put the cubes in cups.

There are important safety considerations to think about regarding using fire. Make sure you go over your fire-safety rules with students before hand. At the very least, students should wear goggles, tie their hair back, and not lean over the flame or the substance that is being heated. Remove papers from the table.

Caution students to remove the wax from the heat immediately after it melts before it starts smoking. The wax can flash if held over the flame too long. Flashover occurs when the heated wax releases flammable gases that catch fire. If flashover occurs, tell them to drop the spoon. They should not touch it!

Students should be aware that the sugar can burn after it melts, a chemical reaction causing it to turn brown. Be prepared to open the windows to blow out any smell if necessary.

We suggest that you put one match and one piece of striking surface in each vial. If a group fails to light their candle with the first match, they can trade the burned one for a single replacement. This eliminates horseplay with matches!

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Recall with students the 3 materials they heated up in the last activity. What happened to them? Did all 3 materials melt?

The margarine melted—it turned to liquid. The wax got soft, but didn't really melt into a liquid. And the sugar didn't seem to change at all. Ask students if wax and sugar can melt. How can we find out? Students may suggest leaving the materials in the hot water bath for a longer period of time or adding more heat.

Suggest using candles as a way to add more heat. The flame temperature of a candle is very hot—around 1400ºC. Students will make little foil spoons to hold the wax and sugar over the flame.

Show students how to make the spoons like you practiced. Show students how to prepare the candle and foil like you practiced.

Matches will be distributed in the vials—one match only. Students can exchange a burnt match for a fresh one if they can't light their candle.

Project transparency no. 21, *Wax and Sugar Melting*. It has the procedure that students will follow. Using the transparency avoids having paper around. Students can write down their observations after they have completed their work and blown out the candle.

Review safety one more time and get to it! One pair of students melts wax. The other pair of students melts the sugar.

After cleaning up, pass out lab notebook sheet no. 64 and give the groups time to discuss the questions. Then call them back to share out as a class. Follow the discussion outlined on this page of the teacher guide.

Point out that when a liquid changes state to a solid, we call that freezing. Make sure students bring their explanations down to the particle level!

Summarize melting and freezing. Remind students that any change of state is the result of change of kinetic energy of the particles of a material. Nothing changes during change of state except the motion of the particles. The particles themselves do not melt, freeze, contract, expand or change into anything else!! Nothing new is made, so change of state is not a chemical reaction. Every substance freezes at its own unique temperature.

Have students read the article *Rock Solid.* They should answer the questions on lab notebook sheet no. 65, *Rock Solid Questions*. Discuss the questions and pass out lab notebook sheet no. 67, *Response sheet—Phase Change* for assessment.

<Investigation 7, Part 4>
Narrator: In Part 4, students move from the concept of melting to that of freezing. They try to freeze water using ice and determine that they need a colder environment to make that happen. They add salt to the ice and find that enough energy can now leave the water causing it to freeze.

This is what you need from the kit: for each group of four students, you need 2 plastic 250-mL cups, 2 vials, 2 metal-backed thermometers, and 2 glass thermometers, and 2 stirring sticks.

For the class, you need 2 jars of sodium chloride, 1 large plastic 500-mL cup, 1 vial, 2 glass thermometers, 2 syringes, and 2 blue 5 mL spoons. You need to provide ice and a way to crush it using a large sturdy plastic bag and a piece of 2 × 4 lumber about 2 feet long or some other way.

You also need to provide room-temperature water, goggles, and an overhead projector and pens.

Make copies of lab notebook sheets nos. 69, 70, and 71, *Freeze Water A, B, and C.* Have transparencies no. 22, *Freeze Water with Ice* and no. 23, *Freezing Graph* ready. If you are using the assessment charts, have them ready on a clipboard.

Students need at least 25 minutes to observe the freezing process after they have set up the investigation. Therefore, you should move quickly through the first discussion and preparation.

You will need quite a bit of crushed ice for this activity and the next. Put some ice into a sturdy plastic bag, put the bag on the floor, and whack it with your 2×4. You need smaller chunks than you can usually buy, so be prepared to whack it down into the size you need. Each pair of students will need one of the smaller 250 mL plastic cups, about half-full of crushed ice.

At the beginning of the day, set up a demonstration cup. Half-fill one of the large 500-mL plastic cups with crushed ice. Put 10 mL of water in a vial in to the ice.

Put a glass thermometer in the vial and a metal-backed thermometer in the ice. This setup will be monitored by your students throughout the day, so as the ice melts, pour out the melt water and add more ice.

Plan on 2 materials stations. One station will have the room-temperature water, syringes and vials. The students will measure 10 mL of water into a vial. At the other station the students scoop up 2/3 of a cup of crushed ice, add three heaping 5-mL spoons of salt to the ice and get a stirring stick. At their tables, they stir in the salt.

They put the glass thermometer in the vial and the metal-backed thermometer in the salted ice.

The metal-backed thermometers are used to measure the temperature of the ice/salt mixture because the temperature will go way below what the glass thermometers measure.

If you are using the assessment charts, have them ready on a clipboard.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review the melting experiences students have had over the last days. Tell students that since they have spent some time with melting, they can now explore freezing.

Hold up a vial with 10 mL of water in it and ask them what its melting point is. What about freezing point? How can they freeze the water? List their suggestions on the board.

Show the students the demonstration cup and vial you set up and ask a student to read both thermometers. Ask the students what temperature water freezes at. Their response should be 0°C. Ask them if the water in the vial is frozen. Ask them if it will freeze in a while. Many students will respond that it just takes a little more time. Keep this system as is, but they will set up a vial of water and put it in a colder place to see what happens.

Ask students if they have ever made homemade ice cream. Salt is added to the ice surrounding the cream mixture. Basically, the salt makes the ice colder. We can use this idea to see if we can freeze water.

Use transparency no. 22, *Freeze Water with Ice* and lab notebook sheet 69, *Freeze Water A* to show students how to set up the investigation. They will work in pairs.

Before they get started, refer to the data table where they will record the temperatures and observations. They should record every 3 to 4 minutes.

As they get going, check that the students have put the thermometers in the correct places,

That the water level in the vial is below the ice and that they are recording temperatures and observations.

Don't forget that you should have students checking your demonstration of ice and water over the class period.

This is what you can expect to happen over the course of the next half an hour or so.

Almost immediately, the temperature of the ice/salt mixture will drop below -15ºC. The two temperatures will hold steady at -16 or so degrees Celsius and 0ºC for 8 to10 minutes as students continue to record temperatures.

Suddenly, ice will begin to form in the vial. It will look slushy but the temperature will remain at 0ºC as long as it is in the process of freezing.

After 20–25 minutes, the salted ice will have melted considerably and the temperature will have risen. The ice in the vial may be frozen solid, trapping the thermometer.

Follow the clean-up instructions on this page of the teacher guide.

The next task is to graph the data. Pass out lab notebook sheet no. 70, *Freeze Water B.* Students should draw two lines on the graph, one that connects the data points, and a best-fit line.

After students complete their graphs, they use the information on their graphs to complete the five questions on lab notebook sheet no. 71, *Freeze Water C.* They may work together.

When they are done, use transparency no. 23 as sample data in discussion.

The ideas to confirm are that while the water was freezing, the temperature remained at 0ºC. If students did Investigation 6, they should remember that the same thing happened while ice was melting.
The water surrounded by regular ice didn't freeze because once the water reached 0ºC, the system was at equilibrium and energy transfer stopped.

The water surrounded by salted ice did freeze because the salted ice temperature was lower than -15ºC. Energy continued to transfer out of the water in the vial even after it reached 0ºC and when enough energy transferred out, it froze.

At this point you can either reaffirm the heat of fusion to students who did Investigation 6 or introduce it. Heat of fusion is the amount of heat needed to change the state of a substance from solid to liquid or from liquid to solid.

<Investigation 7, Part 5>
Narrator: In Part 5, students investigate all three common states of matter using a condensation system charged with salt and ice. Hot water releases water vapor, which condenses on a cold cup and then freezes to solid water.

This is what you need from the kit: for each group of 4 students, you need 2 large plastic 500-mL cups, 2 small plastic 250-mL cups and 2 stirring sticks.

For the class, you need sodium chloride and a couple of blue 5 mL spoons. You need to provide crushed ice, your ice whacker, sturdy plastic bags, hot 60ºC water, and goggles.

Make copies of lab notebook sheet no. 73, *Water and Ice System Observations.* If you are using the assessment charts, have them ready on a clipboard. Make copies of Mid-summative Exam 7 for assessment at the end of this part.

In order to have enough time to observe the entire process of condensation and then the freezing of the condensation, students need to move quickly through the steps. You could choose to break this into a 2 day experiment but that would mean that you'd have to crush a lot more ice.

Go through your ice crushing routine again to prepare enough ice for each pair of students to have half a cup. Keep the crushed ice in the freezer.

The best way to distribute the salt this time is for you to go to each group when they are ready to put salt into their ice. This keeps the condensate on the cups from being disturbed once the activity is underway.

Preview the multimedia activity called the Particles in Solid, Liquid, and Gas.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review the last few activities with the students by asking them to recall what phase changes they have observed.

Hold up a cup of water and tell students that the particles have so much kinetic energy that the water is already in the liquid phase. Ask students what might happen if they continued to transfer heat to it. What might happen to the particles if the kinetic energy continued to increase?

Several students will probably say that the water will boil. Remind them that this means that the liquid water will change into a gas, water vapor.

Tell students that water vapor is not steam. Water vapor itself is an invisible gas. So, how can you tell if water vapor is present?

Each pair observes a large plastic cup filled to the water line with hot water. They try to figure out an answer to this last question. How can you tell that water vapor is present?

Bring the students back together and if they say they saw water vapor on the sides of the cup or in the air, remind them that water vapor is invisible. To see the water vapor, they can cool it down in order to change it from a gas to a liquid.

Use the image on lab notebook sheet no. 73, *Water and Ice System Observations* to demonstrate how to put a small cup half-filled with ice into their larger cup. They should make sure that the bottom of the small cup is not touching the water.

After a few minutes, ask for observations. Students might say that there is steam on the sides of both cups, fog or dew is on the smaller ice cup, or there are tiny drops of water on the bottom and side of the ice cup.

Ask them what that steam, fog or dew is—they should identify it as liquid water. Discuss what happened at the particle level to cause the change of state from gas to liquid.

The answer lies in the kinetic energy of the particles. When energy transferred away from the water vapor particles they slowed down, their kinetic energy decreased. They could no longer zing around as independent gas particles and they bunched together as liquid. This change of state is called condensation.

The opposite happens when energy is transferred to the particles in liquid water. The particles gain kinetic energy and fly off as independent gas particles. We call this change of state evaporation.

Here is where you break if you don't have time to complete the freezing of the condensation into ice.

Students observed condensation, a phase change from gas to liquid. How could they slow down the particles enough cause the liquid water to freeze into ice?

Suggest adding salt to the ice to bring the temperature down, just as they did in the last activity. Go to each group, dump two 5 mL spoonfuls of salt into their ice and tell them to stir carefully. They don't want the hot water in the lower big cup to slosh onto the ice cup. Leave it alone for a few minutes and then lift the ice cup and observe the bottom. They should observe a thin crust of frost—solid water. Ice will continue to form for another 5 to 10 minutes.

While they wait, ask students to work alone to complete notebook sheet no. 73, following the whole process of phase change at the particle level from the hot water all the way to the solid ice on the cup.

When they are done, follow the steps in the teacher guide to put together a step-by-step description of what happened. Ask what will happen when all the ice inside the cup melts.

After students clean up, ask them to make revisions to their descriptions then show the multimedia activity, *Particles in Solid, Liquid and Gas.* Review the big ideas that students have considered in Investigation 7. When they are ready, give them Mid-summative Exam 7.

<Investigation 8, Introduction>
Narrator: In Investigation eight, students investigate both the macroscopic and microscopic properties of solutions.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages for information about mixtures, solutions, concentration, and saturation. The Why Do I Have to Learn This? section addresses the idea of what it means for a solid to “disappear” into a liquid. The idea of concentration has a lot of relevance today as we consider public health and environmental issues.

<Investigation 8, Part 1>
Narrator: In this part, students compare a mixture of calcium carbonate and water with a mixture of sodium chloride and water. The salt mixture cannot be separated by filtering and is identified as a solution. The solution is left to evaporate, finally separating it into its components.

This is what you need from the kit: for each group of four students, you need a funnel stand, 2 lab-quality filter papers, 4 small plastic cups, 4 self-stick notes for the cups, 2 stirring sticks, 1 syringe, one ½ liter container, 1 well tray, 3 pipettes and 2 hand lenses. For the class you need 2 labeled containers of calcium carbonate, 2 jars of sodium chloride, and four white 2-mL spoons.

You need to provide water, goggles, and an overhead projector and pens. Students need their resources books and you need to make copies of Lab notebook sheets nos. 74 and 75 *Mixtures A* and *B* and no. 77, *How Things Dissolve Questions*.

Make sure you have transparency no. 24, *Well Tray Organization for Evaporation* ready. Make a copy of Investigation 8 assessment for each class. Students work in groups this time.

Get out two jars of sodium chloride and make sure they are at least half-filled. Fill two ½ liter containers with calcium carbonate, label, and cover them. Each container should have a 2 mL spoon.

Find the box of lab-quality filters. Do not use the coffee filters as they will not filter out the calcium carbonate.

Groups share well trays across periods in order to set up their evaporation samples. If you have 4 classes, you will need 8 trays, one tray for each group, assuming you have 8 groups. Label each tray by group number. Label each period like this. So for period one, they will put their salt here, their calcium carbonate here, and water here. Period 2, salt, calcium carbonate, water.

If you have more than 4 classes, you will need another 8 group trays. Label them for each additional class. Label them by group as well.

These pages of the teacher guide and transparency no. 24, *Well Tray Organization* can be used as a guide.

Preview the multimedia. Your students will interact with the Exploring Dissolving simulation. Navigate through both animations, using the info button and plan on how to use the multimedia most effectively.

Make sure you have the Assessment charts for Investigation 8 ready to go. Find the quick writes that students wrote at the beginning of Investigation 7. At the end of Part 1, give them time to review and revise their ideas about dissolving.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Give students a couple of minutes to discuss in their groups what a mixture is. List their ideas on the board.

Define mixture as a combination of two or more substances.

The substances can be 2 solids like the mystery mixture or a cup of trail mix, all liquids, like salad dressings, all gases, like air or a combination of solids, liquids and gases.

Hold up the container of calcium carbonate and tell students they will make a mixture of calcium carbonate and water. Hold up the salt and tell them that they will make another mixture of sodium chloride and water.

Pass out lab notebook sheet no. 74, *Mixtures A* and read through the procedure together. Students will first label the cups, put the substances in, and then observe using the hand lenses before adding water.

Students then add 30 mL of water to the Calcium carbonate and then add 30 mL of water to the salt, stir, and record their observations.

Compare the two mixtures—the Calcium carbonate settles to the bottom and the salt disappears.

Introduce the concept of solution. Do not throw out the mixtures. A solution results when 2 substances are mixed and it looks like one disappears in the other. The process is called dissolving. Ask which mixture is a solution.

When students answer that the salt water is a solution, tell them that a solution has two parts, the solute, which is the substance that dissolves, and the solvent, the substance in which the solute dissolves. In our solution, the salt is the solute and the water is the solvent.

Tell students that mixtures can be put together and can be taken apart. Give the students a few minutes to think about how they could separate the two mixtures they have made. They should come up with evaporating and filtering.

Hold up the funnel stand and show the students how the legs fit into the plastic. Hold up a small filter paper and show them how to fold it in half, in half again, open it up, and place it into the funnel.

Pass out lab notebook sheet no. 75, *Mixtures B.*

Students will filter both mixtures, starting with the salt. Put a labeled cup under the funnel stand to catch any liquid that filters through.

Students should record their observations under the heading "filtering results"

Students do the same with the Calcium carbonate mixture. The calcium carbonate may take up to 10 minutes to completely filter but you can stop them before that if you need to move on. They'll get the idea. When done, students place the filter papers in the empty cups.

When the filtrations are complete, compare the filter papers. They were only able to trap the calcium carbonate. Ask them to compare the two mixtures at the particle level. Why was the filter paper able to trap calcium carbonate but not the sodium chloride? Ask how they could separate the sodium chloride from the water. They will suggest evaporation.

Show them the trays you set up. Tell them to use the pipette to transfer 10 drops of each sample to the appropriate well, water in the top well, calcium carbonate filtrate next, and sodium chloride filtrate in the bottom. Make sure they use a separate pipette for each liquid.

On the lab notebook sheet, *Mixtures B,* students can record the date and time the evaporation started under Follow-up Procedures. Leave the well tray diagram to record observations the next day. This would be a good time break.

The next day, after the well trays have evaporated, give students time to observe the results using hand lenses.

There should be nothing or a slight trace of minerals in the water wells. There might be a tiny bit of calcium carbonate left in those wells. But the big ah-ha are the sodium chloride wells, where there are crystals that look suspiciously like sodium chloride crystals. Students should record their observations on the lab notebook sheet.

Ask students if and how they were able to separate each mixture and after discussion, introduce the *Exploring Dissolving* simulation on the multimedia. Make sure to touch on all parts of the simulation and repeat as necessary.

Students now read the article *How Things Dissolve* in their resources book and answer the questions on Lab notebook sheet no. 77, *How Things Dissolve Questions.*

<Investigation 8, Part 2>
Narrator: In Part 2, students continue their exploration of solutions. They make saturated solutions of sodium chloride and of Magnesium sulfate and find that they can dissolve at least 4 times more magnesium sulfate in the same amount of water.

This is what you need from the kit: for each group of 4 students, you need two plastic 120-mL bottles, 2 self-stick notes, 2 small plastic 250 mL cups, 2 coffee filters this time, a funnel stand, a syringe, a jar of magnesium sulfate with a blue 5 mL spoon, and a jar of sodium chloride with another blue 5 mL spoon.

You need to provide water, paper towels, electronic balances, goggles, and an overhead projector and pen. Make copies of Lab notebook sheets nos. 78 and 79 *How Much will Dissolve A* and *B.* Have transparencies nos. 25, *More Solute* and no. 26, *Saturated Solutions* ready to go.

If you are using the assessment charts, have them ready on a clipboard. Also, make copies of lab notebook sheet no. 81, *Response Sheet—Solutions,* to use for assessment.

Each group needs a jar of magnesium sulfate and a jar of sodium chloride and they need a lot, especially of the MgSO4. Check throughout the day to make sure the jars are full.

Remember, this time you use the coffee filters!

This is a brief outline of this part of the investigation. Make sure to read and follow the teacher guide.

Review dissolving with students. Then ask them to recall how much salt they added to 30 mL of water. They added one 2 mL spoonful.

Project transparency no. 25, *More Solute,* and ask if there is a limit to the amount of a substance that will dissolve in a certain amount of water? Is that amount the same for all substances? How can we find out?

Students work in their groups to come up with a general plan. They can use any of the materials and tools they are familiar with.

Show them the plastic bottle and cap that are new.

Their plans should include the elements listed on this page of the teacher guide. You can discuss the elements as a class or give your students more freedom.

Pass out lab notebook sheet no. 78, *How Much will Dissolve? A*. Point out that students will use 30 g of water as solvent and 2 different substances to compare as solutes, sodium chloride and magnesium sulfate, also known as Epsom salts. Groups now work together to write a final procedure. Make sure they have a method to record how many spoons of substance they add.

See the teacher guide for a few hints to move the students along. Put a self-stick note at the level of the water and label it with the solute. Have groups use a dry funnel to dump the salts into the bottles. Make sure the end of the funnel doesn't even get one drop of water on it. Dry it off if needed. A final hint is to have part of the group do the sodium chloride and the other part of the group do the magnesium sulfate at the same time.

They can speed up the dissolving by shaking the bottle. For results, you can expect that students will be able to dissolve 3 to 4 spoonfuls of sodium chloride.

Students working with the magnesium sulfate will dissolve more than 12! After they have gotten started, suggest that they put in 2 or 3 scoops at a time.

If students aren't sure that all of the solid has dissolved, the general rule is that if in doubt, add another scoop and shake to dissolve as much as possible.

When the groups have pretty much finished up, call the class together and introduce saturation. Follow up with a discussion about what the students observed as they dissolved the sodium chloride and magnesium sulfate. You can follow the questions on this page of the teacher guide.

At the end of the discussion, pose a challenge. Can the students figure out how many grams of sodium chloride and how many grams of magnesium sulfate are needed to saturate 30 mL or g of water?

Before you set groups loose to consider the challenge, ask them what was left on the bottom of the bottle—some leftover undissolved substance.

They can't count that substance because it isn't dissolved. So, they can't just weigh a scoop of substance and multiply it by the number of scoops they used. That doesn't account for the extra undissolved substance.

You might ask them how they can get rid of the undissolved substance and how they will account for the mass of the water.

In the end, have students filter out the undissolved substance using a coffee filter. They can catch the filtrate in a cup, weigh what's left. Subtract out the weight of the cup and the water to get the final amount of substance dissolved.

Provide these suggestions: students should weigh the empty cup first and subtract the mass or zero the balance with the cup.

Wet the filter with water before filtering so that it won't absorb the water in the solution. Use a different filter for each solution.

Transfer the label from the bottle to the cup so that they don't mix them up. Put the cup under the funnel and open the bottle. Pour the solution through the filter to trap all the extra undissolved salt.

When it's finished dripping, weigh the cup with the filtrate on the balance.

Students will record their data on lab notebook sheet no. 79. Point out that water is the solvent in both cases. Remind them that the mass of the solution does not include the cup! When the students are done, make sure that they have recorded their data, and clean up.

Groups record their data on transparency no. 26, *Saturated Solutions*. When all the groups have reported, consider the data and ask if there are any that are outliers. They want to make sure to disregard those before calculating the average amount of sodium chloride and magnesium sulfate that saturated 30 mL or g of water.

Ask students to compare the results and write a conclusion on their lab notebook sheet. They can complete the deeper thoughts section later.

Regroup and discuss the interactions between water (the solvent) and salt (the solute) at the particle level.

Students finish up the deeper thoughts section of the notebook sheet on their own.

When they are done, give them lab notebook sheet no. 81, *Response Sheet—Solutions,* as an assessment. The big idea here is that a solution is saturated when the solvent has no more room for more solute particles.

<Investigation 8, Part 3>
Narrator: In Part 3, students think about two solutions of magnesium sulfate, one with 20 g of magnesium sulfate dissolved in water and the other with 50 g of magnesium sulfate dissolved in the same amount of water. They find out that the second solution is more concentrated and then they pursue that thought, making their own solutions and ordering them by concentration.

This is what you need from the kit: for each group of four students, you need 2 small plastic 250 mL cups, 1 stirring stick, 1 accurate 50 mL graduated cylinder, and 1 pipette.

For the class, you need 2 jars of magnesium sulfate, 2 blue 5 mL spoons, 2 self-stick notes, and 2 ½ liter containers with lids. You need to provide water, one or two electronic balances, goggles, and an overhead projector and pens. Students need their resources books and you need to make copies of lab notebook sheets no. 83, *Magnesium Sulfate Solutions,* and no. 85, *Concentration Questions.*

Have transparency no. 27, *Magnesium Sulfate Solutions* ready. If you are using the assessment charts, have them ready on a clipboard and make copies of Mid-summative Exam 8.

The first thing you need to do is make up two magnesium sulfate stock solutions. This will provide enough for 5 classes. Label 2 containers: Magnesium sulfate solution 1 and magnesium sulfate solution 2. Solution 1 has about 20 g or 4 5-mL scoops of magnesium sulfate. Stir that one up. Solution 2 has about 50 g or 10 scoops of magnesium sulfate. Stir that one up. Put the lids on.

You will want to set up 2 different materials stations. One station has the electronic balances, two full jars of magnesium sulfate, and a couple of blue 5-mL spoons. Students will weigh the magnesium sulfate they will dissolve and later weigh 20 mL of their solution.

The other station is for the rest of the lab equipment, including the cups, stirring sticks, graduated cylinders, pipettes, and water.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Show students your stock solutions of magnesium sulfate and tell them that solution 1 is made of 200 mL of water and 20 g of magnesium sulfate. Solution 2 is made of 200 mL of water plus 50 g of magnesium sulfate.

We say that when solutions are made with the same amount of solvent but different amounts of solute, the solutions are different concentrations. Concentration is the amount of solute dissolved in a measure of solvent. Mathematically, it is the ratio between the solute and the solvent.

Ask students which solution, 1 or 2, is more concentrated. Ask them if they had equal volumes of each solution, would they both have the same mass.

Assign 2 students to weigh a 40-mL sample of Solution 1. They find that it has a mass of about 41.5 g. They also measure a 40 mL sample of solution number 2 and find that it weighs more. So, when equal volumes of solutions made with the same solute are weighed, the one with the most mass is the one that is most concentrated.

Project transparency no. 27, *Magnesium Sulfate Solutions,* and pass out lab notebook sheet no. 83, *Magnesium Sulfate Solutions*. Assign recipes to each group and have them mark on their sheets which one they are preparing.

Point out the material stations, warn students to make their measurements very precisely and get to it! We are making solution 1 with 5 g of magnesium sulfate. Make sure it is exactly 5.0 g. This might take some back and forth. Solution 1 has 25 g of water. Use the pipette to make an exact amount. Add the water to the magnesium sulfate and stir.

When students have completed making their solutions, ask them to figure out how they can determine which solution is most concentrated.

Students figure out that they can all weigh an equal amount of solution and compare. Students first zero the balance with a cup. They then determine the mass of the amount they agreed to compare, 20 mL here. 20 mL of solution 1 has a mass of 21.1 g.

When they are done, they record the mass of that 20 mL in the third column of the table on their lab notebook sheet. Have them record their results on the transparency and then order the solutions from most to least concentrated on their lab notebook sheet.

Recipes 3 and 6 are most concentrated; recipes 2, 5, and 8 are next; and recipes 1, 4 and 7 are least concentrated.

At this point they can calculate the concentration (or what is really in this case, the density) of the solutions by dividing the mass of each sample by 20 mL. Record results on the transparency and students can write them in their notebook sheet and complete the questions.

Take a few minutes to summarize the big ideas about solutions.

Assign the article *Concentration* in the Resources Book. Students should answer the questions on lab notebook sheet 84, *Concentration Questions.*

And when they are ready, give them the *Mid-summative Exam* number *8.*

<Investigation 9, Introduction>
Narrator: In Investigation 9, students observe chemical reactions. They start to identify particles as atoms and molecules. They use atom tiles, magnetic atom tiles and chemical formulas to start representing those chemical reactions as equations.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

Be sure to read through the Scientific and Historical background pages to understand atoms, different kinds of bonds, compounds, molecules, and ionic compounds. The Why Do I Have to Learn This? section addresses possible misconceptions around the term “reaction.” It also describes the models used to help students better understand how reactions happen.

<Investigation 9, Part 1>
Narrator: In the first part, students review chemical formulas and learn that the basic particles of elements are called atoms. They start to use sticky-dots as representations of atoms and build familiar compounds using those dots.

This is what you need from the kit: for each group of four students, you need the colored coding stickers which you group together in cups as described in a few moments.

For the class you need the set of magnetic atom representations, five half-liter containers or cups for the dots, and tape.

You need to provide a fine-tipped pen for each group to label the stickers. Students may have pens that are good enough. You also need scissors to prepare the dots and a large plastic zipper bag for the magnetic atom tiles. Make sure you have an overhead projector and pens.

Students need their resources books and you need to make copies of Lab notebook sheets nos. 86 *Representing Substances* and 87, *Analyzing Substances,* an optional sheet to use if you wish.

Have transparencies nos. 28, *Atoms and Compounds* and 29 *Naming Particles* ready. Make one copy of Assessment Chart 9 for each class.

Students start off working on their own and need their own sets of dots. Cut the dots in segments for each student and cut enough for all of your classes. Cut strips of: 2 blue dots, 3 orange dots, 8 red dots, 1 green dot, and 3 yellow dots. Put all the same-colored dots in the same container.

Find the large magnetic atom representations, remove them from the die-cut sheet and store them in the plastic bag. Make sure you test to see if they will stick to your white board! If not, you may have to use tape or pins to stick them to your white board or to a bulletin board

Make sure you have the Assessment charts for Investigation 9 ready to go.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Ask students to review the meaning of the word substance in their groups. List down what they recall.

Put some of the magnetic atoms on the board and use them to introduce atoms. Make sure that you have at least 3 oxygens and two hydrogens to use in a little bit. Point out examples like hydrogen, oxygen, and carbon.

Bring 2 oxygen atoms together to make a particle of oxygen gas, and ask students how many atoms have combined? Two. How many kinds of atoms have combined? One. Tell them that any substance that is made of only one kind of atom is an element.

What if there are three oxygens together? How many atoms are there? Three. How many kinds of atoms? One. Name this particle ozone and tell students that it is another form of the element oxygen.

Make a particle of water and define this particle as a compound. A compound is any particle made of two or more different kinds of atoms.

Spend a little time with the periodic table working on the differences between elements and compounds and use transparency no. 28 *Atoms and Compounds* to add to the information base. Introduce bonds, molecules, and ionic compounds.

Have students turn to this page in their resources books, which is the same as the transparency and ask them to take turns in their groups explaining the differences between the basic particles.

Ask students to discuss the questions on transparency no. 29 *Naming Particles,* in their groups.

After a few minutes introduce the colored dots as models of atoms that they can use to make models of the particles of different substances. Refer students to the magnetic atoms as the colors are the same.

Use the magnetic atoms to illustrate the set of colored dots students will get.

Ask one student per group to get cups for each member of the group and put a strip of each colored dot for each member in one cup so they can distribute them at their tables. When students return to their table, dump out the dots and put one strip of each color in each cup so that each student has a complete set.

Students should label the dots with the appropriate symbol, O for oxygen on the red dots and so on.

Pass out lab notebook sheet 86, *Representing Substances* and tell students to make representations of one particle for each substance. They should then fill in the fourth and fifth columns.

After students begin working, ask them for attention, and introduce the concept of atomic bonds and how they can represent them, either with little lines between the atoms, overlapping or touching. Any of those are fine.

Once the students are finished, use the magnetic atoms to review their work. It's okay if the atoms are not yet in "atomically" correct order. Straight lines and random orders are fine as long as all the players are present.

You might want to spend some time reviewing how subscripts work. That is, the 2 in H_2O refers only to the number of hydrogen atoms in a molecule of water.

If parentheses are added, things become a little more complicated. So, this 2 goes with the whole thing here which means that there are 6 oxygens, 2 carbons, and 2 hydrogens. You can also show them some common combinations and how they arrange.

Pass out lab notebook sheet no. 87, *Analyzing Substances* if you wish to use it for practice in class or as homework.

<Investigation 9, Part 2>
Narrator: In Part 2, students determine that limewater is a positive test for carbon dioxide by blowing into it. They represent that reaction with atom tiles—carbon dioxide plus calcium hydroxide makes new products, calcium carbonate and water. They then translate this into a written balanced equation.

This is what you need from the kit: for each group of 4 students, you need two prepared bags of atom tiles which come in the kit in die-cut sheets.

You also need 1 plastic 120 mL bottle, one #3, 2-hole stopper, two 7 ½ cm rigid plastic pipes, one 10-cm long plastic tube, and one 45-cm long plastic tube. Get out the slim straws and cut each one into 3 pieces, one for each student.

For the class, you need calcium hydroxide powder, a funnel stand, a paper coffee filter, a plastic 120 mL bottle, one of the 45-cm long plastic tubes, a small binder clip, the air pump with pin, the set of magnetic atom representations, 2 of the accurate 50-mL graduated cylinders and a ½ liter container.

You need to provide water to make the limewater and a 2-liter plastic bottle to store it in, scissors, vinegar in a basin to rinse used bottles, an electronic balance, goggles, and an overhead projector and pen.

Students will need their resources books and you need to make copies of Lab notebook sheets nos. 88 and 89 *Limewater Investigation A* and *B* as well as lab notebook sheet no. 91, *How Do Atoms Rearrange Questions.*

Make sure you have transparency no. 30, *Limewater Investigation* ready and enough copies of the teacher master called, *Atom-Tile Inventory*.

If you are using the assessment charts, have them ready on a clipboard.

The student atom tiles come in die-cut sheets. Pop out the tiles and put them into one-liter baggies. Use the teacher master sheet, Atom-Tile Inventory, which can be cut into pieces. Make sure that you have the exact number of each tile in each baggie. Put one of the inventory sheets in the baggie with the tiles. Keep extra tiles in a back-up baggie to replace those lost.

Prepare the limewater using the directions in the teacher guide. Wear goggles and avoid breathing the calcium hydroxide when preparing the limewater as the dust is an irritant.

Each class will need about 300 mL of limewater and you should prepare it a couple of days in advance. You can store it in a 2-liter bottle. You want to get rid of the extra air because the limewater will react with carbon dioxide in the atmosphere. You can do this by squeezing all the air out of the bottle all the way to the top. Screw the cap on.

For Investigation 9, Part 2 your students will set up a bottle system. To save time and avoid confusion you may want to set them up yourself.

To set up the bottle system, you'll need the plastic bottle with 30 mL of limewater, the #3 stopper with two holes in it, the long flexible tube, the short flexible tube, and two plastic pipes. To set up the system, first make sure again that you filled 30 mL of limewater into the bottle and then take your stopper, and insert the tubes into the top or the large end. They must go all the way through, so you see them at the bottom. If it's hard to put them in, you can go ahead and take one end and dip it in some water, and push it through. Sometimes that makes it a little bit easier. Then take the short tube and put it on the bottom of one of the pipes, then take the long flexible tube and put it on the top or the large end of the stopper on the same pipe. Then put the stopper into the bottle. Now you're set up to start pumping air through the limewater.

First, you will demonstrate bubbling, just plain old air through the limewater using the air pump. Ask a student to hold the bottle and then take the air pump and insert the tip into the end of the long tube. Take a binder clip and clip it on to the end, just to hold it there. This isn't an air tight seal, but it will work for this demonstration. All you need to do then is pump air through the limewater.

After the demonstration, each group of students will need a bottle system. Students will take turns blowing exhale breath into the limewater through the flexible tube. They will each use their own personal mouth piece. To make the mouth pieces, find the straws, leave the covers on, and cut them into thirds. Each student will fit the straw onto the end of the flexible tube.

Plan for 2 materials stations. One will have the limewater, the straw pieces, and the graduated cylinders.

The other station has the plastic bottles and the stopper-and-tube setups. If you choose to have students make their own setups, have all the materials ready.

Set up a clean-up station. Dump a liter of household white vinegar in a tub. Students can take their bottle and dump out the liquid into the first tub. Swish it around a couple of times in the vinegar. Rinse it in clean water and set aside to dry. This will take care of any calcium carbonate film that is left on the inside of the bottle from the reaction.

Remember to review safety with your students. They should wear goggles and if they get limewater on their skin or in their mouth, they should rinse it off immediately.

This is a brief out line of this part of the investigation. Make sure you read and follow the teacher guide.

Limewater is a substance that can be used to help identify gases. It is a saturated solution of calcium hydroxide. We can bubble gases through it and see what happens.

Write the formula for calcium hydroxide on the board. These stick together. Have a student put up the magnetic atoms to make a particle of calcium hydroxide and then identify the OH groups which like to stick together. Pump air through the limewater as you practiced. Nothing changes.

Pass out lab notebook sheet no. 88, *Limewater Investigation A* and use transparency no. 30, *Limewater Investigation,* to introduce the investigation.

Go over safety and remind students to change the straw between uses. When they have seen the limewater turn cloudy, they need to record their observations and write a conclusion.

Discuss the results and conclusions, introducing the word precipitate to indicate the insoluble new substance. Now is a good time for a break.

Reflect on the change in the limewater—bubbling air through it caused no change, but bubbling breath through it did. What was different about the exhaled air? Maybe one of the gases in breath reacts with limewater.

You need to slowly guide your students through the next part, checking for understanding as you go. First thing is to do is model a particle of calcium hydroxide on the board with the magnetic atoms. Students use the atom tiles to do the same thing.

Pass out lab notebook sheet no. 89, *Limewater Investigation B* and point out question 1.

Tell students that the starting substances in a reaction are called reactants and the new substances formed are called products.

The second question asks students to think about the other reactant. After discussion about the gas that bubbled through the limewater, the other reactant can be tentatively identified as carbon dioxide.

Once the reactant tiles for calcium hydroxide and carbon dioxide are out, tell students to put the rest of the tiles in the baggie and put it aside. The trick here is to make models of the reactants and then rearrange them to make the products using only the reactant tiles.

As students think about the products, remind them that they worked with a white powder in Investigation 8 that did not dissolve in water (calcium carbonate).

Students can take a stab at finishing up question 2 on the notebook sheet.

When done, students use the magnetic tiles to recreate the reaction on the board together as a class. So we decided that its calcium carbonate. Here's our carbonate group and then, what's left? Water.

Only after you are sure that students are with you should you put up the entire equation and model the one-to-one correspondence using arrows. No atoms are lost, none are gained.

Students are now ready to write this reaction using chemical formulas. Use the suggestions in the teacher guide to help you and then instruct students to finish their notebook sheets. Collect these to check student understanding.

Assign the article *How do Atoms Rearrange?* in the Resources Book. Students should answer the questions on lab notebook sheet 91, *How do Atoms Rearrange? Questions.*

<Investigation 9, Part 3>
Narrator: In Part 3, students think about what might happen if they were to mix hydrochloric acid and baking soda. They observe a demonstration reaction; work with the atom tiles to predict the products and then conduct the reaction themselves to confirm their predictions.

This is what you need from the kit: for each group of four students, you need 1 FOSS vial holder, 1 white midispoon, 1 30 mL unmarked vial, 1 vial of sodium bicarbonate from Investigation 1, 1 plastic 120 mL bottle, 1 stopper and tube set which you (or they) will prepare, 1 well tray, one self-stick note, a pipette and a syringe.

For the class, you need 1 plastic 120 mL bottle, 1 syringe, 1 2-mL spoon, 1 jar of sodium bicarbonate, and self-stick notes. You need prepared limewater.

Hydrochloric acid comes in a separate shipping container as a 3 Molar solution. You will dilute this by half to a 1.5 Molar solution and store it in your own bottle.

You need to provide water to dilute the hydrochloric acid, plastic bottles to store it in, vinegar in a basin, goggles, an overhead projector and pens. Students need their resources books and you need to make copies of lab notebook sheets no. 93, *Acid/Soda Reaction Products,* and no. 97, *Lavoisier Questions.*

Have transparencies no. 31, *Baking Soda and Hydrochloric Acid* and no. 32, *Test for Carbon Dioxide* ready. If you are using the assessment charts, have them ready on a clipboard. Make copies of lab notebook sheet no. 95, *Response Sheet—Reaction,* for assessment.

Make sure you have 1 vial of sodium bicarbonate per group and take out the green minispoons. Students will use the white midispoons instead. Also make sure you have enough limewater for each of your classes. Each group will use about 10 mL. About 100 mL per class should do.

Prepare a 1.5 molar solution of hydrochloric acid by diluting the acid in the kit one to one with water. Each class will need about 50 mL of dilute acid. *Always remember to wear goggles and gloves and "Do as you otter, add acid to water!"* Store the dilute acid in a clean relabeled plastic bottle.

The bottle system used in Investigation 9, Part 2 will be changed to look like this for Part 3. You need to change the stopper and tube system from the way you had it in Part 2. Notice in Part 2 the flexible tubes were on the same pipe. This time, what you will do, is take the short tube off of the bottom and then put it on the top of the other pipe next to the long tube. Set this aside for a moment and then prepare your limewater.

Use one of the vials and place 10 mL of limewater about 1/3 full in the vial. Students will place the vial into the vial holder, so it fits snuggly. To prepare the bottle system, you'll take three scoops of Sodium Bicarbonate using the midispoon and put them into the bottle. Now, take the bottle and snap it in to the large hole in the vial holder. Then take your stopper system and plug it in to the bottle. Once the bottle system is ready, one partner will get the dilute Hydrochloric acid. The student will draw in 5 mL of the Hydrochloric acid. Then the student will draw in 30 mL of air until the syringe is full. At this point the student returns to his or her station, and another student takes the long flexible tube and puts it into the limewater. They syringe goes on top of the short flexible tube and the student pushes in all of the Hydrochloric acid and all of the air.

Prepare a vinegar basin to clean the bottles as you did in Part 2. Plan for 2 materials stations. One will have the syringes and acid.

The other station is for the rest of the lab equipment, including the vial holders, midispoons, baking soda vials, bottles, stopper-and-tube setups, empty vials, and limewater with a syringe or graduated cylinder to measure 10 mL limewater into the vial.

Remember to review safety with your students. They should wear goggles and if they get limewater or acid on their skin, they should rinse off immediately.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review with students the calcium hydroxide/carbon dioxide reaction that made calcium carbonate. Ask students if they have ever made a model volcano erupt using baking soda and vinegar. Will a reaction occur between them? Whoa!!! What is the evidence a reaction occurred?

Tell students that the chemical name for vinegar is acetic acid. We know that acetic acid reacts with sodium bicarbonate. The question is will hydrochloric acid; will this acid react with sodium bicarbonate? Tell students that hydrochloric acid is the acid found in our stomachs!

Measure two 2-mL spoonfuls of baking soda into your 120-mL plastic bottle. Draw 15 mL of the dilute hydrochloric acid into your syringe. Put it into the bottle and show your students.

Write the formulas for hydrochloric acid and sodium bicarbonate on the board and tell students to get out their atom tiles to figure out the products. If they have trouble, ask if a new product was formed. Was it a precipitate? A gas? What?

Bring the work to the board and use the magnetic atoms to represent the reaction. So, what do we get? Carbon dioxide, plus water and what's left? Salt! This might be a good time for a break.

Project transparency no. 31, *Baking Soda and Hydrochloric Acid* and discuss the reactions that could possibly be the result of mixing baking soda and hydrochloric acid. Ask students how they could determine that the product of the reaction for sure was carbon dioxide.

Ask students to design an experiment to test the gas with limewater.

Use lab notebook sheet no. 93, *Acid/Soda Reaction Products,* and transparency no. 32, *Test for Carbon Dioxide,* to preview the experimental set up. Show them the materials and procedure as you practiced before, point out the materials stations, make sure they have their goggles on, and get to it.

Students need to complete the questions on the lab notebook sheet. They can use the atom tiles if they like and then bring their attention to question 3. Were they able to confirm the presence of salt, sodium chloride? Well, if it is a product, how can they confirm it? "Evaporation!"

Set up group evaporation trays, similar to how you did in Investigation 8, except this time, each group will just use one well. Period 1's sample will go in here, period 2 in here, period 3 in here, period 4 in here, and period 5 in there.

Clean up using the vinegar bath. This is a good time for a break.

The next day, check out the evaporation trays. Students should be able to identify the sodium chloride crystals, thereby confirming that it was one of the products.

Follow the suggested discussion on this page of the teacher guide.

Pass out lab notebook sheet no. 95, *Response Sheet—Reaction* to use as an assessment.

Assign the reading on *Antoine-Laurent Lavoisier*. Students can answer the review questions on lab notebook sheet no. 97, *Lavoisier Questions.*

<Investigation 9, Part 4>
Narrator: In Part 4, students learn that hydrochloric acid is also the acid found in their stomachs. They take what they've learned in previous parts about hydrochloric acid and plan an experiment to neutralize it using common antacids.

This is what you need from the kit: for each group of four students, you need 2 plastic 250 mL cups, 2 syringes, and 2 antacid tablets.

For the class, you need a 1.5 molar hydrochloric acid solution and the magnetic atom representations. You need to provide goggles, an overhead projector and pens. Students need their resources books and you need to make copies of lab notebook sheet no. 99, *Heartburn Chemistry.*

Make sure you have transparencies no. 33, *Heartburn Chemistry Results* and no. 34, *Reaction Vocabulary* ready. If you are using the assessment charts, have them ready on a clipboard and make copies of *Mid-summative 9,* for assessment.

Check to see that you have enough dilute hydrochloric acid to cover 15 mL per group. You might need about 150 mL per class.

Students will work in pairs so each class needs up to 16 antacid tablets. If you need more than come in the kit, you can order more, or buy them at the store. Check the label, though, for you want the kind that has only Calcium carbonate as the active ingredient. The tablets in the kit have 500 mg of calcium carbonate each.

Remember to review safety with your students. They should wear goggles and if they get acid on their skin, they should rinse it off immediately.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Review the Response Sheet as a nice way to segue into the question of antacids.

Go over the equation on the board with the magnetic atoms. Make sure that students have correctly written the equation, as some of them may have missed the need for two particles of hydrochloric acid in order for the equation to balance.

Show students a roll of the antacid tablets and challenge them to figure out how much acid one tablet could neutralize. Give them a few minutes to come up with ideas and then pass out lab notebook sheet no. 99, *Heartburn Chemistry* to write down the procedure they will use. Make sure they plan on adding acid to a tablet in small increments and looking for bubbles after each increment.

Ask them how they will know when the antacid has neutralized as much acid as it can.

When the reaction no longer bubbles, they will have to subtract the last unreacted milliliter of acid from the total. Review safety and get to it! Students can start off with 15 mL of hydrochloric acid in their syringe. Make sure they have a way to record each milliliter added, with a tally or some other method.

Students should find that one antacid tablet will neutralize between 8 and 9 milliliters of hydrochloric acid. They can put the leftover acid from the syringe into the cup and dump it in the sink, and clean up.

Ask students to average their group's 2 results and record the average on transparency no. 33, *Heartburn Chemistry*. Calculate the class average and ask students to complete the notebook sheet. For question 2, make sure they multiply their results by 10 to determine how much stomach acid the tablet could neutralize.

Take a few minutes to summarize the big ideas about reactions and use transparency no. 34, *Reaction Vocabulary* to ensure that students have recorded complete definitions in their notebooks.

Assign the articles *Organic Compounds* and *Dr. Donna Nelson—Chemist* in the Resources Book. When students are ready, give them the *Mid-summative 9 Exam*.

<Investigation 10, Introduction>
Narrator: In Investigation 10, students explore other classes of reactions including rusting. They also explore limiting factors which were first introduced way back in Investigation 3.

Look over the At a Glance chart paying close attention to the objectives, assessment opportunities, preparation, an outline for conducting the investigation, and when to use the student resources book.

The Scientific and Historical background pages describe different classes of chemical reactions and limiting factors. The Why Do I Have to Learn This? section reminds us that there is more to chemical reaction-life than bubbles. As our students prepare for making decisions that affect life on Earth, they need to understand how to apply and extend what they have learned in Chemical Interactions.

<Investigation 10, Part 1>
Narrator: In this part, students investigate limiting factors. They work with baking soda and a citric acid solution to determine that the quantity of product formed in a reaction is directly linked to the amount of reactant that is used up first.

This is what you need from the kit: for each group of four students, you need 1 jar of sodium bicarbonate, 1 white midispoon, 2 cups, 2 self-stick notes, 2 syringes, 2 small glass bottles, two #1-1-hole rubber stoppers, and one half-liter container for waste.

For the class you need self-stick notes, a jar of citric acid, a syringe, a small glass bottle, a #1-1-hole rubber stopper, a jar of sodium bicarbonate, 1 white midispoons and a cup of prepared citric acid solution A.

You need to provide plastic bottles to store the citric acid solutions, water, an electronic balance, goggles, and an overhead projector and pen.

Students need their resources books and you need to make copies of Lab notebook sheet no. 101 *Citric Acid/Baking Soda Reaction*. Make sure you have transparency no. 35, *Citric Acid Reaction* ready. Make one copy of Assessment Chart 10 for each class.

Prepare two stock solutions of citric acid. Each class needs about 300 mL of each solution if students are working in pairs and do multiple trials. To make Citric Acid Solution A, dissolve 16g of citric acid per liter of water and store in labeled plastic bottles. (1 liter is enough for 3 classes)

To make Citric Acid Solution B, dissolve 8 g of citric acid in 1 liter of water. Again, store in labeled plastic bottles and remember that 1 liter is enough for 3 classes. You can store it in larger bottles if you want.

Prepare to show the effect of doubling the mass of sodium bicarbonate in the reaction. You need a bottle-and-syringe system, a jar of sodium bicarbonate, a midispoon, and a cup of prepared citric acid solution A. Make sure you have the Assessment charts ready to go.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Hold up your bottle-and-syringe system. Ask students to remember when they used it to put baking soda in the bottom. We put citric acid in the syringe and pushed it in. Ask what happened to the syringe. It went up! They are going to do this again, but this time, they will compare the effects of using different amounts of citric acid in solution.

Project transparency no. 35 and go over the steps with the students. They need to set up a system for recording their results on a blank piece of paper.

List the materials on the board; Make sure students have their goggles and other materials. They should label their cups and then put a full syringe of each citric acid solution in the appropriate cup. Get to it. Make sure students do 2 to 3 trials and record their results.

Clean up and discuss the results. Students should find that the trials that they did with solution A produced about twice as much gas. Lead them to the conclusion that this solution is probably twice as concentrated as solution B.

Ask them why greater concentration results in more gas being produced and give them some time in their groups to discuss.

They should conclude that there is twice as much citric acid to react or twice as many particles available. Ask them about changing the amount of baking soda. Will that affect the amount of gas produced?

Demo using the equipment you prepared. Use six midispoons of baking soda (double the amount) and 5 mL of citric acid solution A. Results are the same as produced using three midispoons.

Give students time to come up with an explanation and then summarize the discussion introducing the terms limiting factor and in excess.

Now have students identify which reactant was in excess and which was the limiting factor in their reactions.

Pass out lab notebook sheet no. 101, *Citric Acid/Baking Soda Reaction* and give the students time to work independently. Collect the sheets to use as an assessment of how well they understand the concepts and the next day, discuss their responses.

The final readings for the course are New Technologies and Gertrude B. Elion. There is no lab notebook sheet with these readings, though there are questions at the end of the first article.

<Investigation 10, Part 2>
Narrator: In Investigation 10, Part 2 students observe a reaction between solid iron and oxygen from the air. This is what the set up looks like.

For this part of the investigation, you may choose to set up one demonstration per class (there are enough materials for 5 set-ups) or arrange your students in 5 groups to set up the experiment on their own, tear them down at the end of the class. Reuse the materials in subsequent classes. The setups at the end of the day will be used to demonstrate the results the following time.

You will need these materials from the kit for each of the five set ups: steel wool (your source of solid iron), one of the tall plastic cups and the lid that goes with it, one of the plastic graduated cylinders with the black base, a push pin, and a jar (either from the kit or one you provide).

In addition, you will need to provide a piece of cardboard to cut on, a hobby knife, an electronic balance, a hair dryer (if needed), dishwasher detergent, and a hot water source.

After students observe and discuss the rust reaction, they will view the video, *Atoms and Molecules* which you will find in the kit. Make copies of Lab notebook sheet no. 103 *Rust.*

If you are using the assessment charts, have them ready on a clipboard, and, make copies of the *Final Summative.* As this is the last investigation in the course, there is no mid-summative!

The first thing you have to do is modify the graduated cylinder. Take off the base and set it aside. Take your push pin at the 50 mL mark on the yellow, make a hole with the pin. The next thing you need to do is to modify the lid to hold the cylinder. Turn the lid upside down and use the hobby knife to extend the four straw slits. Once you're done with that, turn the lid right side up and push up the flaps. Take the graduated cylinder, turn it upside down, and push it up through the flaps. It should fit snuggly and the flaps will hold the cylinder in place.

The steel wool in the kit has been lightly oiled to prevent rusting, but that defeats the goal of the investigation. So you need to remove the oil and to do that remove a few grams of the steel wool and put it in a jar. Add hot water, enough to cover the steel wool and about 10 drops of dishwasher detergent or a stream. Close the jar and shake it vigorously for about a minute.

After shaking for at least a minute, open up the jar, take out the steel wool, squeeze out as much of the soap as you can, and then you'll need to rinse it. Either hold it under running water or put it in a tub and swish it around. When you're done the steel wool can be used immediately or you can dry it with a blow dryer for later use.

Fill the large plastic cup about halfway with water. Weigh ½ a gram of steel wool and submerge it in the cup of water. Make sure it gets completely wet. Go ahead and take it out, give it a few good shakes to get rid of the excess water, and then fluff it up. You want air to be able to pass through it as easily as possible. Take it and put it into the graduated cylinder up to the top third. Make sure not to compress it. Then push the cylinder up through the lid and snap the lid on to the cup.

Now slowly push the cylinder into the water. When you reach the 50 mL mark the water will stop rising inside, but will continue to rise outside. Push it until the water on the outside is at 45 mL and you can still see the level of the water on the inside at 50 mL. Then take the cup and put it someplace safe where the students can observe it without disturbing it.

This is a brief outline of this part of the investigation. Make sure you read and follow the teacher guide.

Have students share their previous knowledge about rust. After some discussion, tell students that when iron reacts with oxygen, the product is rust. Write the chemical name and formula on the board.

Choose how you are going to conduct this part, either in groups or as a class demonstration. Whichever way you choose, when done, make sure that the water levels both outside and inside the cup are correct. Confirm that the upside down cylinder is full of air and water cannot come in higher than the hole you put in at the 50 mL mark of the cylinder.

The next day, pass out lab notebook sheet no. 103, *Rust,* and give students time to record their observations and responses to the questions. After they have made their best effort, follow the discussion in the teacher guide and make sure students have balanced the reaction between iron and oxygen.

At the end of the day, you can dump the water into the sink and the steel wool into the trash. Save the rest of the materials for the following time you teach the course. If you want to remove the rust stains on the cylinders, use gloves and 3-molar hydrochloric acid and a bottle brush or toothbrush to clean them.

Watch the video, *Atoms and Molecules* which includes both review and new ideas. Discuss the video and prepare for the final summative.

Spend some time reviewing the big ideas that students have interacted with in chemical interactions.

When students are ready, give them the *Final Summative Exam.*