Occasional Paper No. 122

MATTER AND MOLECULES
TEACHER’S GUIDE: ACTIVITY BOOK

Glenn D. Berkheimer, Charles W. Anderson, and Theron D. Blakeslee
with the assistance of Okhee Lee, David Eichinger, and Karen Sands

Published by

The Institute for Research on Teaching
College of Education
Michigan State University
East Lansing, Michigan 48824-1034

August 1988

This work is sponsored in part by the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded from a variety of federal, state, and private sources including the United States Department of Education and Michigan State University. This material is based upon work supported by the National Science Foundation under Grant No. MDR-855-0336. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the position, policy, or endorsement of the funding agencies. © All rights reserved by Michigan State University.
The Institute for Research on Teaching was founded in 1976 at Michigan State University and has been the recipient of major federal grants. Funding for IRT projects is currently received from the U.S. Department of Education, Michigan State University, and other agencies and foundations. IRT scholars have conducted major research projects aimed at improving classroom teaching, including studies of classroom management strategies, student socialization, the diagnosis and remediation of reading difficulties, and school policies. IRT researchers have also been examining the teaching of specific school subjects such as reading, writing, general mathematics, and science and are seeking to understand how factors inside as well as outside the classroom affect teachers. In addition to curriculum and instructional specialists in school subjects, researchers from such diverse disciplines as educational psychology, anthropology, sociology, history, economics, and philosophy cooperate in conducting IRT research. By focusing on how teachers respond to enduring problems of practice and by collaborating with practitioners, IRT researchers strive to produce new understandings to improve teaching and teacher education.

Currently, IRT researchers are engaged in a number of programmatic efforts in research on teaching that build on past work and extend the study of teaching in new directions such as the teaching of subject matter disciplines in elementary school, teaching in developing countries, and teaching special populations. New modes of teacher collaboration with schools and teachers’ organizations are also being explored. The Center for the Learning and Teaching of Elementary Subjects, funded by the U.S. Department of Education’s Office of Educational Research and Improvement from 1987-92, is one of the IRT’s major endeavors and emphasizes higher level thinking and problem solving in elementary teaching of mathematics, science, social studies, literature, and the arts. The focus is on what content should be taught, how teachers concentrate their teaching to use their limited resources in the best way, and in what ways good teaching is subject-matter specific.

The IRT publishes research reports, occasional papers, conference proceedings, the Elementary Subjects Center Series, a newsletter for practitioners (IRT Communication Quarterly), and lists and catalogs of IRT publications. For more information, to receive a list or catalog, and/or to be placed on the IRT mailing list to receive the newsletter, please write to the Editor, Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.

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Abstract

This is the teacher's guide for the activity book of Matter and Molecules, a set of instructional materials about the kinetic molecular theory written at the middle school level. The complete Matter and Molecules materials include a science book, an activity book, 17 transparencies, three wall posters, and teachers' guides for both the science book (Occasional Paper No. 121) and activity book.

The Matter and Molecules materials were used in a research and curriculum development study during 1986-1988. The project staff studied Grade 6 students' prior knowledge of the aspects of the kinetic molecular theory. This information was then combined with teaching strategies identified in earlier studies to design instructional materials particularly effective in promoting meaningful conceptual change learning. Such learning requires students to go beyond the memorization of terms and to use scientific conceptions to explain common phenomena. For students, this kind of learning in science often requires them to go through the difficult process of conceptual change, reshaping and abandoning ideas or misconceptions that they have developed from experience and have believed for a long time.

The first year of the project, the Lansing Grade 6 science teachers used Models of Matter, which is the third unit in the sixth-grade level of the Houghton Mifflin Science Program. The project staff conducted pre- and post-clinical interviews and tests and observed the classrooms of four collaborating teachers. Posttests only were given to the other Grade 6 science classes. This data informed the development of the Matter and Molecules materials.

The second year repeated all segments of the first year except all teachers used the Matter and Molecules instead of the Models of Matter materials. The Matter and Molecules materials were found to be helpful to the teachers, and the students using these materials were more successful in undergoing conceptual change than students who used the Models of Matter materials.
MATTER AND MOLECULES
Teacher's Guide: Activity Book

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INTRODUCTION
WRITING DESCRIPTIONS AND EXPLANATIONS

This unit is based on a basic belief about the nature and purposes of scientific knowledge: We believe that science was developed for the purpose of describing and explaining natural phenomena. This means that an important part of teaching science consists of giving students the chance to practice their own descriptions and explanations. For that reason, this unit contains many questions that require students to write out descriptions or explanations.

Although this writing is essential for student learning, it is also a lot of work, for the students and for you. We would like to give you a few suggestions about how to make the work load manageable while still giving the students plenty of practice in developing descriptions and explanations.

You do not have to check every activity and question set yourself (though you certainly can if you want to). The last question set in each lesson cluster contains questions reviewing the content of the entire lesson cluster. If you grade those question sets, which are packaged separately so that they can be taken up or used as tests, you should be able to do an adequate job of monitoring the progress of individual students.

It is important for students to answer the remaining questions, but there are a variety of ways that they can get practice and feedback in answering these questions without your having to read every student answer. For example:

1. Students can answer their questions individually, then meet in groups of three to compare their answers and develop a group consensus answer. The group consensus answers can then be compared in a class discussion.

2. Groups of students working together on a question set or laboratory activity can develop a group consensus answer and write that group answer in their Activity Books.

3. Students can check each other’s papers. It is possible for students to learn a great deal from a class discussion that focuses on what qualities make an answer acceptable or unacceptable.

4. Student answers can be used as a basis for class discussion rather than individual checking. You can solicit a variety of answers from the students, and lead the class in a discussion of the merits of each answer.

You can probably think of a variety of other arrangements that will work equally well. What is important is that students keep writing and discussing their descriptions and explanations, with enough feedback from you or from each other to help them understand their mistakes and improve the quality of their descriptions and explanations.

Some questions are intended primarily for the purpose of eliciting students’ ideas about topics that they have not yet studied and may only partially understand. These questions should not be graded on a right-or-wrong basis; they should be used as a basis for discussion by small groups of students or by the whole class.
LESSON CLUSTER 1
States of Water

Activity 1.1: Changing Solid Water to Liquid Water--Fast

You will show that ice is really solid water by changing it into liquid water, as quickly as possible.

Get an ice cube and seal it in a plastic bag so that nothing can get in or out. Now see how quickly you can change the ice into liquid water. Time yourself.

Starting time

Ending time

Melting time

1. How did you try to speed up the melting?

2. How does this activity show that ice and water are really the same?

3. How could you change the liquid water in your bag back into ice?

4. Do you think you would have more, less, or the same amount of ice as you started out with? Explain your answer.

Continue on next page
Activity 1.1: Solid Water and Liquid Water

Teaching Suggestions:

1. Separate the class into groups of about three students each and distribute the materials. Circulate around the room to monitor the activity and to encourage the students to write answers to the questions.

2. As part of your directions, stress that the students seal the ice cube in the ziplock bags so the water does not leak out. You may want to place a time limit on the activity. The students in each group should decide together how best to melt the ice fast. Caution the students not to roll or pound the ice cube and break the bag.

3. After the students have completed the activity, collect the materials and discuss the activity.

Student Responses

Calculating time: Many students will find it easier to "count forward" from the starting time to the stopping time than to subtract the times.

1. Students' responses will vary. They might include placing the ice cube bag system between their hands, under their arms, etc.

2. This question is designed to help students focus on the key idea that a change of state does not change the substance: Ice and water are the same substance because ice melts to form only water.

3. This question gets at the major point of the activity: Water and ice are interconvertible, and thus two different states of the same substance.

Students could change the liquid water back into ice by placing the plastic bag containing the water in a freezer or pouring the water into an ice cube tray and placing it in a freezer.

4. Adequate answers include the idea that when ice melted there was no water lost or gained and thus there would have to be the same amount remaining.

(Students sometimes say that there would be less ice because some of it evaporates, or that there is more ice because ice weighs more than liquid water, perhaps because it's solid and hard. This is not true. The same amount of ice and water weigh the same, as shown in the next question.)
5. My friend predicted that the liquid water from a melted ice cube would weigh less than the solid ice cube. My friend designed an experiment to find out whether her prediction was true. She placed an ice cube in a ziplock bag, weighed it, allowed the ice to melt, and weighed it again. Note the results:

![Scale Diagram](before-after.png)

BEFORE

AFTER

Notice that there was no change in weight. Explain the results of the experiment.
5. Optional: You may want to do the experiment described in this question. If you want to check the weight before and after ice melts, check for leakage (which tends to decrease the weight) and condensation of water vapor in the air on the cold plastic bag (which tends to increase the weight).

A problem in doing this experiment is that some students believe that the condensation on the outside of the bag is really water leaking from the inside of the bag. Condensation will be discussed in Lesson Cluster 9.

The students' explanation should include the idea that the weight would have to remain the same since no water was lost or gained as the ice cube melted.

This is a very difficult idea for many students, and not of central importance for this unit. You should not expect all your students to master this idea (that mass is conserved in changes of state) and use it consistently.
Demonstration 1.2: Distilling Water

Answer the questions below after your teacher has demonstrated the distillation of water.

1. Would you expect the flask to have more water in it, the same amount, or less water at the end of the experiment? __________ Why?

2. Draw arrows on the picture below to show how the water is moving through the distillation apparatus.

3. Complete the following sentences:
   a. Inside the flask, water is changing from __________ __________ to __________ __________.
   b. __________ __________ is traveling through the tube.
   c. In the test tube, water is changing from __________ __________ back into __________ __________.
   d. The bubbles in the boiling water are made of __________ __________.

Continue on next page
Demonstration 1.2

Teaching Suggestions:

If students see water in the tube, they may think that this water is water vapor. To prevent this confusion, set the distillation apparatus up about 10 minutes before class and let it operate several minutes before the students observe it closely. Make sure students understand that there is an invisible gas (water vapor) coming out of the tube and that water is accumulating in the test tube.

Student Responses

1. Less. As the water boils in the flask, some of it changes to water vapor, moves through the gas tube, and collects in the test tube.

   (There is some confusion about the use of the terms "steam" and "water vapor." Scientists use them both to mean invisible water in the gas state. In common language, though, steam often refers to the visible condensate above boiling water. This is really tiny drops of water--liquid water! Our practice in this unit is to refer to the invisible gas as water vapor and to the visible droplets as "steam"--in quotation marks to indicate the non-scientific usage.)

2. Arrows should show water moving from the boiling water, through the tube, and into the test tube.

3. a. Liquid water to water vapor or gaseous water
    b. Water vapor
    c. Water vapor back into liquid water
    d. Water vapor. (Many students believe that the bubbles are made of air. They are not. The bubbles have only water in the gas state inside them.)

5. a. Look carefully at the tube. Can you see the water vapor inside the tube?

b. Can you see the water vapor inside the bubbles of boiling water?

c. What does this tell you about water vapor?

6. How does this experiment verify that liquid water and water vapor are two different states of the same substance?
4. No. The bubbles coming up through the water consist of water vapor, not air. Water is changing to water vapor at the bottom of the flask where it's hottest, making the bubbles.

5. a. No—water vapor is invisible. But sometimes some water condenses in the tube—changes from water vapor back into liquid water.
   b. No
   c. You cannot see water vapor—water vapor is invisible.

6. Since liquid water can change into water vapor, and water vapor can change back into liquid water, liquid water and water vapor are two different states of the same substance.
Question Set 1.3: The Smallest Pieces of Water

1. What are the smallest pieces of water called? ____________________________________________

What are these smallest pieces made of? ________________________________________________

2. Draw a picture of a water molecule and label the atoms in it.

3. Suppose you saw a tiny speck of dust floating in a drop of water. Draw a picture to show how the size of the speck of dust compares to the size of water molecules.

4. Draw arrows in the picture you drew above to show how the water molecules are moving.

5. My friend said that if you froze some water into ice, then let the ice sit completely still in the freezer, the water molecules would eventually slow down and stop moving.

Was my friend right? ________ Explain your answer __________________________________________

__________________________________________
Question Set 1.3: The Smallest Pieces of Water

1. Molecules
   Atoms (2 hydrogen atoms and 1 oxygen atom).

2. [Diagram of a water molecule]

3. Any illustration, like the one below, that shows the dust particle as much bigger than the water molecules is appropriate.

4. The arrows should show water molecules moving in all directions, sometimes colliding with each other.

5. No. Water molecules in ice are moving more slowly than water molecules in water, but they continue to move all the time. If the ice cube is put in a colder freezer, the molecules will slow down more, but they are always moving.

(Students sometimes think that molecules of ice are not moving because ice is so hard. This is not true: ice molecules are constantly vibrating. This is a difficult idea to grasp, but it will come up again in Lesson Cluster 7 on melting and solidifying.)
Question Set 1.4: Molecules and the States of Water

1. How are ice, liquid water, and water vapor the same? (Talk about molecules in your answer).

2. How are ice, liquid water, and water vapor different? (Talk about molecules in your answer. Draw pictures if it helps.)

3. My friend says that when water freezes the molecules get cold and turn hard. Do you agree? _____ Explain your answer.

4. My friend says that there is water between the molecules of liquid water. Do you agree? _____ Explain your answer.

5. My friend says that there is air inside the bubbles of boiling water. Do you agree? _____ Explain your answer.
Question Set 1.4: Molecules and the Three States of Water

1. Ice, liquid water, and water vapor all consist of the same kind of molecules—water molecules.

2. Water molecules in ice are locked in a rigid pattern, vibrate in their places, but do not move past each other.

   Water molecules in liquid water slide and bump past each other.

   Water molecules in water vapor move freely and have much greater spaces between them than either ice or liquid water.

3. No. When water freezes, the molecules themselves do not change. As water is cooled the molecules slow down and move into a rigid array or pattern and vibrate in place.

   (The property of coldness actually indicates that the molecules are moving slowly, not that they themselves are cold. Hardness indicates that the molecules are locked in a rigid array, not that they themselves have become harder.)

4. No. All water is made of water molecules.

   (The molecules are close together, but there is some space between molecules of liquids. Spaces between the molecules are empty. There is nothing in these spaces. This is a difficult idea for some students, especially those who have the naive conception that molecules are like pieces of dust or little germs in air, or bacteria or dirt in water.)

5. No. The bubbles of boiling water are water vapor and water vapor consists of water molecules only.

   (Many students get confused between boiling water and the dissolved air that comes out of water when the water is first heated. When you first start heating a container of water, tiny bubbles form on the inside surface of the container. These are air bubbles from the dissolved air in water. But the bubbles in boiling water are water vapor or steam.)
LESSON CLUSTER 2
Other Solids, Liquids, and Gases

Question Set 2.1: Are Other Substances Made Of Molecules?

1. See if you can classify the following substances by writing a solid, liquid, or gas. Can you think of other solids, liquids, or gases to add to the list below?

   Steel ________  Alcohol ________
   Helium ________  Sugar ________
   Milk ________  Carbon dioxide ________

2. Draw pictures to show how you think the molecules might be arranged and might be moving in:

   Alcohol liquid:

   Ice (solid water):

   Oxygen gas:

   (You will learn more about the answer to this question in Lesson 2.3.)

3. How are liquid water and water vapor the same? How are they different?
Question Set 2.1: Are Other Substances Made of Molecules?

1. Encourage students to add many other substances to this list.

<table>
<thead>
<tr>
<th>SOLID</th>
<th>LIQUID</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Alcohol</td>
<td>Helium</td>
</tr>
<tr>
<td>Sugar</td>
<td>Milk</td>
<td>Carbon dioxide</td>
</tr>
</tbody>
</table>

2. Students may need to be encouraged to use their imagination in drawing pictures of molecules of alcohol and oxygen. Accept any reasonable shapes, but the arrangement of molecules should be similar to any liquid, solid, and gas. (The actual shapes of alcohol and oxygen molecules are shown on pages 14 and 23 of the science book.)

**Alcohol liquid:** alcohol molecules are constantly moving, sliding and bumping past each other.

**Ice (solid water):** molecules locked in a rigid array, vibrate in their places.

**Oxygen gas:** Oxygen molecules far apart, bouncing around freely in space.

You may want to use a student analogy to illustrate the arrangement and movement of molecules in solids, liquids, and gases.

**Solids:** Students are in their seats in a classroom. They are moving but they stay in their seats—a rigid pattern.

**Liquids:** Students are doing a laboratory experiment moving past each other, but staying in their classroom.

**Gases:** Students are changing classes, moving freely and are far apart.

3. Both water and water vapor have the same kind of molecules—water molecules. They are different in that water is a liquid and water vapor is a gas. The molecules of water vapor move freely and are very far apart compared to liquid water.

(Students may wonder whether the molecules of water vapor move faster than the molecules of liquid water. They do, only if the water vapor is hotter than the liquid water. Molecules of a gas at room temperature, like oxygen or water vapor in the air, move at about the same speed as molecules of liquid water at room temperature.)
4. How are water vapor and oxygen gas the same? How are they different?

5. Why can you change ice into water but not into glass?

6. My friend says that we see the sunlight because the sun sends light molecules to us on earth. What do you think?
4. Water vapor and oxygen are both gases and they are both substances made of molecules. They are different because they have different kinds of molecules.

5. Ice and water have the same kind of molecules—water molecules. Glass molecules and the water molecules in ice are different. Therefore ice could not change into glass.

6. Light is not a solid, liquid, or gas, and it is not matter. Only matter is made of molecules. Light is a form of energy.
Activity 2.2: Making Mixtures

1. Make each of the mixtures listed below and stir it thoroughly. Look at each mixture with a magnifying glass, then describe it using the chart below.

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Can you see different substances in the mixture?</th>
<th>What does the mixture look like? (Write or draw.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt and pepper</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Salt and sugar</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Dirty water</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sugar and water</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Syrup and water</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

2. Can you tell a pure substance from a mixture by looking at molecules with a magnifier? ______. Explain your answer. ____________________________________________

3. What is a pure substance? What is a mixture? Talk about molecules in your answer. ____________________________________________

4. What do you think happened to the sugar grains when you mixed it with water? Talk about molecules in your answer. ____________________________________________

5. Suppose you could look at the sugar water with magic eyeglasses that showed the molecules. What do you think you could see? Draw or write your answer. ____________________________________________
Activity 2.2: Making Mixtures

Teaching Suggestions:

Because each group of students will prepare six mixtures, you may want to place directions on the chalkboard and assign specific tasks to each group member. This activity works best when small amounts of each mixture is used. For best results, there should be no more than one inch of the mixture in the bottom of each tumbler.

Emphasize that we can see substances but not molecules.

Student Responses

1. Salt and pepper: Yes
   Salt and sugar: Responses will vary (differences in crystal shapes are visible with a magnifying glass).
   Dirty water: Yes
   Sugar and water: No (assuming sugar is dissolved).
   Syrup and water: No

2. You could tell the difference between pure substances and mixtures if you could see molecules with a magnifier. But you cannot see molecules with a magnifier.

3. A pure substance is made up of only one kind of molecule. A mixture is made up of two or more different kinds of molecules mixed together.

4. The sugar grains break up into individual molecules.

   The molecules of both the sugar and water are constantly moving. They intermingle so that the molecules of sugar spread throughout the water.

   (Some students think that the sugar disappears and does not exist any longer. One way to tell that the sugar still exists is to taste the water. More on dissolving in Lesson Cluster 5.)

5. The sugar molecules are intermingled throughout the water molecules.
Question Set 2.3: Molecules in States of Matter

1. Pick a solid, a liquid, and a gas other than ice, liquid water, or water vapor and fill out the chart below.

   a. The substances that you picked:

   solid: ________  liquid: ________  gas: ________

   b. What does a single molecule look like? (Make up a shape if you don’t really know!)

   solid: ____________________________  liquid: ____________________________  gas: ____________________________

   c. How the arrangement and motion of the molecules of the substances would look with "magic eyeglasses."

   solid  liquid  gas

   d. If you didn’t already, draw arrows to show how the molecules of each substance are moving.

Continue on next page
2. The sun was shining in the window and we could see specks of dust floating in the air. "Oh," my friend said, "I can see the dust molecules in the air." What my friend said was almost right, but not quite. Can you explain what was wrong?


3. My friend and I went out on a boat in the ocean one day. We went swimming, and the water tasted very salty. However, the ocean water looked very clear. I said, "The ocean water appears to be pure here." My friend said, "Even "clear" ocean water is really a mixture." Was my friend right? ______________

Explain your answer. __________________________________________

__________________________

Draw your idea of what the molecules of "pure" ocean water would look like with magic eyeglasses.
Question Set 2.3: Molecules in States of Matter

Teaching Suggestions:

After the students have completed this question set, you might want to use the transparency "How are molecules arranged and how do they move?" or the poster to discuss the students' answers.

Student Responses

1. You may have to encourage some students to use their imagination in making up shapes for molecules for substances that they do not know.
   a. Students' choices will vary.
   b. Any shapes are OK, as long as different substances have differently shaped molecules.
   c. Arrangements and motions should be similar to those previously described for molecules of solids, liquids, and gases.
   d. Arrows should show vibration for the molecules of the solid, movement through space for the molecules of the liquid and gas.
LESSON CLUSTER 3
The Air Around Us

Activity 3.1: Is the Air in a Cup a Real Substance?

Let's try some activities to find out more about air. Collect some air in a small plastic bag by moving it through the air. Try to answer the following questions:

1. How do you know air is in the bag?

Squeeze the plastic bag. Then, answer the following questions:

2. Can you feel the air when you squeeze the bag?

3. As you squeeze the bag harder and harder, do you notice any difference? If so, describe the difference.

Try another activity. First, push an upside-down cup into a container of water and mark the level of water inside the cup with a grease pencil. Then, remove the cup, tape one end of a hose inside the cup, and leave the other end so it will be outside the water. Place the cup and hose in the container as shown in the picture. Do you think you can fill up the cup with water, without turning it rightside-up?

Suck the air out of the cup through the hose.

Continue on next page
2. Your friend was wrong because a speck of dust is huge compared to a molecule. A speck of dust is made of millions of billions of molecules itself. A molecule is so tiny you cannot see it even with a microscope.

3. Yes! Ocean water is a mixture of salt and water, and many other substances.

   Students' drawings should show at least water molecules and salt molecules mixed together. They may represent salt molecules any way they want.

   (There are really no salt "molecules" in ocean water, though. Salt crystals are made of equal numbers of sodium and chlorine atoms, alternatively arranged in a rigid array. The chemical name of salt is sodium chloride, and its chemical formula is NaCl (Na stands for sodium). When salt crystals dissolve in water, the sodium and chlorine atoms move about separately. They are called "ions," because one has a positive electric charge and the other has a negative electric charge.)
4. Do you notice any change in the surface level of water inside the cup? ______
   What happens? __________________________________________________________

5. Blow air back in the cup through the hose. Do you notice any change in the surface
   level of water inside the container? _____ What happened? ____________________

   ______________________________________________________

6. How can you explain this? __________________________________________

   ______________________________________________________

7. You might have noticed that however hard you pushed the glass into the water, you could not fill up the cup with water. Use what you know about molecules to explain this.

   ______________________________________________________
Activity 3.1: Is the Air in a Cup a Real Substance?

Teaching Suggestions:

Plastic bag activity:
1. When students collect air in the plastic bags, suggest that they trap air by scooping it through the air, not by blowing into it. Breathing into the bag may leave water vapor, which could be a source of confusion for this activity. Instruct students that once they have trapped air in the bag, to twist the top of the bag tightly so that no air can leak out during the activity.

Cup and hose activity:
2. You will need clear cups or plastic tumblers for this activity. To prevent the transfer of bacteria from one student to another during this activity, you should have both ends of the rubber tubing cleaned with alcohol before letting students begin. Also, allow only one student in a group to suck the air from the cup. You may also attach a straw to the end of the tube and discard it after each student uses it. Note how tape is used to keep the end of the hose near the top of the cup.

Student Responses:

1. The student should say that it is taking up space in the bag and they can feel it when they squeeze the bag.

2. Yes.

3. Students should note that the air can be squeezed into a smaller space. Advise the students not to squeeze too hard, or they'll break the bags.
Question Set and Demonstration 3.2: Clean Air and Smells

1. Name the four major gases that make up air.

2. My friend said that all molecules in the air are the same. Is my friend right?
   Explain why you think so.

3. Your teacher will release a small amount of perfume in the room. What do you think perfume is made of?

4. How did the perfume travel from where it was released to your nose? Use molecules in your explanation.

5. Ammonia is another substance that you can smell. Invent a shape for ammonia molecules and draw a picture of what air in your kitchen might look like with magic eyeglasses shortly after you opened a bottle of ammonia.
4. Students should recognize that the water level in the cup goes up when the air is sucked out.

5. The water level goes back down when air is blown into the cup.

6. Students should see that this is a result of air taking up space. When air was taken out of the cup, water had space to go into the cup. When air was pushed into the cup the water was pushed out because air takes up space.

7. The molecules of air in the cup pushed against the molecules of water, keeping the water out of the cup.
Activity 3.3: Breathing Out and Breathing In

Let's do a simple activity. Breathe on a cool piece of glass or plastic.

1. What do you see?

2. What do you think the fog is made of?

3. Where did the fog come from?

4. What does this tell you about what is in the air that you breathe out?

Now let's try an activity about carbon dioxide in air. Your teacher will give you a straw and a cup full of water mixed with BTB. BTB is a substance that is normally blue, but carbon dioxide gas (CO₂) turns it yellow. The tiny amount of carbon dioxide gas usually present in the air around us is not enough to change the color of BTB from blue to yellow.

5. Use the straw to bubble your breath through the BTB solution.

Describe the change in the solution.

6. What does this tell you about what is in the air that you breathe out?

7. How is the air you breathe out different from the air you breathe in?
Question Set and Demonstration 3.2: Clean Air and Smells

Teaching Suggestions:

1. During this question set, you will need to release a small amount of perfume.

Student Responses:

1. Nitrogen (N₂), oxygen (O₂), carbon dioxide (CO₂), and water vapor (H₂O). (Air also contains argon, helium, hydrogen, and other gases.)

2. No. Students should realize that there is no such thing as an "air molecule," but rather that air is made up of different kinds of molecules which are mixed together.

3. Molecules that can be detected by your nose.

4. Some of the molecules of perfume left the container and then mixed in and spread throughout the air until the smell reached your nose. (In addition to molecules of air moving randomly throughout the room, air currents may also help the smell move toward your nose.)

5. Students may use their imaginations to some extent in this drawing, but they should include some ammonia molecules mixed in with the other molecules of air, and should display air by making the molecules far apart from each other.

A molecule of ammonia--(NH₃)--is pictured on page 24 of the science book. Students should be able to figure out how ammonia molecules mix with the other molecules in air even before they see that picture.
Question Set 3.3: Cluster Review

1. What kinds of molecules is air made of?

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
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</table>

2. How does the size of a carbon dioxide molecule compare with the size of a speck of dust? __________________________________________

3. When you smell something, what does that tell you about the molecules in the air?
   __________________________________________
   __________________________________________
   __________________________________________

4. How do smell molecules move through the air and get to your nose?
   __________________________________________
   __________________________________________
   __________________________________________

5. (Fill in the blanks below with the names of gases in the air--nitrogen, oxygen, carbon dioxide, and water vapor.) Compared to the air you breathe in, the air you breathe out has more ____________________________, more ________________________ , and less ________________________ .
Activity 3.3: Breathing Out and Breathing In

Teaching Suggestions:

It is not particularly important that the glass or plastic the students breathe on be cold--just cool enough so when the students breathe on them they will get a fog.

Follow directions in the Science Book Teacher’s Guide (Lesson 3.3) for making and testing BTB solution.

Student Responses:

1. Students should see a fog on the piece of glass or plastic.

2. Tiny droplets of water. Students can run their fingers through the fog to see that it is water.

3. The fog came from your breath.

4. The air we breathe out contains a large amount of water vapor.

5. The solution should turn yellow. Students may ask whether the yellow BTB solution can change back to blue BTB. It usually will if left overnight. Try it. The carbon dioxide escapes from the water and BTB solution.

6. The students should respond that there is carbon dioxide in the air we breathe out.

7. The air we breathe out contains more CO₂ and more water vapor than the air we breathe in.
LESSON CLUSTER 4
Compressing and Expanding Air

Demonstration 4.1: Molecules Hitting Things

Answer the questions below after your teacher has done the demonstrations.

1. In your own words, explain how the ping pong ball stays up in the air. Try to use molecules of air in your answer.

2. Why doesn’t the basketball/football get flat when you sit on it? What is holding you up?

3. a. Are there molecules hitting the chimes when the air is still?

   b. Why don’t the wind chimes ring when the air is still?
Question Set 3.3: Cluster Review

1. Students should list nitrogen, oxygen, carbon dioxide, and water. The formulas are: N₂, O₂, CO₂, and H₂O. Their pictures should correspond to these formulas. (There are pictures of these molecules on page 23 of the Science Book.)

2. A speck of dust is trillions of times bigger than a carbon dioxide molecule.

3. When you smell something, the molecules of that substance are intermingling with the air molecules.

4. The smell molecules are constantly moving and so are the molecules of air. This constant movement causes the smell molecules to reach your nose. If the air in the room is not still, the smell molecules are also carried with the air flow.

5. More carbon dioxide, more water vapor, and less oxygen.
Demonstration 4.1: Molecules Hitting Each Other

Directions for doing the demonstration are in the Science Book Teacher's Guide.

1. Students should include these ideas: The air moving out of the hair dryer is a stream of molecules moving mainly in one direction. The molecules hitting the ball from the bottom and sides cause the ball to be lifted and held in the stream of air. The molecules hit the ball hard enough to lift it.

2. The inflated ball doesn't get flat because the air inside is made of molecules which hit the inside of the ball and push back out on it.

3. a. Yes. Molecules of air are hitting the chimes when air is still; molecules are always moving.

b. The molecules of still air are moving, but they hit on all sides of the chimes with equal force. When the wind is blowing, more molecules are hitting the chimes on one side than the other.
**Activity 4.2: Compressing Air and Water**

Before we begin this activity, let's review what we've learned about how molecules are arranged and how they move in liquids and gases. Draw in one of the magic eyeglasses below how molecules are arranged in a liquid like water, and in the other magic eyeglasses how molecules are arranged in a gas like air.

---

**WATER (LIQUID)  AIR (GAS)**

1. How far apart are the molecules of a gas compared to a liquid? ________________________________

2. In which of these two states of matter do you think it would be easier to push the molecules together? ________________________________ Why?

---

The following activity will help you see if your prediction is correct.

Your teacher will give you a plastic syringe and a cup of water. Look carefully at the syringe and move the plunger in and out. Notice that the end of the plunger has a seal so that no air can get past the plunger. Air can move in and out only through the hole in the tapered end. While you are moving the plunger in and out, feel the air coming out of the syringe.

Continue on next page
Activity 4.2: Compressing Air and Water

Teaching Suggestions:

Have the students complete questions 1 and 2, page 18 before you proceed with the activity.

Student Responses:

1. Compared to the water molecules, the air molecules in the student drawings should be very far apart. Both drawings should indicate molecular motion.

2. Students should predict that it would be easier to push air molecules together. The molecules of a gas are very far apart compared to a liquid. The gas molecules can be pushed closer together but the molecules of a liquid are already close together and cannot be pushed much closer together.
3. Below is a drawing of a syringe. How would molecules of air be arranged in the syringe when the plunger is all the way out? Draw the air molecules in the syringe.

4. Now fill your syringe with water. Hold it over the cup. Now carefully place your thumb over the end of the syringe so that no water can escape and try to push the plunger in. Can you push the plunger in when the syringe is filled with water?

5. Now try the same experiment with air instead of water and pull the plunger out as far as it will go. Place your thumb firmly over the end of the syringe. Keep your thumb on the syringe tightly so no air can escape. Try to push the plunger in. What happened?

Continue on next page
3. Students' drawings should show that molecules of air in the syringe are distributed all over the syringe, not bunched up at one end or the other. They should have a lot of space between them. (Some students think that air molecules are closer together either near the plunger or near the end by the opening. Be sure to point out that the molecules are evenly distributed around the inside of the syringe.)

4. No. The water cannot be compressed because the molecules are very close together and cannot be pushed any closer together.

5. Now the plunger will go in about half way.
6. Why can you push the plunger in when there is air in the syringe, but not when there is water in it?

7. Why can't you push the plunger all the way in with air in it?

Did your explanations for Questions 6 and 7 talk about molecules? Remember that a good explanation talks about molecules. These explanations should talk about the way molecules are arranged in liquids (water) and in gases (air). Go back and write some more for Questions 6 and 7 using these ideas about how molecules are arranged in order to explain what happens in the syringe.

Now, pull the plunger out as far as it will go. Place your thumb firmly over the end of the syringe and push it in as far as it will go. Keep your thumb on the syringe. Let go of the plunger.

8. Explain why the plunger moves back out.
6. You can push in the plunger with air because the molecules are far apart and can be pushed closer together. The molecules of a liquid are already close together so the molecules cannot be pushed closer together. (Some students explain, in a simplistic way, that water is "harder" than air. You should ask them to think about why water is "harder.")

7. You can't push the plunger all the way in because when you push the molecules closer together, they hit each other and the plunger more often. Therefore, they push out harder on the plunger.

8. The plunger moves back to the original position. This is because the molecules that were forced into a smaller space hit each other and the plunger more frequently. The molecules hitting the plunger push the plunger back to its original position.
Question Set 4.3: Thick Air and Thin Air

1. In the drawings of the syringes below, draw what you think the molecules of air would look like in the syringe BEFORE you compressed it and AFTER you compressed it.

BEFORE

AFTER

2. In the magic eyeglasses below, draw what the molecules of air would look like in mountain air and in a scuba tank.

MOUNTAIN AIR

SCUBA TANK

3. Which would have more molecules in a gallon: a gallon of air from the top of a mountain or a gallon of air from a valley? Explain your answer.

4. If the valve of a scuba tank full of air is opened, what do you think will happen? Use what you know about molecules to explain your answer.
Question Set 4.4: Explaining Bicycle Tire

1. What is happening to the air as it is being pumped into a bike tire? Is it expanding or being compressed? ______ Explain in terms of molecules.

2. My friend says there is more air near the valve of the bike tire where the air was pumped in. Do you agree with him? Explain why or why not.

3. What is happening to the air as it is released from a bike tire? Is the air expanding or being compressed? ______ Explain in terms of molecules.

4. Briefly state the two parts of a good explanation.
   a. ________________________________
   b. ________________________________
Question Set 4.3: Thick Air and Thin Air

1. The molecules in the syringe to the right should be drawn closer together. Both drawings should show about the same number of molecules. Students may draw different types of molecules.

2. The molecules in the scuba tank are much closer together than the molecules in the mountain air. (Students should also remember to use arrows to show that molecules are always in motion.)

3. A gallon of air from a valley. In a valley, molecules of air are closer together, so there would be more in a gallon than on top of a mountain. The higher you go in the atmosphere the fewer molecules you have in a gallon.

4. Air will escape. The air in the scuba tank is compressed and the molecules are pushed close together. They are moving fast and hit each other quite often. When the valve is opened, the molecules of air push each other out of the valve. The air inside the tank expands out of the tank.
Question Set 4.4: Explaining Bicycle Tire

Student Responses:

1. The molecules of air are being pushed closer and closer together. The air in the tire is being compressed.

   (Some students might say that it is expanding, because the tire expands a little when it is pumped up. But the air is being compressed. This confusion illustrates why it is important to identify the appropriate substance as part of the explanation.)

2. No. The molecules of air are constantly moving. This causes the molecules of air to spread out evenly throughout the tire.

3. The air is expanding as it escapes. When the valve is opened, the molecules of air rush out, move more freely and farther apart.

4. Should be similar to the statement in the Science Book, Lesson 4.4. A good explanation answers at least two questions:

   a. A question about substances: What substance is changing and how is it changing?

   b. A question about molecules: What is happening to the molecules of the substance?
Question Set 4.4: Cluster Review

1. What are the two questions that a good explanation must answer?
   a. A question about ______________________:

   __________________________________________

   __________________________________________

   b. A question about ______________________:

   __________________________________________

2. Explain what is happening to the air as it is being pumped into a bicycle tire. Make sure your explanation answers both questions.

   __________________________________________

   __________________________________________

   __________________________________________

3. Explain what happens if you run over a nail on your bicycle and the tire starts to leak. Make sure you answer both questions.

   __________________________________________

   __________________________________________

   __________________________________________

4. Look back at the explanation you gave for Question 8 in Activity 4.2. Why does the plunger of the syringe move back out after you let go of it? Did your explanation answer both questions? Try to write a better explanation now, one that does a good job of answering both questions.

   __________________________________________

   __________________________________________

   __________________________________________

Continue on next page
5. Helium balloons are filled with gas from a helium tank. A whole balloonful of helium gas can be compressed into one tank.

Explain how all that helium can fit in the tank. Make sure your explanation answers both questions.

6. Explain what happens when the gas in a helium tank is used to fill a balloon. Make sure you answer both questions.
Question Set 4.4: Cluster Review

1. Students can copy the answers to this question from the text.
   
   a. A question about substances: What substances are changing and how are they changing?
   
   b. A question about molecules: What is happening to the molecules of the substances?

2. An example of a good explanation: The air (substance) is being compressed as it is pushed into the tire. The pump pushes the molecules of air closer together. The teacher should remind students that a good explanation answers the two questions listed in number 1.

3. An example of a good explanation: The air (substance) escapes through the hole in the tire and expands. The molecules of the air move farther apart when they get out of the tire.

(Some students will say that the molecules move through the hole in the tire, but they will not say that they move farther apart. The reason they move farther apart is that they were pushed close together when the tire was inflated.)

4. An example of a good explanation: The compressed air (substance) inside the syringe pushes against the plunger and forces it back out. The molecules of the air push by hitting the plunger and bouncing off.
LESSON CLUSTER 5
Explaining Dissolving

Activity 5.1: Where Did The Sugar Go?

1. Look at a tea bag and some grains of sugar with a magnifying glass. Draw how they look below.

<table>
<thead>
<tr>
<th>TEA BAG</th>
<th>GRAINS OF SUGAR</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

a. Does the tea bag have holes in it? ____________________________

b. Are the holes in the tea bag big enough for a grain of sugar to get through? (If you aren't sure, try it and see! Put some sugar in the tea bag and shake it. Does any come out?)

________________________________________________________________________

c. Do you think the holes in the tea bag are big enough for molecules of sugar to get through? Explain your answer.

________________________________________________________________________

2. Put half a spoonful of sugar in the tea bag. Drape it over the rim of the cup. Add just enough water to reach the bottom of the tea bag.

Continue on next page
5. An example of a good explanation: Helium (substance) is compressed and put into the tank. The molecules of helium are pushed closer together.

(Helium gas actually consists of individual atoms rather than molecules containing two or more atoms. Most students will not know this, however, and the distinction is not important for this unit. What is important is that there are the same number of molecules—or atoms—of helium in the tank as in the balloon!)

6. An example of a good explanation: Helium (substance) expands as it leaves the tank and goes into the balloon. The helium molecules (or atoms) are moving farther apart as the gas moves out of the tank and into the balloon.
a. What do you see happening underneath the tea bag? (You can draw on the picture on the previous page to illustrate your answer if you want.)

b. Taste the water. What do you taste?

c. Why can't you see the sugar anymore?

d. How do you think the sugar got out of the tea bag?

Now look back at your text. See how your explanation compares with the one there!

e. If you let this cup stand overnight, would the sugar rise to the top, settle to the bottom, or spread evenly throughout the water?

Talk about molecules to explain your answer.
Activity 5.1: Where Did The Sugar Go?

1. Tea bag drawings should show filaments with gaps between them. Drawings of grains of sugar should show some detail and some size, and not be just dots. If students draw just dots, they may be confusing grains of sugar with sugar molecules.
   
   a. Yes
   
   b. No. Students' drawings might indicate relative size of grains and holes.
   
   c. Yes. You might point out here that molecules are much smaller than grains. Grains of sugar are made of trillions of molecules.

2. You can drape a tea bag over the side of a cup by wetting the top of the bag and pressing it over the edge.
Activity 5.2: Dissolving, Fast and Slow

1. Fill two cups with the same amount of water and put half a spoonful of salt in each. Can you think of a way to make the salt dissolve faster in one cup than in the other? How? (Don't try it yet.)

2. Try your method on one of the cups (Cup A) while you leave the other cup (Cup B) alone. How long did it take you to make the salt in Cup A to dissolve? __________ minutes.

   Are there still salt grains in the other cup? __________

   If you answered yes, then you did it! You made the salt dissolve faster in one cup!

3. You can't see the salt in your cup anymore. Does that mean it is gone? __________

   How could you tell that it is still there? ________________________________

4. Draw a picture to show how the salt solution would look through "magic eyeglasses" that showed the molecules.

---

Continue on next page
a. Students usually see wavy lines in the water under the tea bag.

b. The water should taste sweet.

c. The reason you can’t see the sugar is that it has broken into molecules—too small to see. (This question, though, will probably elicit some misconceptions from students, like "you can’t see it because it has disappeared," or "because it has melted." You can use this question to help students begin to think about the process of dissolving.)

d. Encourage students to write as much as they can and to explain their ideas clearly. Many will not have complete or even scientific explanations, which is O.K. at this point, since they are just beginning to develop this explanation. It would be a good idea to discuss three or four different student explanations before reading in the text, and point out differences between them.

e. The sugar would spread evenly throughout the water. The molecules of water and of sugar are constantly mixing. The molecules’ motion causes the molecules to intermingle evenly throughout the mixture.

(Some students might suggest that the sugar settles on the bottom. They probably do not understand that molecules are always moving, so they constantly move throughout the water.)
5. Why did your method dissolve the salt faster? Remember, your explanation should include something about substances and something about molecules.

6. Can you dissolve salt and sugar in the same water? Try it and see! Use the space below to draw a "magic eyeglasses" picture of the molecules in a solution of salt and sugar in water.

7. The salt is still there in your salt water solution, but the salt grains have been broken up into molecules. Can you think of a way to get the solid salt back? Describe your idea below.

Check with your teacher to see if you can try your method.
Lesson 5.2: Dissolving Fast and Slow

Teaching Suggestions:

For this activity use Kosher or canning salt because most table salt is sprayed with corn starch (which results in a cloudy mixture).

1. Divide the class into groups. Each group must have 2 cups containing water and salt.

2. Be sure the students understand that they must fill the cups equally.

3. Be sure the students put the same amount of salt in each cup.

4. After the activity is complete, collect materials, clean up and discuss ways students dissolved the salt more rapidly in one cup then in the other.

Student Responses:

1 & 2. Student responses will vary. Some may suggest stirring, or shaking.

3. No, the salt still exists. Taste the liquid which is salty or allow the water to evaporate and salt will remain behind.

4. The student drawing should show water molecules and molecules to represent salt.
Question Set 5.3: Cluster Review

1. The label on my mouthwash says it contains "water, glycerin, benzoic acid, polysorbate 80, FD&C Blue No. 1," and several other substances. Imagine how the molecules of those substances might be shaped, and draw a picture of what my mouthwash might look like through "magic eyeglasses."

2. I dissolved some sugar in water. One of my friends said that the dissolved sugar had just disappeared. Another friend said that the sugar melted, then became part of the water. What would you say?

3. Compare your explanation of how you got the salt to dissolve faster in Activity 5.2, Question Number 5 with the explanation in the science book. Can you make your explanation better? Try rewriting your explanation in the spaces below.

Try explaining why your method got the salt to dissolve faster. Use the parts of an explanation that you have learned about.
5. Stirring moved the water past the grains of salt, and caused more molecules of water to hit the salt grains, so the molecules of salt were broken off from the grains faster.

6. Yes. The magic eyeglasses should show molecules of water, sugar and salt.

7. Place the salt water solution in a pan and allow the water to evaporate. The solid salt will remain in the pan.
4. What are the most important things you learned from this lesson cluster? Use the space below to summarize some of the most important ideas in this lesson cluster.
Lesson 5.3: Cluster Review

Teaching Suggestions:

1. After each child has answered the questions, you may want to write several different answers to each question on the board and compare students' responses.

Student Responses:

1. Students should draw the water molecules in the way they have been drawn previously. The other molecules may be made up by the students: You may want to suggest different shapes for each molecule.

2. Both friends are wrong. This question is to help the students contrast dissolving with disappearing and melting. Students should be able to explain what dissolving is; they should show that the sugar still exists.

(You may want to point out that the sugar has not melted because the sugar or water hasn't been heated. Hot water is not hot enough to melt sugar either, although sugar dissolves faster in hot water--See Lesson 6.1).

3. Do not allow the students to just copy what they had written earlier. The explanation should mention both substances (water and salt), and water and salt molecules.
4. You might ask each student to write three statements in their activity book.

Write all student responses on the board. (Even if a response is incorrect). Now have the students group the responses, and discuss any they may feel are not correct.

Student responses might include these important points from the lesson cluster:

1. All matter is made of molecules.
2. Molecules can move from one place to another.
3. Grains can break apart into molecules.
4. I can see evidence of molecules moving from one place to another.
5. I can make something dissolve faster by stirring it.
6. When sugar or salt dissolve in H₂O the molecules break away and join with the water.
7. A molecule of sugar in a grain or a molecule of sugar in water is the same.
LESSON CLUSTER 6
Heating and Cooling, Expansion and Contraction

Activity 6.1: Candy in Hot and Cold Water

Try doing this experiment: Fill two cups half full with water, one with hot water and one with cold water. Both cups should have the same amount of water. Drop identical pieces of hard candy into each cup. Do not stir the water. Wait and watch for about 10 minutes.

While you are waiting try making some predictions:

1. a. How do you think what happens in the two cups will be the same?

2. b. How do you think what happens in the two cups will be different?

3. c. Explain your predictions.
Activity 6.1: Candy in Hot and Cold Water

Teaching Suggestions

Introduce this activity by having the students read the first paragraph and stressing that in a fair test or controlled experiment everything should be the same in the two cups except temperature. Use identical pieces of candy in the two cups. Different candies dissolve at different rates. Differences in speed of dissolving will be more apparent if the candy is broken into small pieces.

Student Responses

1. Student predictions will vary, but may include:

   a. The candy dissolves in both cups. Wavy lines will be in both cups.

   b. The candy will dissolve faster in the cup with the hot water. There will be more wavy lines in the cup with the hot water.

   c. Hard candy in hot water should dissolve faster than in cold because the molecules of hot water are moving faster and hit the candy more often and harder than in cold. That makes the water molecules knock the molecules of the pieces of candy off faster. (Many students think that the candy "melts" in hot water. You may want to explain that the candy needs a much higher temperature to melt.)
Look at the two cups after 10 minutes and compare them. Were your predictions correct? Try describing and explaining what you see.

2. a. How are the two cups the same?

b. How are the two cups different?

3. There are many ways that the two cups are the same after 10 minutes, and one important way is that some of the candy dissolved in each cup. Try to write an explanation of how this happened. Look back at Lesson Cluster 5 if you need to. Remember to answer the question about substances and the question about molecules in your explanation. Explain what happened to the candy in the water.

4. An important difference is that the candy dissolved faster in one of the cups.

   In which cup did the candy dissolve faster? What was different about the molecules of hot and cold water that would make the candy dissolve faster or slower? (Write down your best guess, then discuss your answer with the class.)
2. Student answers should include the points listed under Question number 1 on the previous page.

3. Molecules of water hit molecules of candy and knock them off of the piece of candy. The separated molecules of candy mix together with the molecules of water.

4. The cup with the hot water. Students may make several suggestions about the difference in the molecules of hot and cold water, but the only difference is that molecules of hot water are moving faster than molecules of cold water. The faster the molecules of water are moving, the more often they knock off candy (sugar) molecules.
Question Set 6.2: Heating and Cooling Solids

1. Try to summarize the main points of this lesson by writing two sentences, one about heating solids, and one about cooling solids. Your sentences should mention both changes in substances and molecules.

   Heating solids: ____________________________________________________________

   ____________________________________________________________

   Cooling solids: ____________________________________________________________

   ____________________________________________________________

2. Three of my friends were arguing about why heating the metal ball made it bigger. This is what they said:

   Barry: The ball gets bigger because the heat makes the metal molecules expand.
   Mary: The ball gets bigger because you are adding heat molecules to the ball.
   Terry: The metal molecules are still the same size but they move farther apart.

   Who was right? ____________________________________________________________ Why do you think so?

   ____________________________________________________________

   ____________________________________________________________

3. My friend taught me a way to open stuck jar lids. If you run hot water over the lid, it gets a little looser and sometimes you can open it. Try to explain why this works.

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

Continue on next page
Activity 6.2: Heating and Cooling Solids

1. When solids are heated they expand because their molecules move faster, push each other farther apart, and the empty spaces between the molecules become larger.

   When solids are cooled they contract because their molecules move slower, move closer together, and the empty spaces between the molecules become smaller.

   (Some students say that molecules become hot when solids are heated, which is not true—only the substance becomes hot. Students may also say that molecules expand, but molecules only move farther apart—the substance expands. This naive conception is held by "Barry" in question #2 on this page.)

2. Terry. When solids are heated the molecules themselves do not get larger and the number of molecules do not increase. The molecules move faster and push each other farther apart. (Since heat is not a substance, there are no heat molecules.)

3. The hot water heats the jar lid and makes it expand. This causes the lid to expand away from the jar. It does this because the molecules move faster and push each other farther apart when the jar lid is heated.

   (The process actually is a little more complicated than the above explanation implies. The jar is also heated and expands, but not as much as the lid because metal expands more than glass with a given rise in temperature.)
4. Most sidewalks have cracks filled with tar every few yards. These are called expansion joints. During the summer these cracks are very narrow. During the winter they are wider. Explain why this happens. (Hint: First explain what happens to the concrete slabs, then explain what happens to the size of the cracks.)
4. In summer the sidewalks get hot and expand compared to the winter. When the sidewalk is heated the molecules move faster, push each other farther apart and the empty spaces between the molecules become larger. Each section of sidewalk is a little larger in the summer than in the winter. The cracks between the sidewalk sections are smaller in the summer than in the winter.
Activity 6.3: The Thermometer

NOTE: DO NOT TOUCH THE BULB OF THE THERMOMETER DURING THIS ACTIVITY.

1. Look very carefully at the thermometer that your teacher gave you. The colored column looks thick when you look at it from the front, but that is because the glass magnifies it. Look at the thermometer from the side. Can you see how thin the column of colored liquid really is? Where is almost all of the colored liquid in the thermometer?

2. Read the temperature on the thermometer. What is the thermometer reading? Do you think the thermometer reading would change if you turned it in different directions? Now, without touching the bulb, try reading the thermometer when it's on its side and upside down. Does turning the thermometer around change the reading?

3. Now put the thermometer into warm water and watch what happens to the column of the colored liquid. Try explaining it.
   a. What do you think happens to the molecules of the colored liquid when the water warms it up?

   b. How does that make the colored liquid move?

4. My friend says that the liquid goes up when the bulb gets warmer because "heat rises." Do you think that is the correct explanation? How could you show that you were right?
Activity 6.3: The Thermometer

Student Responses:

1. Most of the colored liquid is in the bulb. (The colored liquid is probably alcohol colored with dye.)

2. The position of the thermometer should not affect the temperature reading.

3. a. When the liquid is heated the molecules move faster, bump into each other harder, and push each other farther apart.

   b. This causes the colored liquid to expand up through the thermometer tube which gives a higher temperature reading.

4. No. If you turn the thermometer upside down and heat the bulb, the liquid still expands, but it goes down, not up.

   (The idea that "heat rises" is familiar to students, so they often use it to explain something that "gets higher" when it is warmed. This naive conception may come up again in Lesson 6.4, where warm hands are used to expand air in a bottle and force some of the air out of the bottle's top.)

   In situations where hot substances (not "heat") rise (like ocean currents and weather fronts), it would be more accurate to say "hot liquids and gases are pushed up." Heated fluids (liquids or gases) expand, become less dense than the cooler fluid around them, so that hot fluids are buoyed up by the surrounding cooler fluid. This process is known as convection, and is not included in this unit.)
5. Try putting the bulb of the thermometer in cold water. What happens to the colored liquid?  

How could you explain what happened?
5. The colored liquid gets smaller or contracts. When the liquid is cooled it contracts because the molecules slow down and move closer together. This gives a lower temperature reading.

Some students may remember from the Miracle of Water that water is an exception to this general rule between 0 degrees Celsius and 4 degrees Celsius.
Activity 6.4: The Dancing Dime

1. Your teacher will give you an empty soda bottle from the refrigerator. The bottle isn't really empty, though. What substance is inside it? ________________

    Do you think that substance is hot or cold? ____________________________

2. Wet the rim of the bottle and place a dime on it. Make sure that the space between the dime and the rim is wet enough to seal the opening so that nothing can get in or out. Wrap your hands around the bottle to warm it. What happened?

3. Can you explain what happened? Talk about both substances and molecules in your explanation.

4. Instead of placing a dime on the rim of a cold soda bottle, my friend placed a balloon over the rim.
   a. What do you think would happen to the balloon as the bottle got warm? ____________________________
   b. Use molecules in your answer to explain what happened to the balloon. ____________________________
   c. My friend said that if you turn the soda bottle upside down, the balloon would get smaller. Was my friend right? ________________

    Use what you know about molecules to explain your answer.
Activity 6.4: The Dancing Dime

Teaching Suggestions:

This activity will work only if the dime forms a tight seal at the top of the bottle. It needs to be wet around the edges to do this.

Student Responses:

1. Air
   - Cold

2. The dime jumped or danced.

3. When the air inside the bottle is heated it expands because the molecules of air move faster and hit each other harder. This pushes the molecules farther apart. The expanding air pushes on the dime and forces its way out of the bottle. This makes the dime jump or dance.

Note: A good optional activity is to place a balloon on a large, cold soda bottle. As it warms up the balloon will inflate. Challenge the students to explain this change by using the kinetic molecular theory.

4. a. The balloon would get larger or expand.

b. When the air inside the bottle was heated it expanded because the molecules of air moved faster, hit each other harder, and moved farther apart.

   (Some students explain what happens by saying that "heat rises." But the air in the bottle does not move upwards, it only expands and a small amount of air moves out of the opening. Those students who say that "heat rises" will probably be surprised if they tried this activity with the bottle upside down.)

c. No. The molecules move in all directions, not just up. The molecules throughout the bottle and balloon moved faster, hit each other harder, and moved farther apart.
Question Set 6.4: Lesson Cluster Review

1. Try to summarize the main points of this lesson cluster by answering the two questions below. Talk about substances and molecules in each answer.
   a. What happens when substances are heated?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

   b. What happens when substances are cooled?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

2. In the ball and ring experiment, my friend figured out a good way to get a hot ball through a cold ring. He heated the ring! Explain why his method worked.

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

3. Is it correct to say that heat makes the molecules of a substance expand? Why or why not?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

4. If you want something to dissolve fast, should you mix it with hot water or cold water? Why?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
Question Set 6.4: Lesson Cluster Review

Student Responses:

1. a. When substances are heated they expand because their molecules move faster, hit each other more often and push each other farther apart. The empty space between the molecules becomes larger, causing the substances to expand.

   b. When substances are cooled they contract because their molecules slow down, hit each other less often and move closer together. The empty spaces between the molecules become smaller, causing the substances to contract.

2. When you heat the ring it expands and the hole in the ring becomes larger, allowing the ball to go through. The ring expands because when it is heated its molecules move faster, hit each other more often, and push each other farther apart.

3. No. The molecules themselves do not expand or contract. They only move faster or slower.

4. Hot water. The molecules of the hot water are moving faster than the molecules of cold water. The faster the molecules move the more often they will hit the substance and the faster they will knock off molecules of the substance. The hot water will, therefore, dissolve a substance faster than cold water.
LESSON CLUSTER 7
Explaining Melting and Solidifying

Question Set 7.1: Melting Ice and Freezing Water

1. Fill in the blanks.
   a. When a solid changes to a liquid, the process is called:
      ____________________________________________.
   b. When a liquid changes to a solid, the process is called:
      ____________________________________________ or ____________________________________________.
   c. When a liquid changes to a gas, the process is called:
      ____________________________________________ or ____________________________________________.
   d. When a gas changes to a liquid, the process is called:
      ____________________________________________.

2. What causes water molecules to break out of their rigid pattern when the ice is warmed up?
   ____________________________________________
   ____________________________________________
   ____________________________________________

3. What causes water molecules to stick close together in a rigid pattern when water gets cold?
   ____________________________________________
   ____________________________________________
   ____________________________________________

4. How is melting like expansion caused by heating? How is it different?
   ____________________________________________
   ____________________________________________
   ____________________________________________
Question Set 7.1: Melting Ice and Freezing Water

Teaching Suggestions:

You should remind students to use the elements of a good explanation when they answer the short answer/essay type questions.

Student Responses:

1. a. melting
   b. freezing or solidifying
   c. evaporation or boiling
   d. condensation or condensing

2. When ice is heated, the molecules begin to move faster and this increased jiggling causes water molecules to break apart from each other and out of their rigid array; so the ice melts into water.

3. When liquid water is cooled, the molecules slow down. When water molecules slow down, the attraction between them causes the molecules to clump together and settle into a rigid pattern. The water has frozen, or turned into ice.

4. Students should mention in their responses that in both melting and expansion, a solid substance is being heated and its molecules are jiggling faster. However, in melting, the molecules jiggle fast enough to break out of their rigid pattern, whereas in thermal expansion, the molecules remain in the rigid pattern but only move farther apart.
Activity 7.2: Melting and Solidifying Kitchen Substances

1. Your teacher will demonstrate the heating of four substances. One is a liquid, olive oil. The other three are solids, shortening, chocolate, and paraffin or candle wax. Can all three of the solids be changed into liquids? Heat the solids in boiling water. Which solid melts at the highest temperature?

2. Will all four substances change to solids in ice water? Which substance solidifies at the lowest temperature?

3. What are some other substances that can change states in a kitchen? List as many as you can:

4. Pick one solid kitchen substance and explain what happens to its molecules as it melts.

5. Pick one liquid kitchen substance and explain what happens when it solidifies.

6. Expansion occurs when heating a substance makes the molecules move faster, so they jiggle farther apart. How is melting different?
Activity 7.2: Melting and Solidifying Kitchen Substances

Teaching Suggestions:

1. You should do this activity as a demonstration since it requires very hot water.

2. Have the hot plate set up with a beaker of boiling water. Display the chocolate, paraffin, and shortening so the students can see them.

3. Do not put the test tubes directly from boiling water into ice water. The test tubes are likely to break. Cool the test tubes in a test tube rack first.

4. After the students have observed the demonstration, stress that pure substances were not used in this demonstration. The substances were actually mixtures.

Student Responses:

1. Chocolate or paraffin (There is a great variety of mixtures called chocolate. Some melt in your hand while others will not melt in boiling water.)

2. Yes. Olive oil

3. Student responses will vary. Possibilities include cheese, butter, creamy peanut butter, ice cream, and frozen juice concentrate.

4. Choice of substance will vary with the student. Students should explain, regardless of the substance, that when something melts, its molecules move faster and break out of their rigid array.

5. Choice of substance will vary with the student. Students should respond that in all solidifying substances, the molecules slow down. When they do this, the attraction between the molecules causes them to clump together and form a rigid pattern or array.

6. Melting is different because when a substance melts, its molecules not only bounce a little farther apart, but they jiggle fast enough to break out of the rigid pattern that they are in as a solid.
Question Set 7.3: Cluster Review

1. Fill in the names for the changes of state.
   
   a. When a solid changes to a liquid, the process is called ____________________.
   
   b. When a liquid changes to a solid, the process is called ____________________.
   
   c. When a liquid changes to a gas, the process is called ____________________.
   
   d. When a gas changes to a liquid, the process is called ____________________.

2. Why do molecules of a solid break out of their pattern if the solid is heated enough?
    __________________________________________

3. Why do molecules of a liquid form a rigid pattern if the liquid is cooled enough?
    __________________________________________

4. How is melting gold like melting ice? How are they different?
    __________________________________________

5. How is freezing liquid oxygen like freezing water? How are they different?
    __________________________________________

6. Label the following changes as melting, dissolving, expansion, or solidifying.
   
   a. ________________ candle wax turns from solid to liquid.
   
   b. ________________ the liquid rises in a thermometer.
   
   c. ________________ Kool-Aid is stirred in water until all the solid pieces are gone.
   
   d. ________________ lava flowing out of a volcano cools and hardens.
Question Set 7.3: Cluster Review

Teaching Suggestions:

This question set may be used as an evaluation tool. If you choose to use it in this way, make sure to take the Change of State poster down or cover it.

Student Responses:

1. a. melting
   b. freezing or solidifying
   c. evaporation or boiling
   d. condensation or condensing

2. Students should include the idea that when a substance is heated, molecules move fast enough to break out of the rigid pattern or array.

3. Student responses should mention that when a liquid is cooled, the molecules slow down. The attraction between the molecules makes them clump together and settle into a rigid pattern or array.

4. The process of melting gold is very similar to the process of melting ice. In both cases the molecules move fast enough to break out of their rigid pattern. Gold, however, has stronger attractive forces between its molecules, so it melts at a much higher temperature than ice does.

5. This question is similar to the last. Students should state that the freezing process is similar in both cases: Molecules slow down, move closer together, and fit together in a rigid pattern. The difference is that liquid oxygen freezes at a temperature much, much lower than water.

6. a. melting
   b. expansion
   c. dissolving
   d. solidifying
LESSON CLUSTER 8
Explaining Evaporation and Boiling

Question Set 8.1: Explaining Evaporation

1. How many situations can you think of where water evaporates? List as many as you can in the space below.


2. Pick one of the situations above and explain what is happening. Be sure that your explanation discusses both substances and molecules.


3. Will a towel dry out faster in humid air or in dry air? Explain why.


4. If you want your towel to dry out quickly after you have used it, should you leave the bathroom door open or closed? Why?


Continue on next page
Question Set 8.1: Explaining Evaporation

1. Student responses will vary. They may include puddles after a rainfall, morning dew, water evaporating from lakes, and so on.

2. Although choice of situation will vary, student responses should be consistent with the Science Book's explanation of evaporation, also found on the inside back cover. Adequate responses include the following ideas: Liquid water is changing to gaseous water or water vapor. The molecules in the liquid water are sliding past and bumping into each other, and as they do so, some of the molecules gather up enough speed to escape from the liquid water's surface into the air.

3. Dry air. The air has more room for water molecules when the air is dry; therefore, water molecules can escape faster from the towel. (This is an adequate explanation for this unit. Actually, if the air is humid, some of the water molecules in the air condense back onto the towel.)

4. Open. If you close the door, the molecules can only escape out from the towel as far as the bathroom door. The air will quickly become humid, and the towel will not be able to dry out any further.
5. (BONUS) a. Evaporation occurs when fast-moving water molecules escape from liquid water and leave the slower-moving molecules behind. What do you think happens to the temperature of the liquid water? __________________________________________________________________________

Why? __________________________________________________________________________

________________________________________________________________________________

b. Why does your head get cold if you go outside without drying your hair?

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________
5. a. The temperature of the water decreases or gets colder because the fastest moving molecules are leaving the water. Water with fast moving molecules is hotter than water with slower moving molecules.

b. The faster moving molecules are leaving the water on your head and going into the air, leaving the slower moving water molecules behind. Therefore, your head feels cool.
Question Set 8.2: Where Does the Water in the Air Come From?

Look back to Activity 3.3. Do you remember seeing the moisture when you breathed on the glass? Try explaining how that moisture got there in more detail.

1. Where did the water molecules in the air that you breathed out come from?

2. How did they get into the air?

3. Why can't you usually see water in the air that you breathe out?

4. Every day billion of gallons of water flow into the oceans from rivers all over the world, but the amount of water in the ocean stays about the same. That means that billions of gallons of water must also be getting out of the oceans every day. How is this happening?

5. Explain what is happening to the water at the surface of the ocean. Talk about both substances and molecules in your explanation.

Substances: 

Molecules: 

Continue on next page
Question Set 8.2: Where does the water in the air come from?

Student Responses:

1. Your mouth, throat, and lungs. If we trace the water back farther inside your body, it comes from the process of cellular respiration, where food is combined with oxygen to release energy. Water and carbon dioxide are the products of cellular respiration.

2. When you breathe in and out some of the water molecules on the surface of your lungs, throat, and mouth move fast enough to escape into the air. The air that you breathe out, therefore, is very humid or has a lot of water molecules in it.

3. You can't see the water in the air because water vapor is invisible. The water molecules are too small to see and too far apart in the gas state.

4. Billions of gallons of water evaporate from the oceans everyday and mix with the air.

5. Substances: Liquid water is constantly changing to water vapor at the surface of the ocean. Another way to say this is that water is constantly evaporating from the surface of the ocean.

Molecules: Some water molecules are moving fast enough to escape the liquid water at the surface of the ocean. Since the water molecules move into the air and the air molecules are constantly moving, the air molecules and water molecules intermingle or mix.
6. Identify each of the changes in substances below as: expansion, contraction, dissolving, melting, solidifying, or evaporating.

a. _____________________: melted candle wax drips down and turns hard
b. _____________________: a puddle dries up
c. _____________________: a balloon blows up on top of a bottle when the bottle is warmed
d. _____________________: the level of the liquid goes down in a thermometer
e. _____________________: dew on the grass dries up when the sun shines on it
f. _____________________: iron is heated in a furnace until it turns into a liquid
g. _____________________: sugar is stirred in a glass of water until all the solid pieces are gone
6. a. solidifying
   b. evaporating
   c. expanding
   d. contracting
   e. evaporating
   f. melting
   g. dissolving
Activity 8.3: Alcohol Evaporation Race

1. Your teacher will give you two ml of alcohol, which evaporates more quickly than water. See how fast you can evaporate it completely. Time yourself.

   Starting time:        ____:____ minutes and ____ seconds
   Finishing time:       ____:____ minutes and ____ seconds
   Time to evaporate:    _______ minutes and ____ seconds

2. Describe what you did to make the alcohol evaporate faster.

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

3. The molecules of alcohol are different from water molecules (see Lesson Cluster 2 for a picture of an alcohol molecule). But the process of evaporation is essentially the same. Try explaining how the alcohol evaporates.

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

4. Can you think of another way to change the liquid alcohol into alcohol gas that would be even faster? If you can, describe how you would do it.

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
Activity 8.3: Alcohol Evaporation Race

**Student Responses:**

1. Student responses will vary. Students may find it easier to calculate elapsed time by "counting forward" from the starting time to the finishing time.

2. Student responses will vary. They may have thought of blowing on the alcohol, fanning it, spreading it out, or stirring it.

3. Students should include the following ideas in their responses: Alcohol molecules in liquid alcohol slide around and bump into each other. Some of the molecules are moving fast enough to escape from the surface of the liquid, thus, the liquid changes to a gas. The alcohol molecules mix in with the air.

4. Student answers will vary. They may include any of the methods described above, and they may also mention heating the alcohol. (Burning the alcohol is not an acceptable answer, as burning destroys the molecules. The chemical reaction for this is: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$)
Question Set 8.4: Lesson Cluster Review

1. The story "Bartholomew and the Oobleck," by Dr. Seuss, tells how King Derwin of Didd got his magician to make millions of tons of a sticky green substance called Oobleck. Everyone in the kingdom is stuck until the king says, "I'm sorry." Then,

"The sun began to shine and fight its way through the storm... all the oobleck that was stuck on all the people and on the animals of the Kingdom of Didd just simply, quietly, melted away."

a. What would be a more scientifically accurate word than "melted" to describe what happened to the oobleck?

b. What must have happened to the molecules of the oobleck?

c. Show what the air of the Kingdom of Didd might have looked like through magic eyeglasses after the oobleck "melted away." (You can invent your own shape for oobleck molecules.)

2. Sometimes we say that morning fog is "burned off" by the sun when the sun rises. The fog is made of tiny drops of water. Explain what actually happens to the water molecules in these drops when the sun heats the drops up by shining on them.
Question Set 8.4

Student Responses:

1. a. evaporated

   b. Some of the molecules of oobleck would have been moving fast enough to escape the surface of the liquid oobleck. Eventually all of the oobleck molecules would have mixed in with the air.

   c. The air should show at least two different molecules that make up air, with oobleck molecules mixed in.

2. The heat from the sun makes the water molecules move faster. The molecules move around and bump into each other until some of the molecules speed up enough to escape the water droplet. This process continues until liquid water changes to water vapor.
3. What is the difference between evaporation and boiling?


4. Explain how you can smell an open bottle of vinegar even though you are across the room.
   a. What is actually reaching your nose?
   b. How did the vinegar molecules get into the air?
   c. How did the vinegar molecules reach your nose?
3. Student responses should include the following ideas: In evaporation, individual molecules are escaping from the surface of the liquid into the air where their motion becomes freer and more random. In boiling, molecules move faster at the bottom of a heated container. They eventually move fast enough to change to a gas and group together to form bubbles, which rise to the top and escape. Also, water only boils when it is heated; water does not have to be heated to evaporate.

4. a. molecules of the vinegar; vinegar gas

b. Faster moving molecules escaped from the surface of the vinegar and spread through the air.

c. The vinegar molecules that escaped from the liquid mixed in with and spread throughout the air, since molecules are always moving.
LESSON CLUSTER 9
Explaining Condensation and the Water Cycle

Demonstration 9.1: Distilling Dirty Water

Answer the questions below as your teacher is demonstrating the distillation of dirty water.

1. Describe the appearance of the substances:
   a. In the flask of boiling liquid:

   _____________________________________________________________

   _____________________________________________________________

   _____________________________________________________________

   b. In the glass tubing:

   _____________________________________________________________

   _____________________________________________________________

   _____________________________________________________________

   c. In the test tube:

   _____________________________________________________________

   _____________________________________________________________

   _____________________________________________________________

Continue on next page
Demonstration 9.1: Distilling Dirty Water

Teaching Suggestions:

Make sure that all the students can see the apparatus during the demonstration. Keep students alert to the demonstration by asking questions (such as "What do you see happening here?") as you go along.

Student Responses:

1.  
   a. A colored liquid bubbling in the flask

   b. Nothing (Some condensation is possible but not likely if the flask has been boiling for at least 10 minutes.)

   c. Clear or uncolored liquids
2. What kinds of molecules would you expect to see with magic eyeglasses:

   a. In the boiling liquid: _____________________________________________

   b. In the glass tubing: _____________________________________________

   c. In the test tube: ________________________________________________

3. Do you think that all of the substances in the flask are boiling?

   ____________________________________________ Why or why not?

4. Explain what is happening (in terms of substances and molecules):

   a. In the flask of boiling liquid: _____________________________________

   b. In the glass tubing: _____________________________________________

   c. In the test tube: ________________________________________________
2. 
   a. Molecules of water, dye and salt
   
   b. Water molecules or molecules of water vapor
   
   c. Water molecules in liquid water

3. No, because only the water made it to the test tube; water is the only substance boiling. If the dye or salt had been boiling, some of the molecules of dye or salt would have also made it to the test tube.

4. Students should include the following ideas in their responses:
   
   a. All the substances in the flask are being heated, so the molecules are moving faster. The molecules of water that are moving fast enough so that liquid water changes directly to water vapor on the bottom of the flask and forms bubbles which rise to the top of the mixture and escape.
   
   b. Invisible water vapor must be passing through the glass tubing because water vapor is condensing to liquid water in the test tube. Water vapor is invisible because water molecules are too small to see and they are far apart and moving freely through the tube.
   
   c. The water vapor enters the cold test tube and changes back to liquid water. When the water molecules enter the cold test tube, they are moving rapidly, are far apart, and are moving freely. In the cold test tube, the water molecules begin to slow down and cluster together to form liquid water.
Demonstration 9.2: Purifying Water Without Boiling

Answer the questions below as your teacher is demonstrating the water cycle.

1. Label these things in the illustration above:
   a. a place where water is evaporating
   b. a place where water is condensing
   c. a place where there is dirty water
   d. a place where there is water vapor
   e. a place where there is pure water

2. What do you think is happening to the amount of water in Cup A?

   Explain what is happening to the water in Cup A in terms of substances and molecules.

Continue on next page
Question Set 9.2: Purifying Water Without Boiling

1. a. Cup A
   b. On the underside of the plastic wrap, especially near the weight.
   c. Cup A
   d. All through the container
   e. Cup B and underneath the plastic wrap

2. The amount of water is becoming less or decreasing. The water in Cup A is evaporating or changing from a liquid to a gas. As Cup A is heated, more of the water molecules are moving fast enough to escape the surface and mix with the air.
3. What do you see on the underside of the plastic wrap, especially under the weight?

____________________________________________________________________________________

Explain where the drops of water are coming from in terms of substances and molecules.

____________________________________________________________________________________

____________________________________________________________________________________

4. Cup A has water, salt, and food coloring in it. Cup B has pure water. Why can't the salt and food coloring get over to Cup B?

____________________________________________________________________________________

____________________________________________________________________________________

5. Do you think the air in the container has water in it? ________________

Why can't you see the water in the air? ____________________________________________

____________________________________________________________________________________
3. Drops of water. As the fast moving molecules in the water vapor come near the cool plastic wrap, they slow down and the attraction between molecules causes them to cluster together to form droplets of water.

4. The salt and food coloring boil at a much higher temperature than water; they do not evaporate from Cup A.

5. Yes, the water molecules are moving rapidly, are very far apart, and too small to see.
Question Set 9.3: Evaporating and Condensing

CONDENSATION  SPREADING  EVAPORATION
OF WATER VAPOR

1. Where inside the solar still would you expect to find these kinds of molecules:
   a. Water molecules: 
   b. Salt molecules: 
   c. Nitrogen and oxygen molecules: 

2. If you looked at both the salt water and the drinking water in the solar still with magic eyeglasses, what differences would you expect to see in the molecules?

3. Suppose you have just taken a hot shower with the bathroom door closed. The mirror in the bathroom gets cloudy. Explain how this happens. Describe what happens to substances and molecules at each stage.
   a. Evaporating:
   b. Spreading:

Continue on next page
Question Set 9.3: Evaporating and Condensing

Student Responses:

1.  
   a. In the dirty salt water, in the air, in the water droplets on the plastic cover, and in the drinking water  
   b. In the salt water  
   c. In the air  

2. If you look at ocean water with magic eyeglasses, you would see water molecules, salt molecules, and a variety of other kinds of molecules. If you look at the drinking water with magic eyeglasses, you would see only water molecules.

3.  
   a. The hot shower water evaporates, and water molecules mix in with the air. (Hot water evaporates faster than cold water. Even in cold water, some of the molecules are moving fast enough to escape the surface of the water. When the water is heated though, more molecules are moving fast enough to escape the surface of the water drops coming from the shower.)  
   b. The humid air spreads throughout the bathroom. The water molecules coming from the shower mix with the other gases in the room and move all through the bathroom.
c. Cooling and Condensing: ____________________________________________________________

________________________________________

4. Some bathrooms have a fan that blows air out of the bathroom. If you turn this fan on, there will be less fog on the mirror. Why?

________________________________________

________________________________________

________________________________________

5. The water in the shower is soapy. Why doesn't any soap get on the mirror?

________________________________________

________________________________________

________________________________________

6. Here are some other situations where water evaporates, then condenses:

- food covered with plastic wrap in the refrigerator
- soup warming on the stove (but not boiling) with a lid on the pot
- "seeing your breath" on a cold morning.

Pick one of these situations and answer the questions below.

Situation you picked: ________________________________________________________________

a. Where does the water evaporate from? _____________________________________________

b. Where does the water condense? _________________________________________________

c. How do the water molecules get from the place where water evaporates to the place where water condenses?
c. Water droplets collect on the cool surfaces of the bathroom, including the walls and bathroom mirror. As the molecules move throughout the air in the bathroom, they hit cooler surfaces, slow down, and form droplets of water.

4. Bathroom fans move the moist humid air out of the bathroom before the water vapor has a chance to condense. The water molecules that would slow down and form droplets of water on mirrors and walls are blown out of the bathroom before they have a chance to hit cold surfaces, slow down, and form droplets of water.

5. Soap does not get on the bathroom mirror because it does not evaporate and condense as readily as water. The molecules of soap are very large and do not move fast enough to escape the surface of the soapy water.

6. 

a. Water evaporates from the food, the soup, and your mouth.

b. The water condenses on the plastic wrap, the pot lid, or in the air.

c. The water molecules spread throughout the air until they reach something cool enough to make them slow down and condense.
Question Set 9.4: The Water Cycle

1. My friend was upset with the people that make drinking glasses. "You know," he said, "they ought to learn how to make glasses that don't leak. Every time I fill up a glass with cold water, some of it seeps through to the outside of the glass!" How would you explain to my friend where the water really came from?

2. Why does water condense on the outside of a cold glass but not on a cup of hot coffee?

3. My friend was puzzled over something else. "I don't understand," he said, "how the rivers of the world can empty billions of gallons of water into the oceans every day, but the oceans never seem to get any fuller. What's happening to all that water?" Can you answer my friend's question?

4. Sometimes dew forms on grass when the grass cools off at night. Explain how this happens.

5. BONUS: The magicians in "Bartholomew and the Oobleck" made millions of tons of oobleck by boiling a few pounds of a variety of things in one little pot on Mount Neeka-tave. Could such a thing actually happen? Explain:
Question Set 9.4: The Water Cycle

Student Responses:

1. Your friend should realize that the water on the outside of the glass came from water vapor in the air which condenses on the outside of the cold glass when the molecules of water slow down and come together to form droplets.

(Some students think that the water on the outside of the glass has just evaporated from the glass, moved around the glass, and condensed on the outside. They often do not realize that there is always some water vapor in the air that can condense on the glass; it will appear even if the glass has a cover over its top.)

2. Water vapor condenses on cold objects such as the glass because the water molecules slow down and cluster together. The water molecules would not slow down near a hot cup of coffee: The hot cup would actually make them move faster.

3. The water evaporates from the oceans in the form of water vapor which condenses to form clouds. The water molecules, when the water is heated by the sun, move faster which increases the number of molecules moving fast enough to escape from the water's surface into the air.

4. The air around the grass, which contains invisible water vapor, is cooling down. The water molecules begin to slow down. These slower moving molecules cluster together, forming water droplets directly on the grass.

5. No. If only a few pounds of Oobleck evaporated from Mount Neeka-tave, only a few pounds of Oobleck should condense later.
**Question Set 9.5: Explaining Precipitation**

1. Complete the chart below:

<table>
<thead>
<tr>
<th>Type of Precipitation</th>
<th>How it happens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Evaporation</td>
<td></td>
</tr>
<tr>
<td>2. Spreading</td>
<td></td>
</tr>
<tr>
<td>3. Cooling and Condensation</td>
<td></td>
</tr>
</tbody>
</table>

| a. Clouds and rain     | Water evaporates from oceans, plants, etc.          | Air cools off and water vapor condenses into droplets (clouds). Drops fall to earth (rain). |
| b. Fog                 | Water vapor mixes with air.                        |                                                     |
| c. Dew                 | Water evaporates from oceans, plants, etc.         |                                                     |

2. How is dew like the fog on a bathroom mirror (see Question Set 9.3)?
Question Set 9.5: Explaining Precipitation

1. Complete the chart

   a. 2. Spreading--the water vapor mixes and is carried high up.

   b. 1. Evaporation--Water evaporates from oceans, plants, and so forth. 3. Cooling and Condensation--Air cools and water vapor condenses into small droplets of water which we call fog.

   c. 2. Spreading--Water vapor mixes with the air. 3. Cooling and condensing--Air cools and water vapor condenses on the grass and other plants on the surface of the earth (dew).

2. Dew is like fog in that water vapor from the air condenses when it comes in contact with a cool object (grass or the mirror).
3. The illustration above shows water evaporating from the ocean, rising, and condensing to form clouds.

a. Use the magic eyeglasses to draw the molecules that you would expect to see in the ocean and inside a cloud droplet.

b. How are the ocean water and the water in the cloud droplet different?

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c. Why are the ocean water and the water in the cloud droplet different?
3.

a. Student drawings in the magic eyeglasses should show different kinds of molecules in ocean water such as water, salt, and so forth; and only water molecules inside a cloud droplet.

b. Ocean water contains a number of different substances including salt and water. A cloud droplet contains almost pure water.

c. Water evaporates and eventually forms clouds, but ocean salt does not evaporate.
Question Set 9.6: Cluster Review

1. Identify each of the changes in substances below as: expansion, dissolving, melting, evaporating, boiling, or condensation.

   a. __________________________: when you "see your breath" on a cold day
   b. __________________________: a metal ball gets larger when it is held in a flame
   c. __________________________: soup bubbles on a stove
   d. __________________________: salt is heated in a furnace until it turns into a liquid
   e. __________________________: salt is stirred in water until the grains disappear
   f. __________________________: the sun comes out and "burns the dew off the grass"
   g. __________________________: fog forms on the inside of a car windshield

2. a. Water vapor is invisible. What is the "steam" that you can see above boiling water?

b. How did the "steam" form?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

3. I am alone on the desert and the Bad Guys have put poison in my water supply. What could I do to get drinking water?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

Continue on next page
Question Set 9.6: Cluster Review

1.
   a. condensing
   b. expanding
   c. boiling
   d. melting
   e. dissolving
   f. evaporating
   g. condensing

2. a. water droplets
   b. "Steam" is formed when fast moving molecules escape from the water surface to form water vapor and then, when cold, the molecules slow down, move closer together, and form tiny water droplets that we call "steam."

3. Set up a solar still so that the water would evaporate away from the poison, condense on the plastic cover, and drip into a cup. This water is pure enough to drink.
4. Sometimes the windows of my kitchen get steamy when I cook soup in the winter. Give a three-step explanation of how this happens. Mention both substances and molecules for each step.

a. Boiling:

b. Spreading:

c. Cooling and Condensing:

5. Raindrops keep falling on my head when I go outside on a rainy day. What are some of the places that the water in those raindrops has come from?

6. How did the water molecules get from lakes and rivers to the raindrops that fell on my head?
4. When water in the soup is boiled, the water molecules moved fast enough to fly apart, so the water changes directly into water vapor or a gas.

b. The humid air from the boiling water spreads throughout the kitchen. When the bubbles of water vapor come to the surface, the water vapor is mixed with the air and spreads throughout the kitchen.

c. The water vapor in the air condenses on cool surfaces in the kitchen, such as the windows. As the water vapor in the air cools, the water molecules slow down and form droplets.

5. The water in the raindrops has come from the oceans, lakes, rivers, and a little from plants and animals.

6. The faster moving molecules escape the surfaces of rivers, lakes, and plants, and mix with the air. As the air rises and is cooled, the water molecules slow down and cluster together in large numbers as clouds. Then, when the clouds gather and the air is cooled further, the water molecules slow down, cluster together into larger droplets and fall as rain.
CUMULATIVE TEST FOR LESSON CLUSTERS 1-4

1. Why can you change ice into water but not into glass?

2. Why can’t you see air?

3. Describe the ways in which ice, liquid water, and water vapor are different when you look at them through magic eyeglasses. Draw pictures if you want to, but also use words.

4. Describe, as best as you can, what molecules are.
1. Students should say that ice and water are made up of the same kind of molecules, but ice and glass are not.

2. Students should say that the molecules that make up air are so small and so far apart (that is, not clumped together as they are in solids and liquids) that air cannot be seen. This is true for most gases.

3. Students should describe both the arrangement and motions of water molecules in the three states:

   ice: molecules are close together, in a rigid pattern, vibrating back and forth

   liquid water: molecules are also close together, but not in a pattern, sliding past each other as they constantly move around

   water vapor: molecules are very far apart, constantly moving, sometimes colliding with each other.

4. Sixth grade students should be able to say that molecules are the smallest pieces of a substance, or that molecules are the particles or bits that the substance is made up of. Some students say that molecules are very small things in substances. When they say that, it's not clear what they mean.
5. Why is it that we can see trees, but we can't see the molecules that trees are made up of?

6. When you put your finger over the end of an empty syringe and push down on the plunger, you can push it in part of the way, but not all of the way.

   a. We know that there is air in the syringe. Explain why you can push the plunger in with your finger over the end and push air together.

   b. When you push it in almost to the end, it gets very hard to push it any farther. Explain why you can't push the plunger all the way in.

7. When you smell soup cooking on the stove, what does that tell you about the molecules in the air?
5. The important part of a correct answer is that individual molecules are too small to be seen. (The situation is analogous to seeing a beach. We can see the beach even when we are much too far away to see individual grains of sand.)

6. a. Students should talk about molecules in their answer, and not just say that air is compressible. The plunger can be pushed part of the way in because the molecules that make up air are far apart and they can be pushed closer together.

b. The plunger can't be pushed in all the way because the air molecules are pushed closer together, they hit back on the plunger more and more often, until it becomes too hard to push them in any farther. (This is a difficult question, and you may want to use it as an "extra credit" question.)

7. The important part of a correct answer is that there are soup molecules in the air if you can smell the soup. (Of course, soup is a mixture of different substances, and not all of them evaporate into the air, nor are all of them smelly. But if you can smell it, then some smelly molecules have left the soup and mixed in with the air.)
8. How is it that molecules of smelly substances can move through the air and finally get to your nose?

9. Industries sometimes dump poisonous or harmful liquids that they want to get rid of into rivers and lakes.
   a. If you took some water out of a river or lake that had been polluted in this way, would that water be a mixture or a pure substance?

   b. Explain your answer.

   c. Draw what you think you would see if you looked at polluted water with magic eyeglasses.

10. How are ice, water, and water vapor the same? Talk about molecules if you can.
8. Students should say that molecules are always moving. That is why some of them that are mixed in with the air eventually get to your nose. Some students say that the air carries the smell (or the molecules) to your nose. A better explanation includes the idea that the molecules of the smelly substance are always moving.

9. a. The polluted water is a mixture.

b. It is a mixture because it is made up of two or more kinds of molecules, water molecules and the molecules that make up the poisonous or otherwise harmful liquids.

c. Drawings should show water molecules and at least one other kind of molecule.

10. Students should talk about water molecules in their answers. The molecules that make up ice, liquid water, and water vapor are the same—they are all water molecules.
11. Is air a pure substance or a mixture? 

   Explain your answer:

   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________

12. How is humid air different from air that is not so humid?

   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
11. Air is a mixture. Students' should say that it is a mixture because it is made of more than one kind of molecule. Whether they list the different components of air (nitrogen, oxygen, carbon dioxide, water vapor, and other substances) or not is not important.

12. Humid air has more water vapor in it than air that is not so humid. Another acceptable way of saying this is that humid air has more water molecules mixed in with the other molecules.
CUMULATIVE TEST FOR LESSON CLUSTERS 5-9

1. When you breathe on a piece of cold glass, it fogs up.
   a. What do you think that fog is?
      __________________________________________________________
   b. What state (solid, liquid, or gas) do you think the fog is? ____________
   c. Explain how you think the fog formed on the glass. Remember to talk about substances and molecules.
      __________________________________________________________
      __________________________________________________________

2. I dropped some salt in water. After a few minutes, it had disappeared. One of my friends said that the salt had melted, then became part of the water. What would you say to explain why the salt disappeared?
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

3. A solid chunk of steel was sitting outside on the sidewalk on a very hot and sunny day. The steel got very hot. By the middle of the afternoon, would you expect it to
   a. be a little smaller than before
   b. be a little larger than before
   c. stay exactly the same size as before
   d. I don't know

   Explain your answer.
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
1. a. The fog is water—liquid water, in very tiny drops. Some students call it moisture; they may or may not know that moisture is water.

b. It is a liquid. Some students call it "water vapor," but it is not a gas at all.

c. Students' answers should include the following points:

1. water vapor in your breath was cooled by the cold glass
2. the water molecules slowed down
3. and they stuck together to form little drops of liquid water.

Some students will mention that the reason they stick together is that there is an attraction between molecules that holds them together if they are moving slowly enough. Explicitly mentioning attraction is desirable, but not necessary, for an explanation of condensation at the sixth grade level.

2. Students should say that the salt dissolved, not melted, and that the molecules of salt are broken off the salt grains and mix in with the water molecules.

3. The correct response is: b. be a little larger. Students should say that when the steel is heated, its molecules move faster and therefore farther apart, making the steel expand. (Substances: the steel expands when it's heated. Molecules: the molecules of the steel move faster and farther apart.)
4. Explain what is happening to the molecules that make up ice when ice melts.

Draw pictures of what you might see if you looked with magic eyeglasses at ice and the puddle of water under the melting ice.

ice          water

5. You put a glass of water out on a table where no one touches it, and you leave it there for a week. Does anything happen to the water?

How can you explain what you think happens to the water. Remember to talk about substances and molecules.

6. Explain why a piece of candy dissolves faster in hot water than in cold water. Remember to talk about substances and molecules.
4. The important parts of the explanation of melting are that (a) the molecules move faster as the ice is warmed and (b) they eventually move fast enough to break out of the rigid pattern they were in as a solid. (Some students may include a statement about the attraction between molecules, but that is not essential for a sixth-grade version of an explanation of melting.)

The drawing for ice should show water molecules close together and in a pattern. Arrows should indicate that the molecules are vibrating back and forth.

The drawing for water should show molecules close together, but in no particular arrangement. Arrows should indicate that the molecules can move past each other.

5. Students should say that the water level goes down, or that the water evaporates.

The explanation of evaporation is that some of the molecules of the water are moving fast enough so that they can break away from the liquid and mix with the air. As more and more of the molecules leave the liquid, the water level goes down. (Some students may talk about the attraction between molecules, but this idea probably is not essential in a sixth-grade explanation of evaporation.)

6. Candy dissolves faster in hot water than in cold because the molecules of hot water are moving faster, hit the solid candy more often, and break molecules of candy off of the piece of candy more quickly.
7. Explain what is happening when you smell ammonia, or perfume, or the odor of skunks, or anything that is smelly.

8. Fill in the blanks with "solid", "liquid", or "gas".
   a. Solidification is a process that changes a substance from a ____________ to a ____________.
   b. Evaporation is a process that changes a substance from a ____________ to a ____________.
   c. Boiling is a process that changes a substance from a ____________ to a ____________.
   d. Condensation is a process that changes a substance from a ____________ to a ____________.

9. A solar still can be used to change salt water into drinking water.
   a. Explain how a solar still works. You can use a drawing to help your explanation, if you like.

   ________________________________________________________________

   ________________________________________________________________

   ________________________________________________________________
7. A good response should say that molecules of the smelly substance are mixed in with the air when you smell something. Students may say that molecules of the substance are reaching your nose when you smell something; this response is acceptable. Some students fail to mention the substance when they explain smells (by saying something like "molecules in the air reach your nose"), but it is not clear what they think molecules are from this type of response.

8. a. liquid to solid  
b. liquid to gas  
c. liquid to gas  
d. gas to liquid

9. a. Students should explain that water from the salt water container evaporates (or turns into water vapor and goes into the air), hits the plastic cover and condenses (or turns back into liquid water), then runs down the plastic cover and collects in the drinking water container. Students may use a drawing to illustrate this.
9. b. Describe what happens to a simple Water Molecule from the time it is part of the salt water until it is part of the drinking water. Tell about everything that happens to this molecule — where it is, how fast it is moving, and how close it is to other molecules.

(Please do not give molecules human characteristics.)

10. You take a can of soda pop out of a machine and leave it on a table for a while.
   a. What would you see on the outside of the can?

   b. Where has this stuff come from?

   c. Explain how it formed on the outside of the can. Use a three-step process.

      Evaporation:

      Spreading:

      Cooling and condensation:
9. b. Students should include these steps as they trace the movement of a water molecule:

1. The molecule leaves the surface of the salt water, and mixes with the air (evaporation).
2. The molecule moves through the air until it reaches the plastic cover (spreading).
3. The molecule slows down, and eventually sticks together with other water molecules to form drops on the plastic cover (cooling and condensation).
4. The molecule, as part of the drop, moves with the drop down the plastic cover and into the container.

10. a. small drops of water

b. The water on the outside of the can was in the air in the form of invisible water vapor.

c. **Evaporation:** water evaporates from oceans, lakes, plants, animals, etc.
**Spreading:** water vapor (or water molecules) mix with the air and move around until they come close to the can.
**Cooling and condensation:** the can cools off the water vapor and it condenses (or the can slows down the water molecules and they cluster together).
EXPLAINING CHANGES IN MATTER

SUBSTANCES

1. Wind or pressure:
   Gases push on other objects.

2. Compressing and expanding gases:
   Gases can be pushed into a smaller space, then push back out into a larger space again.

3. Dissolving:
   Solids dissolve in liquids.

4. Thermal expansion:
   Solids, liquids, and gases expand when heated (or contract when cooled).

5. Melting:
   Solids change into liquids when they are heated.

6. Freezing:
   Liquids change into solids when they cool down.

7. Boiling:
   Liquids turn into gases and bubble away when they are heated.

8. Evaporation:
   Liquids that are left standing become gases that mix with the air.

9. Condensation:
   Drops of liquid water form when air containing water vapor is cooled.

MOLECULES

Gas molecules hit the objects and bounce off of them.

Molecules of a gas can be pushed closer together because there is empty space between them. They push back out by hitting the sides of the container.

Molecules of the liquid hit molecules of the solid and break them away. The two kinds of molecules mix together.

Molecules of hot substances move faster, so they push each other farther apart.

When they are moving fast enough, molecules of the solid escape from their rigid pattern and start moving past each other.

Attraction between molecules of a liquid pulls them into a pattern if they go slow enough.

Fast-moving molecules of the liquid break away from each other and begin to fly around freely, making bubbles of gas.

Faster moving molecules escape from the liquid and mix with air molecules.

Water molecules in the air are attracted to each other and come together in drops when their motion slows down.