INTRODUCTION TO LESSON CLUSTER I
States of Water

A. Lesson Cluster I Goal and Lesson Objectives

Goal

Students should be able to describe the three states of water in terms of the arrangement and movement of water molecules.

Lesson Objectives

I.I. Describe ice (solid water) and liquid water as two different states of the same substance.

1.2. Describe ice (solid water), liquid water, and water vapor as three different states of the same substance.

1.3. Describe liquid water as composed of invisible water molecules.

1.4. Describe the differences among the three states of water in terms of the arrangement and movement of water molecules.

Describe the unique properties of water and how these properties affect our lives.

B. Key Elements of a Good Description

1. At the visible or macroscopic level, students should be able to state that ice, liquid water, and water vapor are the same substance. Liquid water changes into ice or water vapor by heating or cooling. During the changes of states, liquid water does not disappear or change weight.
2. Students should recognize that there is invisible water vapor in the air.
3. At the invisible molecular level, students should explain the observable properties of ice, liquid water, and water vapor in terms of the arrangement and motion of water molecules. Key points include the following:
    a. Ice, liquid water, and water vapor are all made of water molecules, H_2O.
    b. Water molecules are too small to be seen, even with a microscope, and they are always in motion.

c. Ice, liquid water, and water vapor differ in the arrangement and motion of water molecules:

- Ice: Water molecules are locked in a rigid pattern, and vibrate in their places.
- Liquid water: Water molecules slide and bump past each other.
- Water vapor: Water molecules move freely with much more space between them than in the liquid or solid state.

C. Conceptual Learning

This lesson cluster introduces the unit by focusing on water, a substance that is familiar to students in its solid (ice), and liquid (water) states. This substance is used to introduce many key ideas of the unit, ideas which will be applied repeatedly throughout the unit. Some of the ideas that may cause difficulty for your students are discussed below.

Lessons I and 2:

At the observable or macroscopic level, students must recognize the essential sameness of water in all three states of water. First, although most students understand that ice and liquid water are the same substance, a variety of subtle misconceptions are common:

a. Some students believe that when ice melts into water, it loses weight, because ice is solid or hard.

b. Some believe that when water evaporates, it loses its weight, or that when water" evaporates, it disappears or becomes weightless.

Second, many students have difficulty with the idea of water vapor. The cause of the difficulty is that water vapor is invisible, whereas ice and liquid water are observable. Many students have the following common misconceptions:

a. Water does not change into gas, or water vapor.

b. "Foggy steam" from boiling water is the gaseous state of water. It is not; it is really tiny drops of liquid water.

c. There is no water vapor in the air. Students who believe this have difficulty understanding condensation in Lesson Cluster 9.

d. The bubbles in boiling water are air.

Lesson 3, 4 and 5:

At the invisible or molecular level, you will probably find that many of your students haven't heard of the word "molecules." Even if some students have heard of it, their understanding is likely to be substantially different from the ideas conveyed in this unit. Furthermore, although many students might have heard of the term atoms, their understanding may not be scientific. Their acquaintance with the term atoms may even interfere with the new term molecules.

The size of molecules is one characteristic that is difficult for students to understand because it lies outside the realm of their normal experience. Although students think of molecules as small, it is hard to convey just how small they are. Many students think of molecules as similar in size to other tiny objects that they are familiar with, such as specks of dust, bacteria, or cells. Even if they say that molecules are smaller than these objects, they may still think that they can see molecules with a microscope. In reality, a typical human cell contains perhaps 100 trillion molecules; a dust speck, even more. Thus, molecules are too small to be seen.

Students also have difficulty in understanding that molecules are constantly moving. Molecules are always moving, even in substances such as ice where no motion of the substance is visible. Many students think that molecules are moving in liquid water because liquid water is flowing, but molecules are not moving in ice because ice is not moving. The constant motion of molecules is difficult for students to believe, both because it seems to contradict the evidence of their senses and because they have never encountered objects that, like molecules, are so tiny that they are unaffected by friction and thus never come to a stop.

Students are confused between observable properties of a substance and properties of the molecules themselves. Many students may believe, for instance, that molecules of water become hard and cold when the water freezes, rather than simply becoming locked into a rigid arrangement and motion in their places. Some students may even think that when water changes into ice water, water molecules change into ice molecules.

Many students believe that there are molecules in substances rather than the substances are made of molecules. For example, they think that water contains molecules (like blueberries in a muffin) rather than consisting of molecules and nothing else (like grains of rice). Students may think there is "air" or "water" between water molecules. Thus, it needs to be strongly emphasized that water is made of only molecules and there is nothing between water molecules.

D. Conceptual Contracts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Conservation of matter	Matter is conserved in all physical changes.	Matter not always conserved, especially in changes involving gases (e.g., water disappears when it is heated).
Water vapor in air	Air contains invisible water vapor.	Water in air is visible (e.g., fog, "steam"). There is no gaseous state of water.
Molecular constitution of matter	All matter is made of molecules.	Molecules are in substances (e.g., water has molecules in it, with water between the molecules).
Size of molecules	Molecules are too small to see, even with a microscope.	Molecules may be comparable in size to cells, dust specks, etc. Molecules can be seen with a microscope.
Constant motion	All molecules are constantly moving.	Molecules may sometimes be still, especially in solids.
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances (e.g., molecules do not move in ice because ice is frozen).
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules: ➢ solid: vibrate in rigid array. ➢ Liquid: random motion within limits. ➢ Gas: random motion, no limits.	

UNIT INTRODUCTION

Discuss with your students some things that are not matter. Note: Define matter as any solid, liquid or gas. Ask them to name some things that are not matter. These may include the vacuum of outer space, forms of energy such as light and heat, or abstract concepts such as temperature, force, and love.

INTRODUCTION TO LESSON CLUSTER 1

STATES OF WATER

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to describe the three states of water in terms of the arrangement and movement of water molecules.

Lesson Objectives

1.1. Describe ice (solid water) and liquid water as two different states of the same substance.

1.2. Describe ice (solid water), liquid water, and water vapor as three different states of the same substance.

1.3. Describe liquid water as composed of invisible water molecules.

1.4. Describe the differences among the three states of water in terms of the arrangement and movement of water molecules.

Describe the unique properties of water and how these properties affect our lives.

B. Key Elements of a Good Description

1. At the visible or macroscopic level, students should be able to state that ice, liquid water, and water vapor are the same substance. Liquid water changes into ice or water vapor by heating or cooling. During the changes of states, liquid water does not disappear or change weight.

2. Students should recognize that there is invisible water vapor in the air.

3. At the invisible molecular level, students should explain the observable properties of ice, liquid water, and water vapor in terms of the arrangement and motion of water molecules. Key points include the following:

   a. Ice, liquid water, and water vapor are all made of water molecules, H_2O.

   b. Water molecules are too small to be seen, even with a microscope, and they are always in motion.

c. Ice, liquid water, and water vapor differ in the arrangement and motion of water molecules:

- Ice: Water molecules are locked in rigid pattern, and vibrate in their places.

- Liquid water: Water molecules slide and bump past each other.

- Water vapor: Water molecules move freely with much more space between them than in the liquid of solid state.

C. Conceptual Learning

This lesson cluster introduces the unit by focusing on water, a substance that is familiar to students in its solid (ice), and liquid (water) states. This substance is used to introduce many key ideas of the unit, ideas that will be applied repeatedly throughout the unit. Some of the ideas that may cause difficulty for your students are discussed below.

Lessons 1 and 2:

At the observable or macroscopic level, students must recognize the essential sameness of water in all three states of water. First, although most students understand that ice and liquid water are the same substance, a variety of subtle misconceptions are common:

a. Some students believe that when ice melts into water, it loses weight, because ice is solid or hard.

b. Some believe that when water evaporates, it loses it weight, or that when water evaporates, it disappears or becomes weightless.

Second, many students have difficulty with the idea of water vapor. The cause of the difficulty is that water vapor is invisible, whereas ice and liquid water are observable. Many students have the following common misconceptions:

a. Water does not change into gas, or water vapor.

b. "Foggy steam" from boiling water is the gaseous state of water. It is not; it is really tiny drops of liquid water.

c. There is no water vapor in the air. Students who believe this have difficulty understanding condensation in Lesson Cluster 9.

d. The bubbles in boiling water are air.

D. Concepts that are difficult for students to understand.

At the invisible or molecular level, you will probably find that many of your students have not heard of the word "molecules." Even if some students have heard of it, their understanding is likely to be substantially different from the ideas conveyed in this unit. Furthermore, although many students might have heard of the term atoms, their understanding may not be scientific. Their acquaintance with the term atoms may even interfere with the new molecules.

1. **Size of molecules**
   The size of a molecule is one characteristic that is difficult for students to understand because it lies outside the realm of their normal experience. Although students think of molecules as small, it is hard to convey just how small they are. Many students think of molecules as similar in size to other tiny objects that they are familiar with, such as specks of dust, bacteria, or cells. Even if they say that molecules are smaller than these objects, they may still think that they can see molecules with a microscope. In reality, a typical human cell contains perhaps 100 trillion molecules; a dust speck, even more. Thus, molecules are too small to be seen.

2. **Molecules are in constant motion**
   Students also have difficulty in understanding that molecules are constantly moving. Molecules are always moving, even in substances such as ice where no motion of the substance is visible. Many students think that molecules are moving in liquid water because liquid water is flowing, but molecules are not moving in ice because ice is not moving. The constant motion of molecules is difficult for students to believe, both because it seems to contradict the evidence of their senses and because they have never encountered objects that, like molecules, are so tiny that they are unaffected by friction and thus never come to a stop.

3. **The behavior of molecules creates properties of a substance**
   Students are confused between observable properties of a substance and properties of the molecules themselves. Many students may believe, for instance, that molecules of water become hard and cold when the water freezes, rather than simply becoming locked into a rigid arrangement and motion in their places. Some students may even think that when water changes into ice water, water molecules change into ice molecules.

4. **Molecules make up substances**
   Many students believe that there are molecules in substances rather than the substances are made of molecules. For example, they think that water <u>contains</u> molecules (like blueberries in a muffin) rather than <u>consisting</u> of molecules and nothing else (like grains of rice). Students may think there is "air" or "water" between water molecules. Thus, it needs to be strongly emphasized that water is made of only molecules and there is nothing between water molecules.

E. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Conservation of matter	Matter is conserved in all physical changes.	Matter not always conserved, especially in changes involving gases (e.g., water disappears when it is heated).
Water vapor in air	Air contains invisible water vapor.	Water in air is visible (e.g., fog, "steam"). There is no gaseous state of water.
Molecular constitution of matter	All matter is made of molecules.	Molecules are <u>in</u> substances (e.g., water has molecules in it, with water <u>between</u> the molecules).
Size of molecules	Molecules are too small to see, even with a microscope.	Molecules may be comparable in size to cells, dust specks, etc. Molecules can be seen with a microscope.
Constant motion	All molecules are constantly moving.	Molecules may sometimes be still, especially in solids.
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances (e.g., molecules do not move in ice because ice is frozen).
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules: -solid: vibrate in rigid array. -liquid: random motion within limits. -gas: random motion, no limits.	States of matter described only in terms of observable properties of the state attributed to individual molecules (e.g., water molecules are hard in ice.)

LESSON 1.1

SOLID WATER AND LIQUID WATER

PURPOSE:

To help students describe ice and liquid water as two different states of the same substance.

ADVANCE PREPARATION:

For each group of 2-3 students you will need ice cubes and a ziplock plastic bag which will provide a water tight seal, and a balance to weigh the ice cube-plastic bag system.

MATERIALS LIST:

For each group of students:	For the class:
one ice cube	one balance
one ziplock plastic bag	

TEACHING SUGGESTIONS:

Have the students read the first two paragraphs of the student text. Elicit as many student responses as possible to the question "How do you know that ice is really solid water?" Discuss the student responses until students understand the problem for the activity.

When you begin to talk about gases, be alert to any student confusion between "gas" and gasoline. Although gasoline is a liquid some people shorten the word to "gas."

LESSON 1.2

SOLID, LIQUID, AND GAS

PURPOSE:

To help students describe liquid water and water vapor as two states of the same substance. To have students infer that ice, liquid water, and water vapor are three states of the same substance.

ADVANCE PREPARATION:

In order to demonstrate the distillation of water, you should collect the materials and assemble the apparatus before class. A drawing of the apparatus on page 3 of the Science Book will help you visualize the setup. You should start heating the water about 10 minutes before class so it is operating during class without any drops of water in the connecting tube. By having the apparatus operating before the students observe it carefully, you can usually prevent some students thinking that drops of liquid water that are in the tube are water vapor.

MATERIALS LIST:

hot plate	small Erlenmeyer flask with one hole stopper
test tube	glass tubing including two right angles
beaker	

TEACHING SUGGESTIONS:

Before you do this activity, you should be aware of how we use "steam" in this unit. Technically, steam refers to hot water vapor, so both steam and water vapor are invisible. However, this is contrary to the way steam is used in everyday conversation. To most people, steam is the "fog" or "white cloud" above boiling kettles or coming off a hot shower. This usage is so common that it is confusing to confront grade 6 students with the scientific definition. Therefore, for the purposes of this unit, we use the technical definition of water vapor (that it is an invisible gas) and the nontechnical, or common, usage of steam (that it is a "white cloud" or "fog").

1. Have the students read the first portion of the student text and discuss it completely.

2. The students should answer question #1 in the Activity Book (Question Set 1.2) before they observe the distillation of water closely.

3. Do the demonstration, have the students complete the Question Set, and discuss their responses completely.

4. Continue with the Science Book. Stress that water vapor is always invisible and that there is always water vapor in the air. Also emphasize that ice, liquid water, and water vapor are three states of the same substance.

LESSON 1.3

MOLECULES, THE SMALLEST PIECES OF WATER

PURPOSE:

To introduce the molecular theory of matter and to help students describe liquid water as composed of invisible molecules that are constantly moving.

MATERIALS LIST:

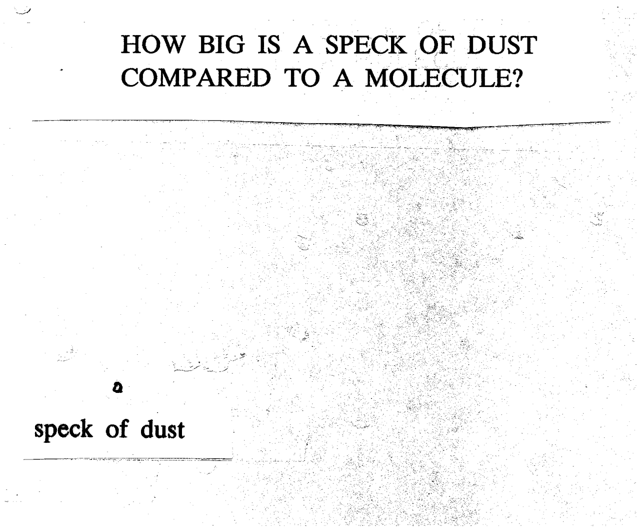
Transparency 1: How big is a speck of dust compared to a molecule?

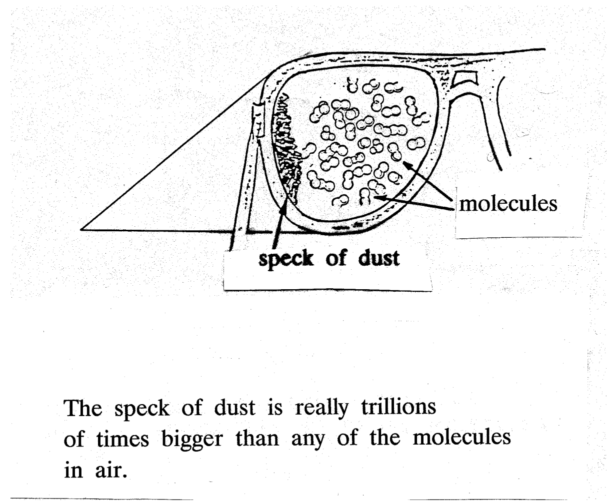
TEACHING SUGGESTIONS:

You may want to re-read the section, Students' Conceptual Learning, found in the Introduction at the beginning of Lesson Cluster 1. In re-reading this section, please note that most students have difficulty believing that water is made of molecules and nothing else. Some students come to think that there are molecules in the water rather than water consisting of molecules and only molecules. You should stress, therefore, that water is made of only water molecules and nothing else. Students also have difficulty believing that molecules are constantly moving, especially in a solid like ice. These two concepts are among the most important concepts in the entire unit as well as in this lesson.

The first paragraph gives you the opportunity to review the major concepts taught in lessons 1.1 and 1.2. You may also want to stress that when ice changes to liquid water, the water has exactly the same number of molecules as did the ice. Thus, there could not be a change in weight. The same is true for liquid water changing into water vapor.

Molecules of water are actually shaped somewhat like the way we have drawn them (see Science Book page 6). This "Mickey Mouse" shape is easy for students to remember. Atoms of hydrogen and oxygen are not solid balls, as the drawing suggest; each atom actually consists of a "cloud" of electrons surrounding a nucleus made of protons and neutrons. But water molecules and other molecules often do act like small hard particles. This is a good place to use Transparency 1:





TRANSPARENCY 1: HOW BIG IS A SPECK OF DUST COMPARED TO A MOLECULE?

BOTTOM LAYER:

Many students believe that molecules are about the same size as or perhaps a little smaller than a speck of dust, a cell, or a germ. Encourage students to express their answers to the question.

OVERLAY:

Many students may have difficulty with understanding the relative size of molecules. Contrast students' incorrect ideas with the scientific notion that the speck of dust is really trillions of times bigger than the molecules of air. Reference to the comparison of a cell with water molecules (illustration: Science Book page 7) may help. [A trillion is equal to 1,000,000,000,000.]

All students have difficulty comprehending how incredibly small molecules are. Although it is not necessary for students to know exactly how small molecules are, they should definitely get the impression that they are very, very small, are constantly moving and never stop moving even in solids such as ice.

LESSON 1.4

MOLECULES AND THE THREE STATES OF WATER

PURPOSE:

To help students describe the differences among the three states of matter in terms of the arrangement and movement of water molecules.

TEACHING SUGGESTIONS:

In using this lesson with students, stress that the difference in properties among ice, liquid water, and water vapor is due to the arrangement and movement of the molecules and not due to any change in the molecules themselves.

Also, stress that molecules are constantly moving and never stop, even in a solid.

Stress that the differences among the three states of matter is the result of the **arrangement** and **movement** of the molecules and not due to changes in the molecules themselves.

SUPPLEMENTARY READING

THE MIRACLE OF WATER

PURPOSE:

To help students describe the uncommon properties of water and how these properties affect their lives.

TEACHING SUGGESTIONS:

We use water frequently in our science activities because it is available, familiar to students and inexpensive. Students need to know, however, that many properties of water are not typical of most substances.

You should use this lesson to emphasize these exceptional properties of water. The exceptional properties include:

1. Most living things contain more water than any other substance.

2. Water dissolves a greater number of other substances than any other substance.

3. Water has a great capacity to retain heat.

4. Most liquids contract when they freeze. Water expands between 4^{o} C and 0^{o} C.

5. Water changes from one state to another within a narrow temperature range. There is always water as a gas (water vapor) in the air, liquid water in the oceans, and solid water (ice) at the earth's poles.

Discuss these properties to help students describe the uncommon properties of water.

MATERIALS LIST

CLUSTER 1, LESSONS 1.1-1.4

Lesson 1.1:

For each group of students: one ice cube and one ziplock plastic bag. For the class: one balance (optional).

Lesson 1.2:

one hot plate
one small Erlenmeyer flask with a one hole stopper
glass tubing including two right angles
one test tube
one beaker

Lesson 1.3:

Transparency 1

Lesson 1.4:

None

INTRODUCTION TO LESSON CLUSTER 2

OTHER SOLIDS, LIQUIDS, AND GASES

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to describe solids, liquids, and gases of a variety of substances in molecular terms.

Students should be able to contrast pure substances and mixtures in terms of their molecular composition.

Lesson Objectives

2.1 Explain that different substances are made of different kinds of molecules.

2.2 Contrast pure substances with mixtures, substances that contain more than one kind of molecule.

2.3 Contrast solids, liquids, and gases of different substances in terms of motion and arrangement of their molecules.

B. Key Elements of a Good Description

Students should explain that different substances are made of different kinds of molecules and that pure substances contain only one kind of molecule, while mixtures contain two or more kinds of molecules. Students should contrast solids, liquids, and gases of all substances in terms of motion and arrangement of molecules:

- Solids: Molecules vibrate while locked together in a fixed pattern.

- Liquids: Molecules move about while remaining close together, sliding past each other and constantly colliding.

- Gases: Molecules move freely about in space, sometimes colliding with each other or with objects.

C. Students' Conceptual Learning

Much of this lesson cluster focuses on the application of ideas from Lesson Cluster 1 to substances other than water, particularly ideas about molecules' small size and constant motion, and the motion and arrangement of molecules in different states of matter. Students should come to recognize that molecules are the basic components of all substances. Some students may still think that molecules are <u>in</u> substances, rather than substances <u>are made</u> of molecules.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Molecular constitution of matter	All matter is made of molecules.	Molecules are in substances.
Size of molecules	Molecules are too small to see.	Molecules may be seen with a microscope.
Motion of molecules	All molecules are constantly moving.	Molecules may be still, especially in solids.
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances.
Different kinds of molecules	Different substances are made of different kinds of molecules.	Substances are made of the same kind of molecules.
Pure substance vs. mixture	Pure substances are made of one kind of molecules; mixtures, two or more kinds of molecules.	Distinction based on observable properties, such as taste, color, etc.
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules.	States of matter described only in terms of observable properties of substance or properties of individual molecules.

LESSON 2.1

WHAT ARE OTHER SUBSTANCES MADE OF?

PURPOSE:

To help students explain that different substances are made of different kinds of molecules.

MATERIALS LIST:

Transparency 2: Why can you change liquid water into ice but not alcohol?

TEACHING SUGGESTIONS:

Some students may know that lead and solder are used by plumbers to seal pipes. Lead is an excellent substance for this because it melts at 327^{o} C (620^{o} F) and boils at 1620^{o} C (2948^{o} F). Solder is 2/3 lead and 1/3 tin and melts at 275^{o} C (527^{o} F). Because of its relatively low melting temperature, solder is also used to connect or solder electrical wire.

After Lesson Cluster 1, some students may think that different substances are made of the same kind of molecules (for instance, that water, sugar, and alcohol all are made of the same kind of molecule). This lesson is designed to help students realize that different substances are different because they consist of different kinds of molecules.

To stress the impossibility of changing one substance to another, you might want to refer to Midas, a legendary Phrygian king who for a time was give the power of turning to gold everything he touched. The only way he could have done that was by substituting gold molecules for the molecules of the substance.

Stress that water molecules are different than alcohol molecules. Each substance has molecules unlike any other substance.

Compare the drawing of the water molecule with the formula H_2O.

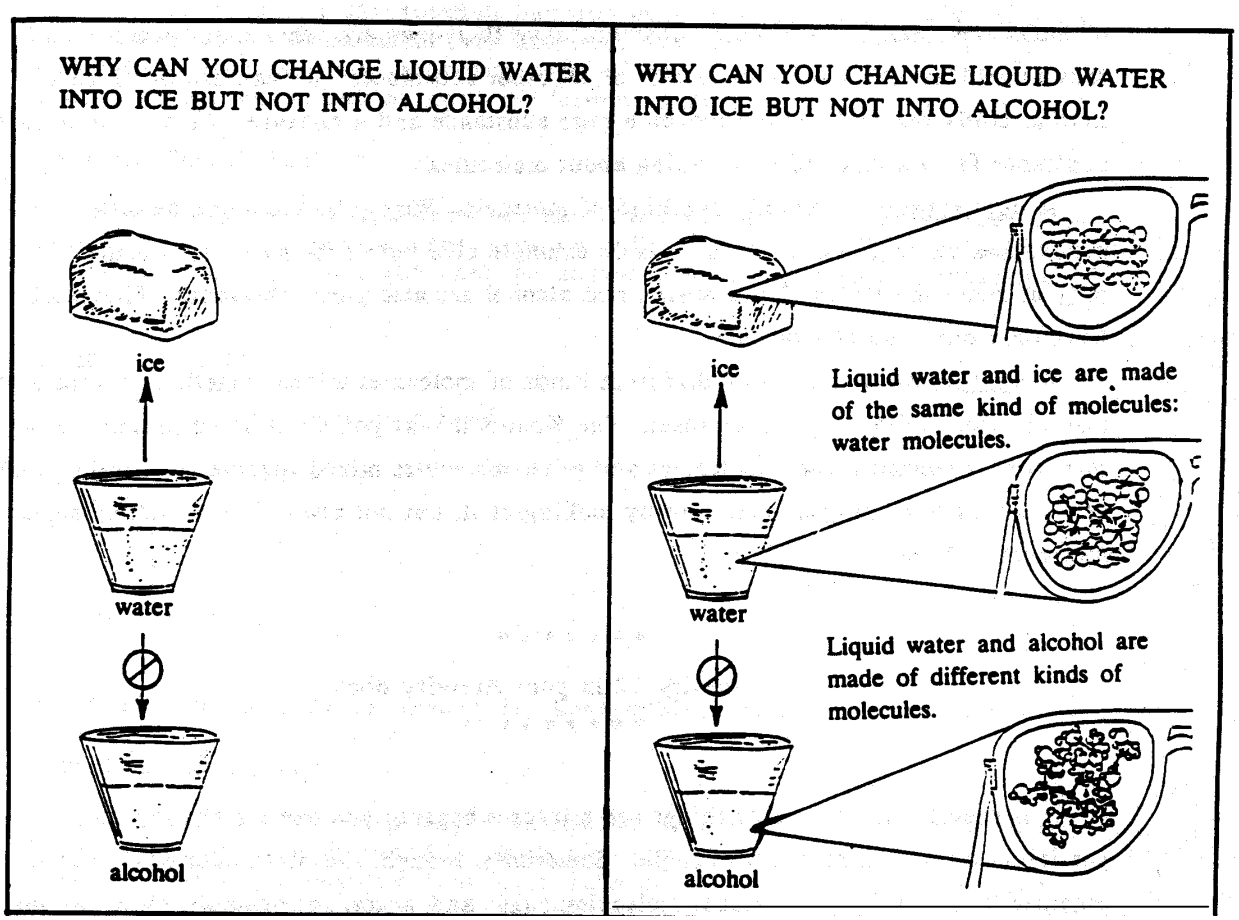
Compare the drawing of alcohol with water. You may want the students to describe how they are the same and how they are different.

At the grade 6 level we do not distinguish the various kinds of alcohol. If students ask, there are many kinds of alcohol such as methyl (wood alcohol), ethyl (grain alcohol), isopropol (rubbing alcohol), etc.

Another way to write the formula for alcohol is C_2H_5OH.

In discussing the drawings of molecules, stress that there are different combinations of atoms that make up various different molecules.

Use Transparency 2 here:



TRANSPARENCY 2:WHY CAN YOU CHANGE LIQUID WATER INTO ICE BUT NOT INTO ALCOHOL?

BOTTOM LAYER:

Many students will know that you cannot change water into alcohol, but will not be able to correctly explain why. They will be able to tell you on a macroscopic level, that, "Water and alcohol are not the same stuff" but not how the two substances are, in molecular terms, different.

OVERLAY:

It is important to point out through the overlay the scientific idea that water and alcohol cannot be changed into one another because their molecules are different. [In connection with this transparency it may also by useful to have students look at the illustrations on page 15 of the Science Book.]

LESSON 2.2

PURE SUBSTANCES AND MIXTURES

PURPOSE:

To help students distinguish between pure substances and mixtures and to realize most common materials are mixtures not pure substances. To describe pure substances as being made of one kind of molecule, and mixtures as made of two or more different kinds of molecules.

ADVANCE PREPARATION:

For each group of students you need to prepare six plastic cups, salt, pepper, sugar, oil, syrup, and dirt or soil. Because each group will need six plastic cups, you might want to assign each group member particular tasks.

MATERIALS LIST:

For each group you will need:

six plastic cups	salt
pepper	sugar
syrup	dirt or soil
water	metric measuring spoons

50 ml graduated cylinder
Transparency 3: What would ocean water look like?

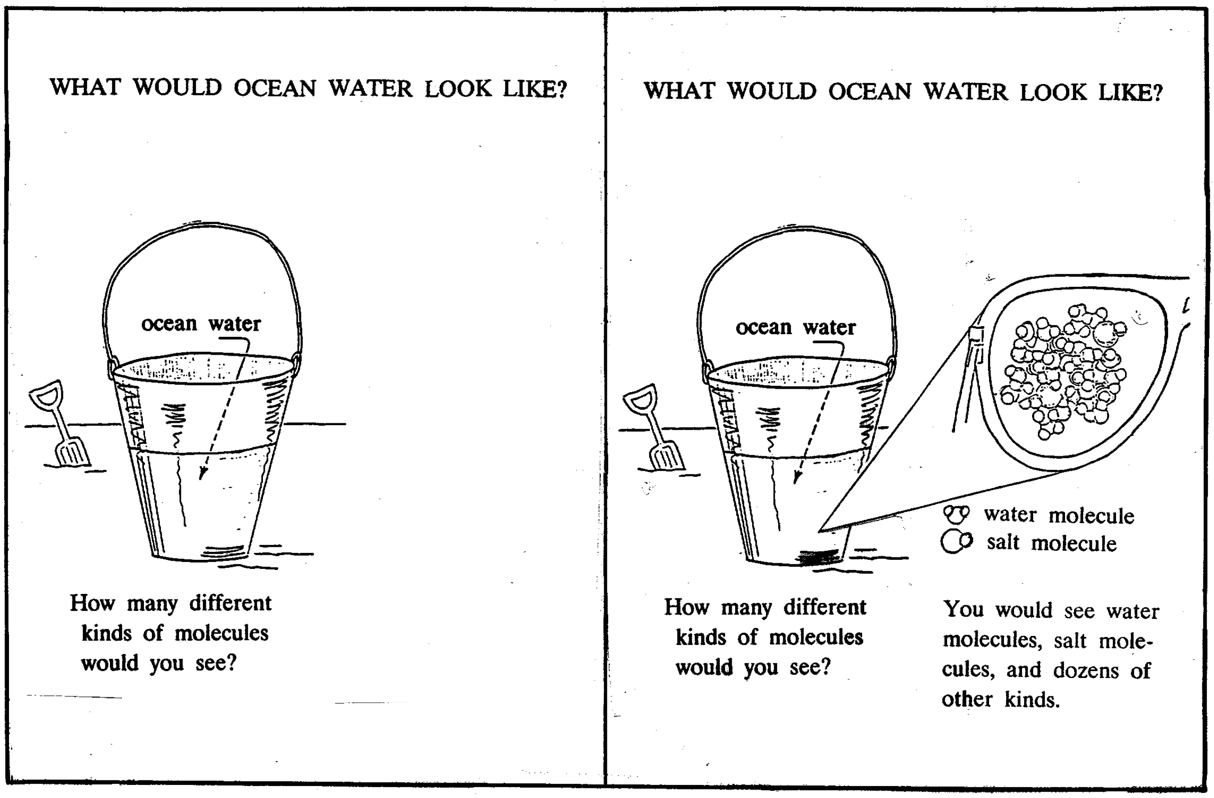
TEACHING SUGGESTIONS:

A majority of students may distinguish mixtures from pure substances based on observable properties, such as taste, color, texture, etc. Students need to recognize that even substances that appear "pure" may actually be mixtures of different kinds of molecules. There is often no way to tell a pure substance from a mixture by only observable properties.

1. After reading the definitions of pure substance and mixtures but before you do Activity 2.2, you may want to have the students list as many pure substances and mixtures as they can. Discuss their examples.

2. After the students discuss the remaining Science Book Lesson 2.2, emphasize that pure substances are made of only one kind of molecule while mixtures are made up of two or more different kinds of molecules.

Use Transparency 3 here



TRANSPARENCY 3: WHAT WOULD OCEAN WATER LOOK LIKE?

Bottom Layer
Often students make distinctions between mixtures and pure substances based on observable properties only; they believe that if something looks clear, then it is a pure substance. Thus, they will say that ocean water is pure because it looks clear. This would imply that ocean water has only one kind of molecule, even though most students will not answer in terms of molecules.

Overlay
Ocean water, even though it looks clear, has several different kinds of molecules, thus making it a mixture and not a pure substance.

Emphasize this difference to your students. Although ocean water is admixture of a number of different substances, only salt is shown in this transparency, as it is the most familiar to students.

LESSON 2.3

MOLECULES AND STATES OF MATTER

PURPOSE:

To help students contrast solids, liquids, and gases in terms of motion and arrangement of molecules.

MATERIALS LIST:

Transparency 4: How are molecules arranged and how do they move?

TEACHING SUGGESTIONS:

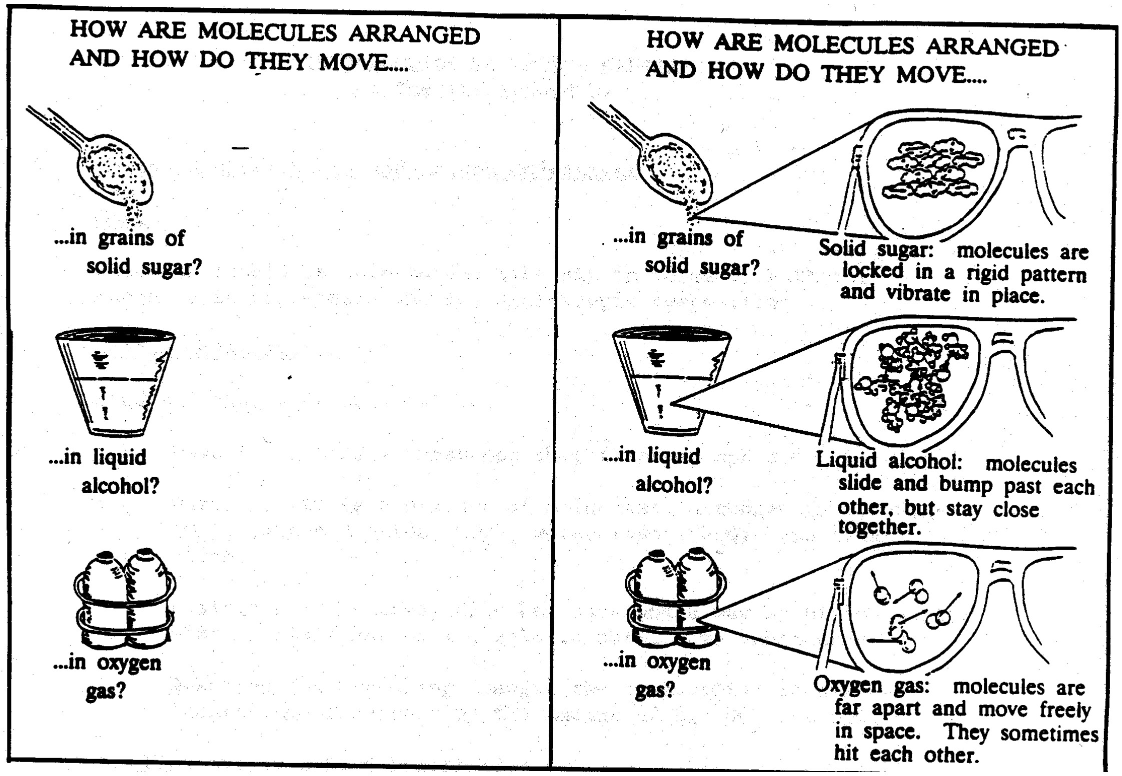
Solid: Some students may think that molecules in solids are not moving or that molecules themselves are hard. You should help these students distinguish observable properties of substances from invisible properties of molecules. Use the transparency to elicit the students' ideas about the arrangement and movement of molecules before you use the overlay. Then contrast the students' thinking with the overlay.

In discussing the molecules of a solid, you might want to use the analogy of students in their seats in your class. The students are in their chairs (fixed position) but they are constantly moving within this place. They do no move past each other.

Liquid: You might want to continue the analogy by comparing the movement of molecules of a liquid with the students moving around the room before or after class. Students are not in a definite array or pattern but moving past each other in a random manner.

Gas: The student analogy of a gas would be students moving very far apart after school is out. They move freely in all directions. (School buses are not a good analogy.)

Use Transparency 4 here:



TRANSPARENCY 4: HOW ARE MOLECULES ARRANGED AND HOW DO THEY MOVE?

BOTTOM LAYER:

Even though students have learned about how molecules move and how molecules are arranged in water, they often cannot transfer these ideas to other substances. Also, many students still have difficulty with movement of molecules in solids.

OVERLAY:

You should contrast students' naive thinking with the overlay, which gives a scientific view of molecules. Emphasize that even though the molecules of one substance (like sugar) may be different than the molecules of another substance (like ice), the molecules are still arranged and move in the same way in the solid state. This is what makes substances solids, liquids, or gases. Pay particular attention to movement of molecules in solids, as students have difficulty with this concept.

SUPPLEMENTAL ACTIVITIES:

1. Look up the molecular formulas of other pure substances, such as propane gas, ammonia, salt, baking soda, and make or draw models of a molecule of each.

2. You can show that milk (and other substances) are mixtures by freezing them. The water freezes before other substances in the mixture freeze.

INTRODUCTION TO LESSON CLUSTER 3

THE AIR AROUND US

A. Lesson Cluster Goals and Lesson Objectives

Goals

-Students should be able to describe air in terms of both its macroscopic properties and its microscopic composition.

Lesson Objectives

Students should be able to:

3.1 Describe air as a substance that takes up space.

3.2 Describe air as a mixture of molecules: nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), water vapor (H_2O), and other gases.

Explain how a variety of other substances may be mixed in air. Also, explain how we are able to smell some substances.

3.3 Describe how breathing changes the composition of air by increasing or decreasing the among of O_2, CO_2, and H_2O.

B. Key Elements of a Good Description

At the macroscopic level, students should describe air as a substance that takes up space. Air is a **mixture** of gases. The component gases vary in proportion from place to place and time to time.

At the molecular level, air is a mixture of different kinds of molecules, mostly N_2 and O_2 with small and sometimes variable amounts of other gases, such as CO_2, water vapor (H_2O), etc. Other substances may also be mixed in air, for instance, dust, germs, smell of substances, etc., but they are not a part of what we call air.

Also at the molecular level, students should explain that breathing changes the of air by increasing or decreasing the amount of CO_2, O_2, and H_2O.

C. Students' Conceptual Learning

This lesson cluster provides opportunities for students to apply several ideas from previous lesson clusters, such as:

-- gas is a state of matter

-- like all matter, air is made of molecules, so tiny that they are invisible, and constantly in motion
-- air contains a mixture of different kinds of molecules
-- there is always water vapor present in air

There are other ways in which the contents of this lesson cluster are new and potentially difficult, however. Some of these problems have to do with ideas about air that are common student thinking and in our language, but are not scientifically accurate. We speak of air as light, "airy," insubstantial, or even as nothing. Students must learn to see air and other gases as forms of matter like liquids and solids, with all the characteristics of matter in general:
-- air is made of molecules
-- air takes up space

The topic of air also causes difficulties for students because air is a complex mixture of gases that are generally colorless, odorless, and thus undetectable except by indirect means. Furthermore, the exact composition of air varies from time to time and from place to place. Many important phenomena, including respiration, photosynthesis, humidity, smells, pollution, and the water cycle, are associated with variations in the mixture of molecules in air. We cannot discuss all of these phenomena in this lesson cluster, or even in this unit. But a good understanding of the nature of air will prepare students for future learning about these phenomena.

Lesson 3.1

The question "Is air something or nothing?" may sound trivial, but some students think that air is nothing. Others who think that air is something still may have ideas that are not scientifically accurate. For instance, some may use air as a generic term for gases. Some may think that air has color or odor. This problem is caused by the fact that pure air is colorless and odorless, and thus not easily detected. Students should realize that air is "something," that it is a form of matter, and that it takes up space.

Matter is often defined as anything that occupies space and has weight. The definition is fine. We have emphasized the former and neglected the latter, because the concept of weight is often difficult for students to understand.

Lesson 3.2

A common student misconception about the composition of air is that molecules of air are substances that can be seen in the air. Some common examples of these misconceptions are as follows:

1. Air is made of dust particles, germs, bacteria, pollution, etc.

2. Dust particles or germs are comparable in size to that of molecules of air.

3. Air is made of some kind of "wavy" lines.

The teacher should take care to dispel these misconceptions by stressing that air is made of molecules. The teacher should also stress the size of a dust particle or other substances compared to the invisible size of molecules.

Another common student misconception about the composition of air is that air is a continuous medium that serves to hold things such as dust, dirt, and smells. The teacher should emphasize that air itself is composed of molecules and that particles of other substances such as dust and dirt can be mixed in air.

Students may also think that air is a single type of gas and thus that "pure air" contains only one type of molecule. The teacher should emphasize that even "pure" air is a mixture, consisting of different kinds of molecules of gases. (The relative amounts of these different kinds of molecules of gases vary from time to time or from place to place.)

Among the different kinds of molecules that make up air, the one students have most difficulty in understanding is the presence of water vapor in the air. The teacher should emphasize that air contains invisible water vapor (H_2O) as well as other kinds of gases, including oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), and a few other gases.

The teacher should also help students understand that other substances may be mixed in the air, such as dust, dirt, germs, smells, etc. These substances are not part of the composition of pure or clean air. The gases that make up pure air are colorless and odorless, so what we see or smell is other substances mixed in air. You also should emphasize that air consists of only molecules and that there is nothing (that is, just empty space) between molecules of air.

Some students may be confused between observable movement of air and invisible molecular motion. For instance, students may think that molecules move in air because air is moving, and molecules stop moving when air is still. The teacher should stress that molecules of air always move and never stop. Since air is in the gaseous state, molecules are far apart and move freely.

Students may have difficulty in understanding the properties of smells of substances:

- smell is matter
- smell is gas
- smell is made of molecules

Smells are substances mixed in air. We smell because the molecules move to our nose. Some common misconceptions are that (1) air carries smell, (2) smell travels through air, and (3) air molecules pick up smell.

Lesson 3.3

You should emphasize how breathing can change the composition of air by increasing the amount of CO_2 and H_2O and decreasing the amount of O_2. A common student misconception is that we breathe in oxygen and breathe out carbon dioxide. The teacher should help students understand by stressing that we breathe in and out air but the mixture of different kinds of molecules are different. That is, the air we breathe in and out contains the same kinds of molecules: nitrogen, oxygen, water, carbon dioxide, and a few others. The amounts of these substances, though, are different. The air that we breathe out has less oxygen, because some of it has been used by our body. It has more carbon dioxide and water vapor, because these are produced by our body.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Matter vs. non-matter	Solids, liquids, and gases are matter, other things are not.	Gases often incorrectly classified as non-matter. Air is nothing.
	Matter takes up space; non-matter does not.	Classification based on other properties (e.g., something you can see or feel).
Smell	Smells are gases and made of molecules.	Smells considered ephemeral, not really matter. Air carries smell or smell travels through air. Air molecules pick up smell.
Water vapor	Air contains invisible water vapor (humidity).	There is no gaseous state of water.
Molecular constitution of matter	All matter is made of molecules.	Substances not describes as as molecular.
Size of molecules	Molecules are too small to see, even with a microscope.	Molecules may be comparable in size to cells, dust specks, etc. Molecules can be seen with a microscope.
Motion of molecules	Molecules are constantly moving.	Molecules may sometimes be still (e.g., still air).
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances (e.g., molecules move in air because air is moving.)
Pure substance vs. mixture	Pure substances are made of one kind of molecules; mixtures two or more kinds of molecules.	Distinction based on observable properties, such as taste, color, odor, etc.

LESSON 3.1

IS AIR NOTHING OR SOMETHING?

PURPOSE:

To help students describe air as a form of matter that has certain definite properties, such as taking up space.

ADVANCE PREPARATION:

This activity will require several large containers of water, preferably ones which are clear to better permit students to see the air levels in tumblers inverted in the water. Large beakers would work well.

MATERIALS LIST:

For each student group:
small plastic bag
plastic cup or small jar
large container of water
2 ft. length of plastic or rubber tubing
grease pencil for marking water levels on cup

TEACHING SUGGESTIONS:

This lesson is designed to show students that air really is "something," that it is a form of matter, and that it does take up space, as shown by the activities. Often students think that air is nothing, or not matter.

The major thrust of this lesson is Activity 3.1: Is the air in a cup a real substance?

LESSON 3.2

WHAT IS AIR MADE OF?

PURPOSES:

To help students describe air as a mixture of molecules: mostly nitrogen (N_2), and oxygen (O_2), but also including carbon dioxide (CO_2), water (H_2O), and other gases. To help students describe air as having other materials mixed in it, such as dust, dirt, and smells.

MATERIALS LIST:

1. Transparencies: "What does the air look like?", "How big is a speck of dust compared to a molecule?", and "What is the smell of baking cookies?"

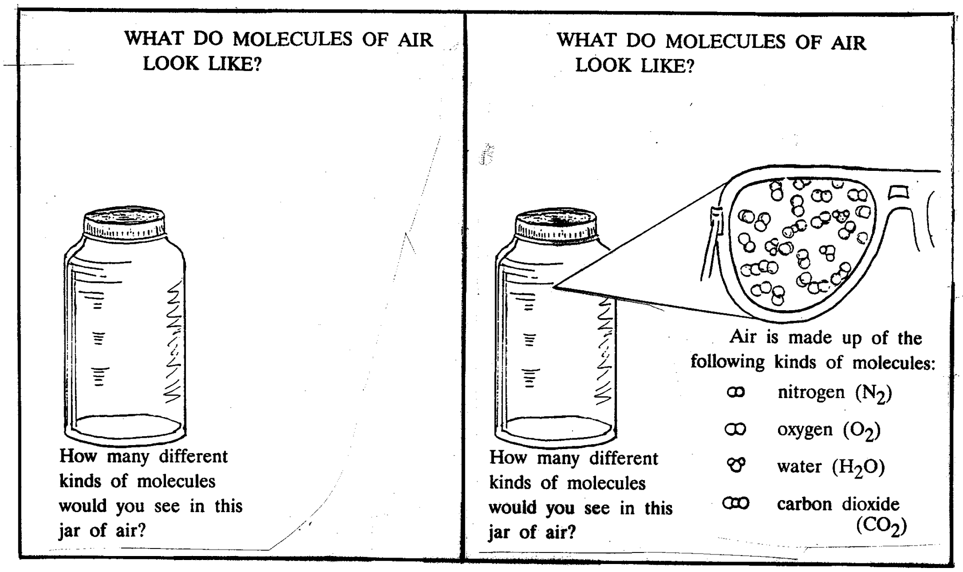
2. Perfume to be released in the classroom.

TEACHING SUGGESTIONS:

Resulting from the preceding lesson the students should be starting to think about air as matter. This lesson will reinforce that concept. Remember: A common student misconception is that molecules of air are substances that can be seen in air, such as dust or pollution. Continue to talk about having magic glasses so that students remember how tiny molecules are.

Have the students read the Science Book out loud or silently, and discuss any problems they might have.

Discuss the questions and the pictures thoroughly. Use Transparency 5 here:



TRANSPARENCY 5: WHAT DO MOLECULES OF AIR LOOK LIKE?

BOTTOM LAYER:

Students have a number of different conceptions about air. Some believe that air is nothing, or that there would be no molecules of air in the jar. Others believe that there is a generic kind of "air molecule." Some think that oxygen is the only thing of which air is made. Others believe that air is made up of pollution, germs, bacteria, smoke, dust, and other substances which can sometimes mix with air.

OVERLAY:

It is extremely important to contrast these naive ideas with the scientific conceptions. Students should learn that air is not only something, but a number of different "somethings," namely, nitrogen, oxygen, water, carbon dioxide, and small amounts of other gases. You should also point out that, although oxygen is a part of the air, it is not the only thing air is made of, or even the most plentiful. Show them that there is much more nitrogen in the air--almost four times more.

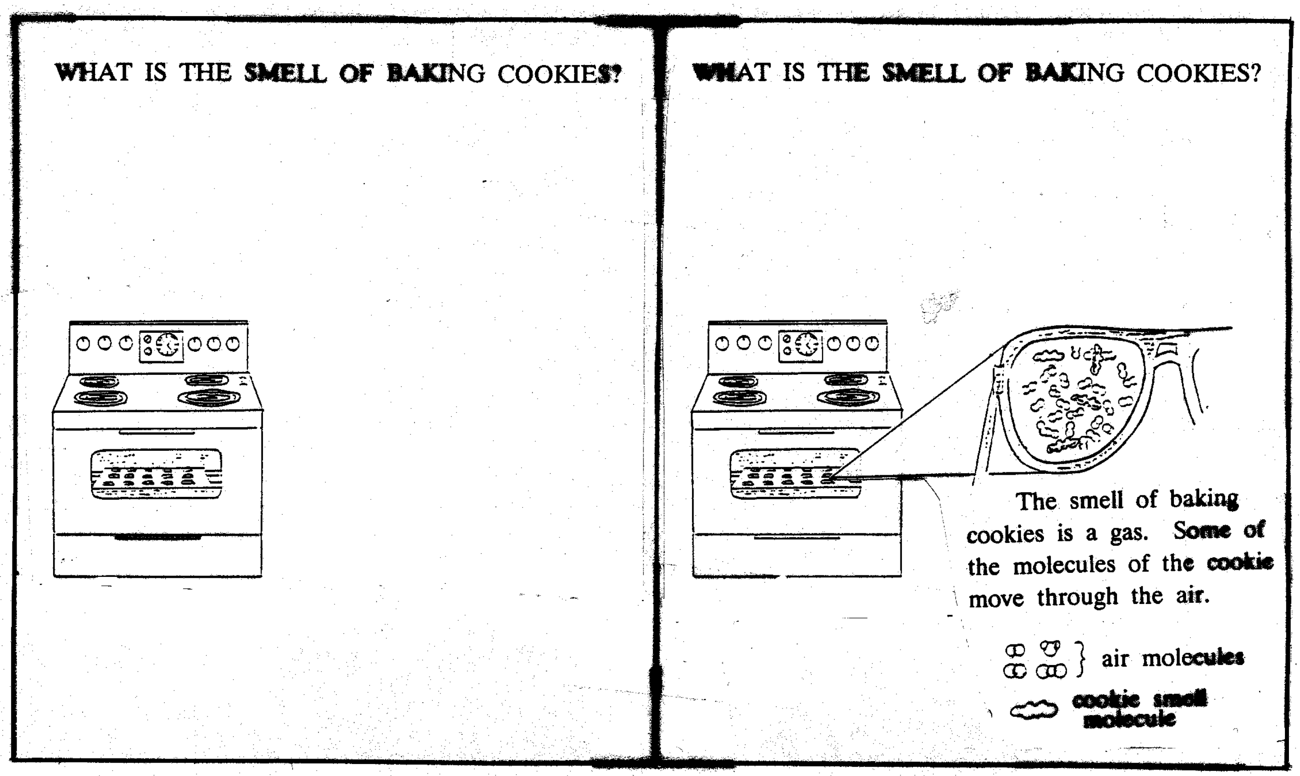
Use Transparency 1 here:

TRANSPARENCY 1: HOW BIG IS A SPECK OF DUST AS COMPARED TO A MOLECULE?

Look for illustration and explanation of student misconceptions in Lesson 1.3.

Before doing the perfume activity, close the classroom windows and doors to avoid drafts.

Use Transparency 6 here:



TRANSPARENCY 6: WHAT IS THE SMELL OF BAKING COOKIES?

BOTTOM LAYER:

Many students do not fully understand smells. These students will say that the smell of baking cookies is "a fume" or "an odor" or "a scent." They usually cannot use what they know about molecules to explain smells.

OVERLAY:

You should help students to see the scientific notion of smells, that all smells are gases and are made of molecules. Some of the molecules of the cookies break away from the cookie and then mix with and move through the air until the smell reaches your nose because of the constant motion of the air and smell molecules.

LESSON 3.3

AIR AND BREATHING

PURPOSES:

To help the students explain that air breathed out contains more water vapor and carbon dioxide than normal air.

BACKGROUND INFORMATION:

Bromthymol Blue (BTB) is an indicator that is blue in the presence of bases and yellow in the presence of acids. BTB turns yellow in this experiment because the interaction of carbon dioxide and water produces a weak acid, carbonic acid ($H_2O + CO_2 \quad H_2CO_3$).

ADVANCE PREPARATION:

Prepare a BTB solution by adding about 35 drops of BTB to 3.5 liters (one gallon) of water. You may find it convenient to prepare more BTB solution to keep for later activities. Use approximately 10 drops of BTB per liter (quart) of water. The solution can be stored in plastic milk containers.

If the BTB solution is yellow when you prepare it, add a very small amount of household ammonia until the solution turns blue. Variations in the mineral content of the water can affect the color of the solution. Often the minerals will cause the BTB solution to turn green instead of yellow. However, this color change will still indicate the presence of carbon dioxide. Distilled or deionized water (available at grocery stores) have very low mineral contents.

MATERIALS LIST:

For each student group:
plastic cup
soda straw
BTB solution

TEACHING SUGGESTIONS:

1. Use the Science Book to introduce Activity 3.3: Breathing Out and Breathing In.

2. After you completed the activity use the Science Book to help students explain what happens to the air when they breathe.

The obsevation that breath breathed out change the color of the BTB soutions shows more CO_2 than in normal air, as you saw in the activity. Water vapor from breath condensing on a cool glass shows more H_2O than in normal air. These observations suggest these two components (CO_2 and H_2O) have variable composition in air. The relative amounts of N_2 and O_2 is quite constant throughout the world (78% N_2, 21% O_2, and about 1% other gases). The relative amounts of other gases are approximately: CO , 0.03%; H O, 0.3%.

Breath at high altitudes is discussed in lesson Cluster 5.3.

You might want to use Question Set 3.3; Cluster Review during the next class period. It can be used, if you wish, as an evaluatory tool.

MATERIALS LIST

CLUSTER 3, LESSONS 3.1-3.3

Lesson 3.1:

For each group:
small plastic bag
plastic cup or small jar
large container of water
2 ft. length of plastic or rubber tubing
grease pencil for marking water levels of cup

Lesson 3.2:

Transparencies 5 and 6
perfume to be released in the classroom

Lesson 3.3:

For each group:
a plastic cup
a soda straw
BTB solution

INTRODUCTION TO LESSON CLUSTER 4

COMPRESSING AND EXPANDING AIR

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to explain the expansion and compression of gases (e.g., air) in molecular terms.

Lesson Objectives

Students should be able to:

4.1 Explain that molecules are constantly moving and hitting each other.

4.2 Explain why air in the syringe can be compressed, but water cannot.

4.3 Explain the various concentrations of air molecules at different altitudes.

4.4 Understand how to make a good explanation, using the example of a bicycle tire.

B. Key Elements of a Good Description

This is the first lesson cluster that focuses primarily on using the kinetic molecular theory to explain observable phenomena. Such explanation, however, will be the primary focus of all the remaining lesson clusters. In general, all good explanations using the kinetic molecular theory should do at least the following:

a. Substances:

Identify the substance that is responsible for the observable phenomenon that is being explained and describe the macroscopic changes that are taking place in that substance.

b. Molecules:

Describe the changes in molecules that are responsible for the macroscopic substances.

For all of the phenomena in this lesson cluster, the key substances are gases that are being compressed or are expanding. Students should learn to explain both why air and other gases can be compressed and why they "push back" harder when they are compressed.

They can be compressed because the molecules of gases are relatively far apart, with lots of empty space between them. They push back harder when they are compressed because when molecules are pushed closer together, more of them hit the walls of the container, so the gas "pushes out" harder.

C. <u>Students' Conceptual Learning</u>

Constructing a complete molecular explanation for a phenomenon is a difficult process for many students. Some students do not even see why we would consider a discussion of molecules an "explanation," since students are used to explaining things by relating them to familiar ideas and events and the idea of molecules is not familiar or comfortable to them.

Even students who are trying to construct molecular explanations for phenomena often find it very difficult. They may have difficulty identifying the key substance that is responsible for the change, focusing, for instance, on the bicycle tire rather than the air inside it. They may not know what is happening to the substance, or to the molecules that it is composed of, or they may not be able to explain the relationship between molecular events and macroscopic phenomena. This unit contains many observable phenomena; the students will need all of these opportunities and lots of help to master this difficult task.

This lesson cluster builds in a variety of ways on ideas from earlier lesson clusters. In particular, students will need to use the ideas that all gases are substances made of molecules, and that those molecules are in constant motion, colliding with each other as well as with objects and the walls of whatever container holds a gas.

This lesson cluster also introduces several new and different ideas associated with the compressibility of substances. On the macroscopic level, many students have had little experience with the compressibility of gases or the relative incompressibility of solids and liquids.

Lesson 4.1 and 4.2

To understand compression or expansion of gases, students should recognize that gases are evenly distributed through the spaces they occupy. Since air is invisible, however, students often postulate that air is distributed unevenly in order to explain a phenomenon. The most common student misconception is that gases (e.g., air) move from one place to another when compressed or expanded. For instance, when air is compressed in a syringe, air stays around the opening of the syringe because air is pushed forward. In contrast, when air expands in the syringe, air stays around the plunger because air is pushed backward. In fact, the constant motion of molecules and their freedom to move any where in the gaseous state assures that they will generally be distributed evenly (actually randomly) throughout the space occupied by a gas.

Compression of gases can be understood because of a molecular characteristic that most students are not aware of: Molecules of gases are relatively far apart and the spaces between them are empty. Some students may not think in terms of spaces between molecules. Furthermore, the teacher should emphasize that air consists only of molecules with empty spaces between these molecules.

In contrast to gases, solids and liquids cannot be compressed by ordinary means. Molecules of liquids and solids are fairly closely packed and in constant contact with each other, so solids and liquids are much harder to compress. However, students may simply think in terms of observable properties of water vs. air, such as, water is hard or water has more "stuff" in it. At the microscopic level, some may think that molecules are larger or harder in water than in air. Thus, the teacher should emphasize that the difference between the compression of air and water is due to the relative distance between molecules. (Those solids that can be compressed are generally porous, like sponges. It is the air pockets that are easily compressed, not the solid itself.)

Lesson 4.3

The concentration of air varies at different altitudes. However, students may think that concentration of air is the same in a valley, at sea level, or in high mountains, and see no relationship to the compression or expansion of air in a syringe. The concentration of air, again, is due to relative spaces between molecules at different altitudes.

It is probably not important in this unit to talk about air pressure, or the weight of the atmosphere. We are only using the examples in this lesson as additional ways of talking about how molecules are arranged in gases. The teacher should stress how concentration of air is related to the amount of air that our body needs: We need to breath harder at higher altitudes, because we take in less air with each breath.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Distribution of gases in space	Gases spread evenly through the spaces they occupy.	Distribution of gases is uneven before or after expansion or compression.
Compression of gases	Gases can be compressed.	Gases move from one region to another when compressed or expanded.
Constant motion	All molecules are constantly moving.	Molecules may sometimes be still, especially in solids.
Spaces between molecules	Gases consist of nothing except molecules with empty spaces between them.	Molecules have "air" or other things between them.

LESSON 4.1

EXPLAINING THINGS WITH MOLECULES

PURPOSE:

To help students explain that molecules are constantly moving and constantly hitting each other.

ADVANCE PREPARATION:

For this demonstration you will need a hair dryer, ping pong ball, and an inflated ball. Wind-chimes are optional.

MATERIALS LIST:

ping pong ball
inflated ball
hair dryer
wind-chimes (optional)

TEACHING SUGGESTIONS:

1. Have the students read the first three paragraphs of the lesson and discuss them.

2. Do the demonstrations. You will need a hair dryer with a round nozzle and a ping pong ball. When the hair dryer is pointed straight up it will support the ball in mid air.

3. Have the students answer the questions in the activity book and discuss them.

LESSON 4.2

COMPRESSING AIR

PURPOSE:

To help explain that a gas has molecules that are very far apart with large empty spaces between the molecules. The gas molecules can be pushed together. Liquids cannot be compressed because the molecules of liquids are already close together.

MATERIALS LIST:

For each group of students:
syringe
plastic cup
water
Transparency 7: What happens to air molecules when the plunger is pushed in?

TEACHING SUGGESTIONS:

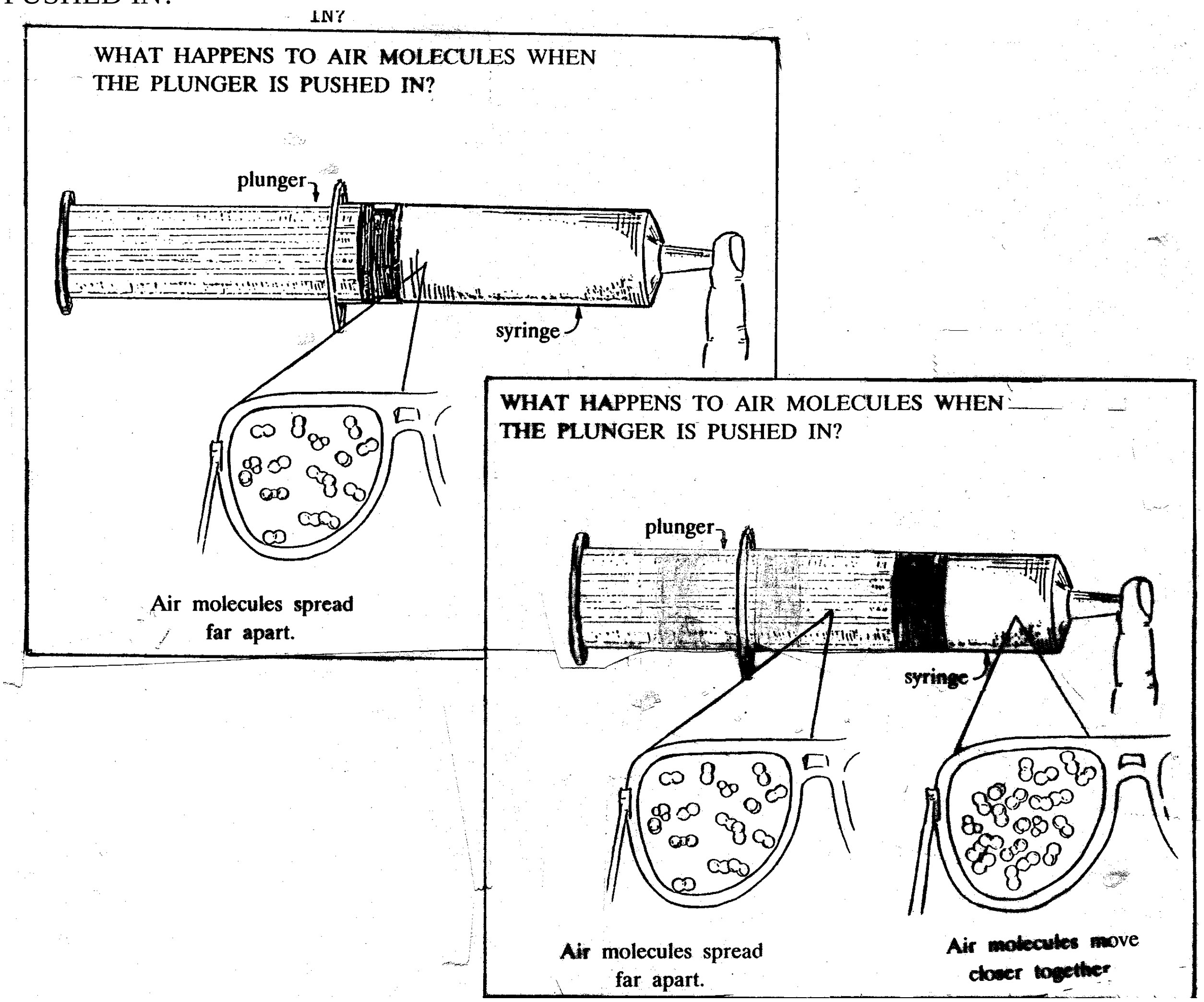
If you anticipate that the students will use the syringes for water fights do not distribute the water until it is needed.

1. Introduce the lesson with Activity 4.2.

2. You might want to review the arrangement and motion of molecules in liquids and gases before the students read the Science Book.

Use transparency 7 here:

TRANSPARENCY 7: WHAT HAPPENS TO AIR MOLECULES WHEN THE PLUNGER IS PUSHED IN?



Bottom Layer

Many students believe that air molecules will escape or try to escape when the plunger of a syringe is pushed in. Some think all or most of the molecules are pushed to the opening of the syringe.

Overlay

Students hold the above misconceptions because they do not understand the idea of compressibility of air. You should point out to students that molecules of air have large, empty spaces between them. This means that when air is compressed, molecules merely move closer together. The molecules remain evenly distributed and are not all at one end of the syringe.

LESSON 4.3

BREATHING THICK AIR AND THIN AIR

PURPOSE:

To help students describe the various concentration of air molecules at different altitudes and to use the kinetic molecular theory to explain compression of gases.

ADVANCE PREPARATION:

You may want to demonstrate compressed gas by using aerosol cans or a CO_2 fire extinguisher.

You may be able to find pictures of scuba divers or mountain climbers.

MATERIALS LIST:

Aerosol can or CO_2 fire extinguisher (optional)

TEACHING SUGGESTIONS:

You can use aerosol cans to demonstrate the force with which compressed gas comes out of the can. Pictures of mountain climbers or deep sea divers using compressed air tanks may be useful in stimulating student interest and discussion.

1. Have the students read the Science Book and discuss the major ideas.

2. Then have the students do the Question Set 4.3.

3. Other examples of thick air and thin air:

    a. Commercial airline flights. Some students probably have flown on commercial airline flights; above 10,000 feet the air is too thin to breathe easily. The entire crew and passenger compartments are pressurized to provide people sufficient air to breathe. Federal regulations require that emergency oxygen masks be provided on commercial airliners that fly above 10,000 feet.

    b. Deep-sea divers

This is a good time to review what students have learned in this lesson and draw out any remaining misconceptions.

You may have students try to explain, after having heard this explanation, how other phenomena work, such as the commercial airliners discussed at the beginning of this lesson.

LESSON 4.4

BICYCLE TIRES

PURPOSE:

The primary purpose of this lesson is to introduce students to a simple way of checking the quality of their explanations. A good explanation discusses both the substances that are changing and what is happening to the molecules of those substances. Students apply this rule to one situation: Pumping air into the bicycle tire. The rule will be used regularly throughout the rest of the unit.

ADVANCE PREPARATION:

(optional)
You may want to pump up a bicycle tire as a demonstration.

MATERIALS LIST:

bicycle pump and tire (or entire bicycle)
Transparency 8: Where does the air go when you pump it into a tire?
Poster 1: To EXPLAIN things, ask TWO QUESTIONS

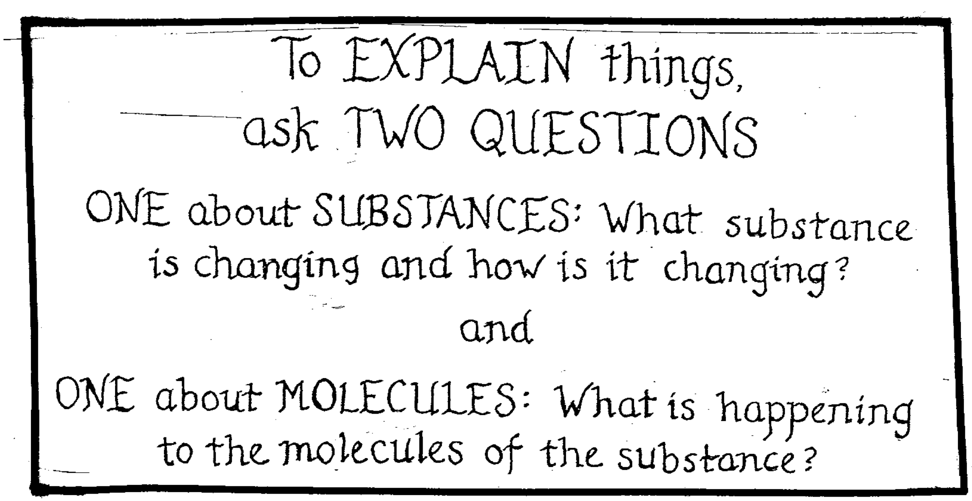
TEACHING SUGGESTIONS:

1. Have students explain what happens when air goes into and out of the bicycle tire.

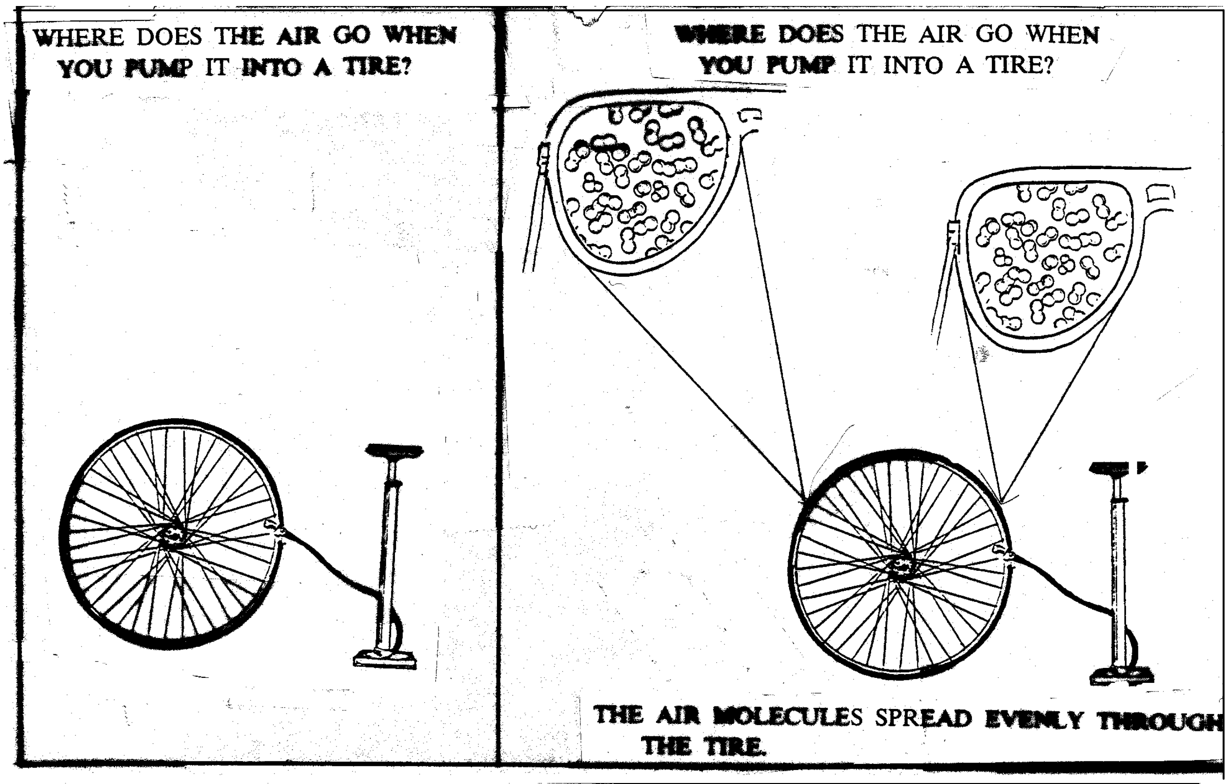
2. You should model applying the rule to check the quality of the explanations.

3. Discuss other situations with students applying the rule themselves.

Use Poster 1 here:



Use Transparency 8 here:



TRANSPARENCY 8: WHERE DOES THE AIR GO WHEN YOU PUMP IT INTO A TIRE?

BOTTOM LAYER:

Many students feel that when you pump air into a tire, the air molecules stay right next to the valve system. They feel air simply goes "into the tire," and do not offer any further explanation.

OVERLAY:

Students' naive ideas should be countered with the overlay. When air is pumped into a tire, the air molecules spread out until they are relatively evenly spaces. Thus, students should understand that the air "goes all over" or spreads evenly throughout the tire.

SUGGESTIONS FOR ADDITIONAL ACTIVITIES:

1. Air pressure at sea level is about 15 pounds per square inch, and, the pressure of a gas is inversely proportional to its volume (i.e., doubling the pressure, halves the volume). Have students figure out what the pressure of the gas in a syringe is when the volume is reduces from 5 ml to 2.5 ml, to 1 ml, to 0.5 ml.

MATERIALS LIST

CLUSTER 4, LESSONS 4.1-4.4

Lesson 4.1:

ping pong ball
inflated ball
hair dryer
wind chimes (optional)

Lesson 4.2:

For each group:
syringe
plastic cup
water
Transparency 7

Lesson 4.3:

aerosol cans or CO_2 fire extinguisher (optional)
pictures of scuba divers or mountain climbers (optional)

Lesson 4.4:

bicycle pump and tire (or entire bicycle - optional)
Transparency 8
Poster 1

INTRODUCTION TO LESSON CLUSTER 5

EXPLAINING DISSOLVING

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to explain dissolving of solids in liquids in terms of molecules.

Lesson Objectives

Students should be able to:

5.1. Explain how sugar dissolves in water.

5.2. Explain why stirring causes solids to dissolve faster than not stirring.

5.3. Demonstrate and understanding that most solutions are complex, that is, have several solids dissolved in water.

B. Key Elements of a Good Description

As already introduces in Lesson Cluster 4, to make a good explanation, students need to answer to questions:

a. What substance is changing and how is it changing?

b. What is happening to molecules of the substance that accounts for the change?

For various phenomena of dissolving in this lesson cluster, the key substances are solids that are dissolving in liquids. It is the solids that are changing, but liquids also have important functions in the change. Thus, students should recognize how solids are changing and how liquids cause this change.

At the molecular level, students should understand two major components involved in dissolving:

a. Molecules of liquids hit the grains of solids.

b. Molecules of solids break away and spread out evenly in liquids.

Unless students integrate all three components in their explanation, their understanding of dissolving is not complete. Furthermore, students should realize that it is the molecular part of the explanation that provides a reason and accounts for the change in substances.

C. Students' Conceptual Learning

Students familiar with dissolving in daily life and, apparently, it seems easy to explain at a macroscopic level (that sugar, for instance, breaks up into pieces too small to be seen). The process of dissolving, however, is complicated at the molecular level. To develop adequate understanding, students should integrate several major components involved in dissolving. Due to this complication of explanation, dissolving may be a difficult task for some students.

Lesson 5.1

When sugar dissolves in water, the amount of sugar is conserved (does not increase or decrease). Some students may not understand conservation of matter. Students may think that, because sugar disappears, it no longer exists. They may mean this when they say that sugar evaporates or dissolves. Students should recognize that even though they cannot see sugar in water, it is still there.

Water has a critical role in dissolving: Water molecules hit the sugar molecules and cause them to break away from sugar crystals. However, many students may think that water has nothing to do with what is happening with sugar. For instance, they may think that sugar crystals in a tea bag get bigger in water (Activity 5.2) get out because the holes in the tea bag get bigger in water, or they may think that the sugar "melts." (Melting is caused by heat and does not require water.)

Some students who remember the conception of empty space between molecules may erroneously think that small holes in the tea bag are actually empty spaces between molecules of the tea bag.

Some students may be confused between sugar molecules and the crystals of sugar. They may think that crystals are actually sugar molecules. The teacher should emphasize that crystals consist of trillions of sugar molecules.

Students may be confused between properties of molecules and observable properties of substances in dissolving. For instance, students may think sugar molecules themselves dissolve in water. Some may also think that after sugar dissolves in water, sugar will go down to the bottom of water and stay there, so it will taste sweeter at the bottom of water than at the top. In fact, sugar molecules are constantly moving and spread out evenly in water.

Lesson 5.2

The speed of dissolving can vary by the method used to speed it up, for instance, by stirring. The teacher needs to note to students that we can make substances dissolve either faster or slower in various ways.

Lesson 5.3

Students who distinguish pure substances from mixtures based on observable properties of substances may have difficulty understanding solutions. Based on color, taste, or other observable properties, some students may think that the water we get from a faucet is a pure substance. Students should recognize that regardless of how a substance appears, the molecules that make the substance determine whether it is pure or a mixture.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Conservation of matter	Matter is conserved in changes.	Matter not always conserved. The word "dissolve" sometimes used as a synonym for "disappear."
Size of molecules	Molecules are too small to see.	Molecules are visible (e.g., crystals or "wavy lines" of sugar as sugar molecules).
Constant motion	All molecules are constantly moving.	Molecules may sometimes be still (e.g., sugar molecules go down and stay at the bottom of water).
Different kinds of molecules	Molecules of one substance are different from molecules of a different substance.	All molecules are alike.
Pure substance vs. mixture	Pure substances are made of one kind of molecule; mixtures, two or more kinds of molecules.	Distinction based on observable properties of substances, such as color, taste, texture, etc.
Molecular explanation of dissolving	Molecules of solute break away and mix with molecules of solvent.	Focus on observable substances or molecules themselves "dissolve."

LESSON 5.1

HOW DID THE SUGAR GET OUT?

PURPOSE:

To help students develop an explanation of how sugar dissolves in water. To make this explanation, they have to recognize that sugar grains have to break apart into much smaller sugar molecules.

MATERIALS LIST:

For each student or each group of 2-3 students:
magnifying glass sugar, 5 cc
empty tea bag plastic cup
water, 150 ml.
Transparency 9: What happens when sugar dissolves in water?

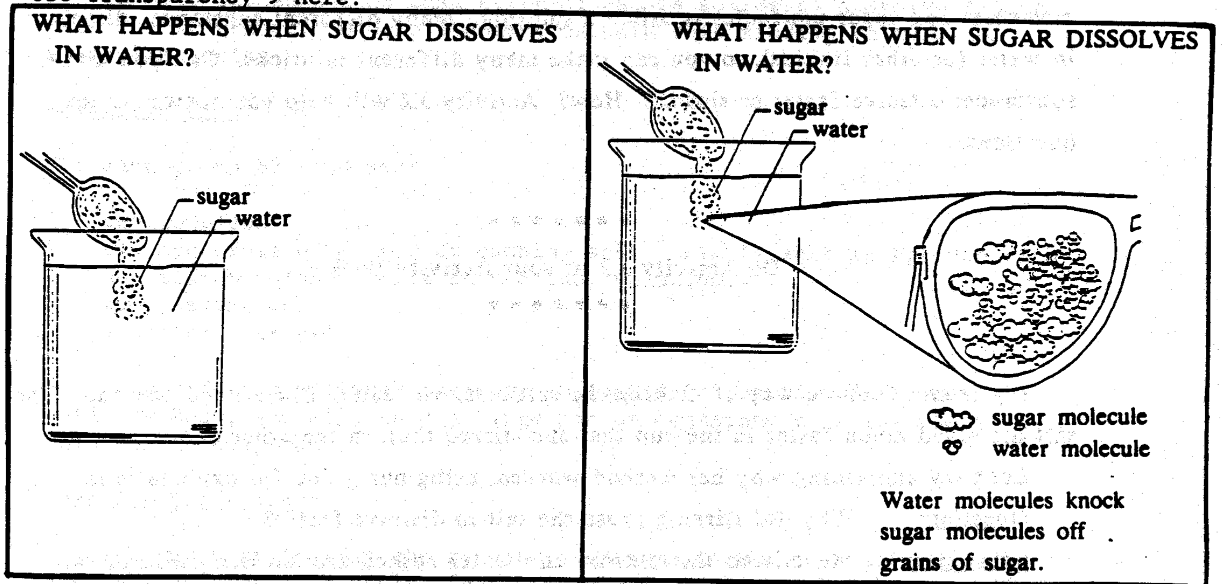
TEACHING SUGGESTIONS:

This lesson begins with a brief introduction and goes right into the activity. Students answer a number of questions as they do the activity. You may want to discuss each question after students have done the activity, or have the class read in the textbook which explains dissolving. The last section of this lesson reviews the explanation and helps students see how the "explanation guide" heuristic applies to this explanation.

Some students do not recognize that water has to go into the tea bag to dissolve the sugar. They may have written in the activity that the sugar gets out because the tea bag holes get bigger in water.

Some students think that sugar crystals are actually molecules. Crystals of sugar are cube-shaped because of the rigid array of (trillions of) molecules in solid sugar.

Use Transparency 9 here:



TRANSPARENCY 9: WHAT HAPPENS WHEN SUGAR DISSOLVES IN WATER?

Bottom Layer

Many students feel that, when sugar dissolves in water, the sugar "disappears" or "melts." Most students will not answer this question in terms of molecules.

Overlay

Students should be challenged to see that just because the sugar is no longer visible does not mean that it is gone forever. On a macroscopic level, the sugar mixes with the water. On the molecular level, water molecules hit the large grains of sugar, knocking off individual molecules. These sugar molecules eventually become evenly dispersed throughout the water. Since we cannot see individual molecules, the sugar seems to have disappeared. We know it is still there, however, because the water tastes sweet.

Remember that the word "substance" is supposed to remind students to ask two questions: What substance is changing? and How is it changing? The word "molecules" is supposed to remind students to write about what is happening to molecules during the change.

It is the molecular part of the explanation that provides a reason and accounts for the change. We want to help students get to the point of explaining the phenomena in this lesson cluster and the following clusters in terms of molecules.

LESSON 5.2

DISSOLVING FAST AND SLOW

PURPOSES:

To help students find that stirring causes solids to dissolve faster than not stirring. To help students explain this finding in terms of molecular motion.

MATERIALS LIST:

For each group of students:
two tumblers
two spoonfuls of Kosher or canning salt (Table salt is sprayed with cornstarch with results in a cloudy solution.)
two plastic cups
coffee stirrer

If you do the optional activity suggested in question 7 of the Activity Book, you will need a large pan or container to allow the salt solution to evaporate.

TEACHING SUGGESTIONS:

You may want to list the student responses to the question "How can you make substances dissolve faster of slower?" on the chalkboard. If the students suggest that heating will make substances dissolve faster, inform them that they will investigate this in Lesson Cluster 6.

After the students do the activity, go over the explanation carefully and discuss the major points with the students.

LESSON 5.3

COMPLEX SOLUTIONS

PURPOSE:

To help students understand that most common solutions are complex; that is, have several solids dissolved in water.

ADVANCE PREPARATION:

Teachers may want to have little cups or bottles of various complex solutions in the room for students to view.

MATERIALS LIST:

Select 3 or 4 items such as:

soda	syrup	liquid dish detergent
mouthwash	kool-aid	hair color dye
catsup	clear shampoo	dish water
honey	apple juice	

Transparency 3: What would ocean water look like?

TEACHING SUGGESTIONS:

Have students collect labels from different complex solutions they may find at home. Discuss why these items are complex solutions. Note: Some items you find in your kitchen or bathroom are not complex solutions, i.e., ammonia (without soap or detergent), bleach (without soap or detergent), hydrogen peroxide, and alcohol. Each of these solutions contains only water and one other compound.

Remember that the word "substance" is supposed to remind students to ask two questions: What substance is changing? and How is it changing? The word "molecules" is supposed to remind students to write about what is happening to molecules during the change.

It is the molecular part of the explanation that provides a reason and accounts for the change. We want to help students get to the point of explaining the phenomena in this lesson cluster and the following clusters in terms of molecules.

Use Transparency 3 here: See Teacher's Guide Lesson 2.2 for a description of Transparency 3.

SUGGESTIONS FOR ADDITIONAL ACTIVITIES:

1. Crystal growing

   An interesting way to extend this lesson cluster is to have students grow two or more different types of crystals. The first step in growing crystals is to prepare a saturated solution. This can be done by dissolving as much of the solid as possible in a hot water solution. Pour this solution in a jar, and cover the jar with cheese cloth to prevent dust from getting into the solution. Allow the solution to cool overnight and crystals should form on the bottom of the jar. Pour the liquid from the crystals into a second jar, take one of the nicest crystals, tie it one a piece of thread, and suspend it in the solution of the second jar. Allow it to stand as the crystals grow.

   If crystals start forming on the bottom or sides of the jar, repeat the procedure just described by pouring the solution into a clean jar and again suspending a seed crystal on a piece of thread.

   There are a number of salts that make interesting crystals. Some are: alum, Rochelle salt, photographer's hypo or sodium thiosulfate, and cupric sulfate. Alum is aluminum sulfate and Rochelle salt is potassium sodium tartarate.

   Growing crystals is tedious and requires a lot of patience. Perhaps you would want to start growing crystals several weeks before you intend to use them.

   Crystals and Crystal Growing, by Alan Holden and Phylis Singer, is a good reference source. It is in the Science Study Series, published by Anchor Books, Doubleday & Co., Inc.

2. Finding complex solutions

   Students bring in solutions from stores and study the labels. (Remember that only clear liquids are true solutions.)

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 has not 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 <u>substances</u> (water and salt), and water and salt <u>molecules</u>.

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 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 H_2O 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.

MATERIALS LIST

CLUSTER 5, LESSONS 5.1-5.3

Lesson 5.1:

For each group:
magnifying glass
sugar
empty tea bag
plastic cup
water
Transparency 9

Lesson 5.2:

For each group:
two tumblers
two spoonfuls of salt (Kosher salt or canning salt)
two plastic cups
coffee stirrer

If you do the optional activity suggested in question 6 or the Activity Book, you will need a large pan or container to allow the salt solution to evaporate.

Lesson 5.3:

Cups of:

soda	syrup	liquid dish detergent
mouthwash	kool-aid	hair color dye
catsup	clear shampoo	dish water
honey	apple juice	Transparency 3

INTRODUCTION TO LESSON CLUSTER 6

HEATING AND COOLING, EXPANSION AND CONTRACTION

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to explain why solids dissolve faster in hot water, and why substances expand when heated.

Lesson Objectives

Students should be able to:

6.1 Explain why hard candy dissolves faster in hot water than in cold water.

6.2 Explain the expansion and contraction of solids.

6.3 Explain the expansion and contraction of liquids.

6.4 Explain the expansion and contraction of gases.

B. Key Elements of a Good Description

Both the rate of dissolving and thermal expansion can be explained by using the principle that molecules of a substance move faster when the substance is heated. In dissolving, molecules of hot water are moving faster than molecules of cold water, and hence break off molecules of candy faster. The molecules of candy that are knocked loose then mix in with the water molecules.

In thermal expansion, molecules of solids, liquids, and gases move farther apart when they move faster. When the molecules move farther apart, the solids, liquids, and gases get bigger.

C. Students' Conceptual Learning

Several tasks in this lesson cluster deal with the conception of thermal expansion in three different states of matter. A principle applies to explain all the tasks: heating a substance makes the molecules of the substance move faster, and therefore they move farther apart. This makes the substance expand. In contrast, when a substance is cooled, things happen in the opposite way. Many students have difficulty understanding and applying this rule to explain phenomena.

First, the explanation of thermal expansion requires knowledge about molecules. Unless students understand this principle in molecular terms, their explanations may be inconsistent across different situations. For instance, the same student may think that a ball will shrink when heated, the column of mercury in a thermometer will rise because of heat pressure, and the dime on a bottle will rattle because hot air rises. They should understand that even though things "appear" different, the scientific conception of thermal expansion applies in all these situations.

Second, students may have difficulty recognizing the cause/effect relationship. Students should understand that when molecules move faster, this causes the molecules to move farther apart. Then, students should associate what is happening to molecules with the change in the substance: When molecules move farther apart, this causes the substance to expand.

Lesson 6.1

This lesson explains why sugar dissolves faster in hot water: Molecules of hot water move faster and hit the molecules of sugar more often. Some students may think that "hot" molecules in hot water move faster than "cold" molecules in cold water. The teacher should stress that there is no change in individual molecules, but only in the motion of molecules.

Lesson 6.2

This lesson explains the thermal expansion of solids. At the macroscopic level, some students may predict that solids "shrivel up" or shrink when heated. They should realize that solids actually expand when heated. At the molecular level, common students' misconceptions are:

a. Molecules themselves expand or contract.

b. Molecules do not move in solids (e.g., the metal) and begin to move when solids are heated.

c. Heat is made of "heat molecules."

Lesson 6.3

This lesson explains thermal expansion of liquids, using the liquid in a thermometer as an example. At the macroscopic level, many students may think that the liquid comes out of the bulb and move up (that is, the liquid changes places from the bottom toward the top) or that "heat pressure" of the hot water causes the liquid to go up. The teacher should emphasize that the liquid expands, not moves from place to place.

Lesson 6.4

The expansion of air is illustrated by "The Dancing Dime" on top of a cold pop bottle. The explanation of the "dancing" is sometimes difficult for students. At the macroscopic level, some students may focus their attention on the bottle, the dime, heat, etc. They should first recognize what substance to focus on: the air in the bottle. Even then, many students may think using the idea of "heat" or "hot air": Hot air rises, heat rises, air pushes up, hot air pushes out the cold air, etc. All these ideas suggest that air moves from one place to another place within the bottle, rather than that air expands.

At the molecular level, some students may be confused between observable properties of substances and properties of molecules. For instances, they may think that molecules of air are cold and do not move when the bottle is frozen and that they begin to move when the bottle is heated.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Thermal expansion	Substances expand when heated.	Substances may "shrivel up" when heated; expansion of gases explained in terms of movement of air.
Constant motion	Molecules are constantly moving.	Molecules may sometimes be still, especially in solids.
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances. Molecules do not move in solids.
Effect of heat on molecular motion	Molecules of hot substances move faster.	Molecules themselves can be hot or cold.
Molecular explanation of thermal expansion	Increased motion moves molecules farther apart.	Molecules themselves expand.

LESSON 6.1

ANOTHER WAY TO MAKE SOMETHING DISSOLVE FASTER

PURPOSE:

To help students explain that hard candy in hot water will dissolve faster than in cold water because the molecules of hot water are moving faster and hit the candy more often than in cold water. That makes the water molecules knock the molecules off the piece of candy faster. To help students describe objects in which the molecules are moving slow as cold objects.

BACKGROUND INFORMATION:

Many of the concepts related to temperature and the speed of the molecules are to complicated for grade 6 students. We have therefore attempted to teach only a portion of the relationship between temperature and molecular motion. For example, temperature is a measure of the average kinetic energy of molecules, not just the velocity or speed of molecules. Since $K.E.=1/2\ mv^2$, the kinetic energy depends upon both the mass (m) of the molecules and their velocity (v) or speed. We have decided not to discuss the mass of the molecules because it is too difficult for grade 6 students. We resolved this issue by stressing that any given substance that has fast moving molecules is at a higher temperature than the same substance with slower moving molecules. What we have presented is correct. We simply chose not to present all the relationships.

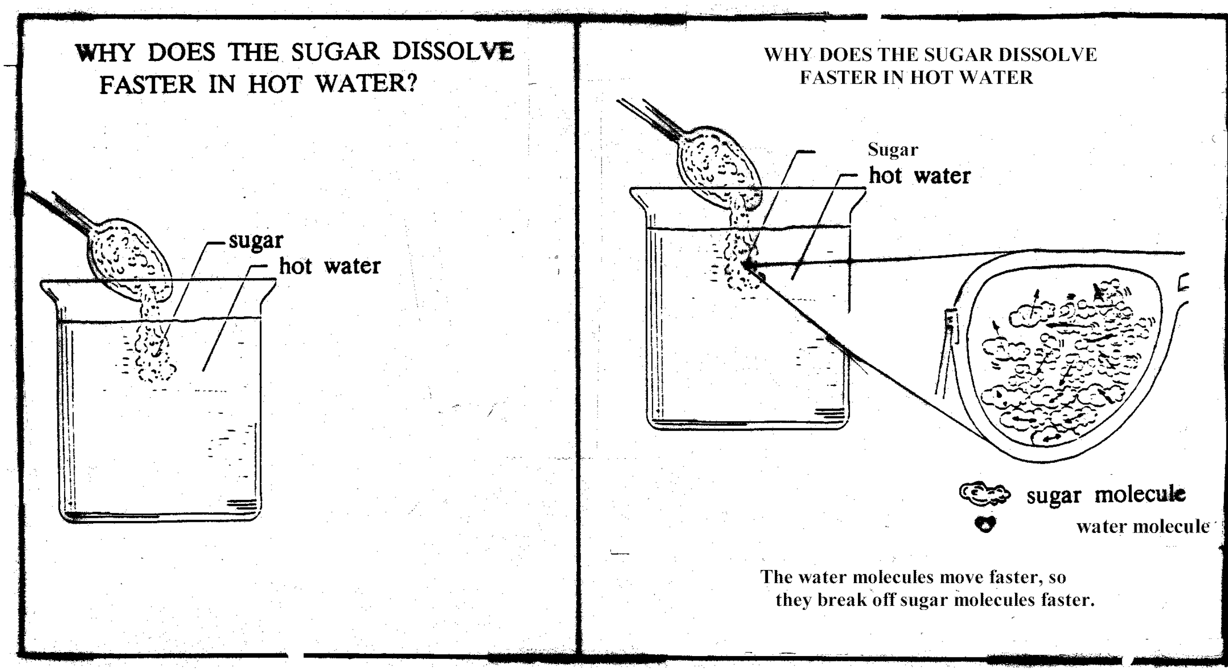
MATERIALS LIST:

two plastic cups
two pieces of hard candy
hot and cold water
Transparency 10: Why does the sugar dissolve faster in hot water?
Poster 2: States of Matter

TEACHING SUGGESTIONS:

1. After students do Activity 6.1, have the students read the remainder of the lesson. Stop frequently to discuss the important parts.

Use Transparency 10 here:

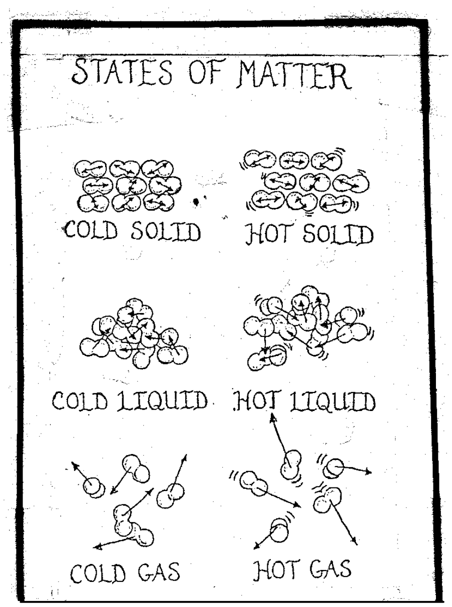


TRANSPARENCY 10: WHY DOES THE SUGAR DISSOLVE FASTER IN HOT WATER?

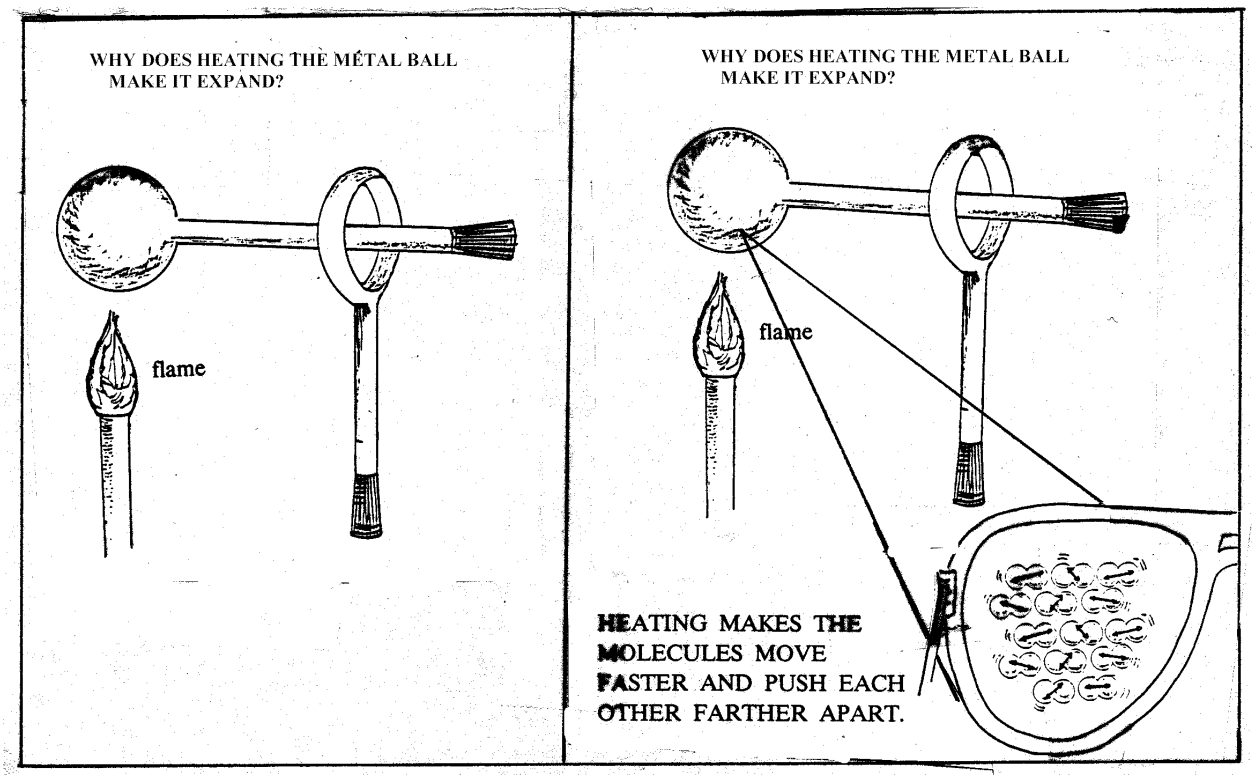
Bottom Layer
Students often answer this question by saying, "heat causes faster dissolving" or "molecules get hotter and so they move faster and dissolve faster." These are elements of the explanation but not an adequate explanation.

Overlay
Heating a system does make the process of dissolving speed up, but that is not really an answer to the question. The important part of the question is that dissolving is faster in hot water. It is not because molecules heat up (molecules are neither hot or cold), but because they move faster, and are thus able to break off sugar molecules faster.

Use Poster 2 here:



Transparency 11 (to be used with lesson 6.2)



TRANSPARENCY 11: WHY DOES HEATING THE METAL BALL MAKE IT EXPAND?

Bottom La3@er
Most students are amazed when the heated ball will not go through the ring, and are not able to explain this phenomenon. This is because they believe that, until the solid melts, heating will have no effect.

Overlay
Use the overlay to counter these naive conceptions. Just like in liquids and gases, when a solid is heated, the molecules move faster.

They do not move fast enough to break out of the rigid pattern (melting),but they do push each other a little further apart, causing the metal ball to expand (expansion caused by heating).

LESSON 6.2

HEATING SOLIDS

PURPOSE:

To help students use the kinetic molecular theory to explain the expansion and contraction of solids.

ADVANCE PREPARATION:

For this lesson you will need the ball and ring demonstration and the Transparency 11: Why did heat the metal ball make it expand?

MATERIALS LIST:

ball and ring apparatus
heat source such as propane burner or candle
Transparency 11: Why does heating the metal ball make it expand?

TEACHING SUGGESTIONS:

Some students believe that when you heat a solid it gets larger or expands because the molecules themselves get larger. Stress that the molecules themselves do not get larger or expand. When a solid is heated the molecules move faster, hit each other more frequently which causes them to move farther apart. The molecules moving farther apart causes the solid to expand.

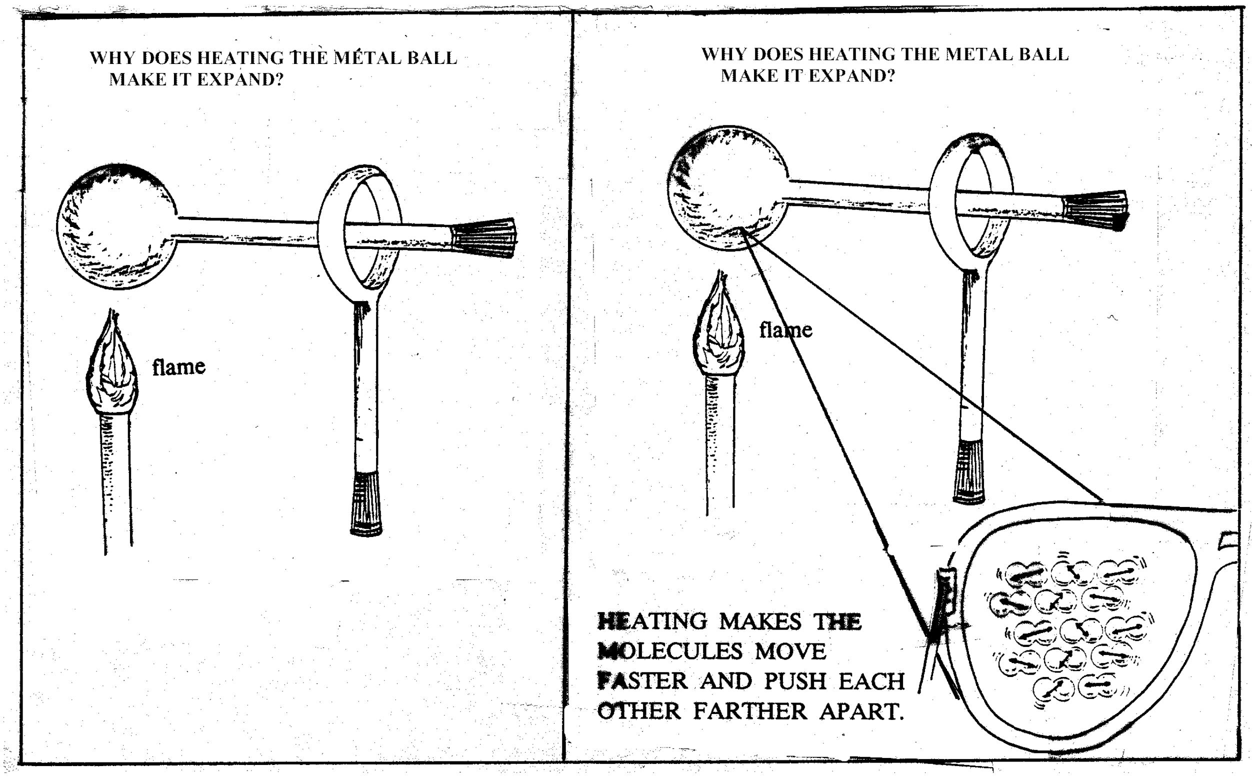
1. Begin with Activity 6.2 Heating and Cooling Solids--The Ball and Ring Demonstration.

2. Use Transparency 11.

3. Continue the lesson in the Science Book.

4. Students may be confused by apparent contradiction of objects such as leaves drying in the sun (water molecules escape), meat cooking (water and fat molecules escape), melting styrofoam (air molecules escape), or burning paper (molecules are broken down into simpler molecules).

Transparency 11 (to be used with Lesson 6.2)



TRANSPARENCY 11: WHY DOES HEATING THE METAL BALL MAKE IT EXPAND?

BOTTOM LAYER:

Most students are amazed when the heated ball will not go through the ring, and are not able to explain this phenomenon. This is because they believe that, until the solid melts, heating will have no effect.

OVERLAY:

Use the overlay to counter these naive conceptions. Just like in liquids and gases, when a solid is heated, the molecules move faster. They do not move fast enough to break out of the rigid pattern (melting), but they do push each other a little further apart, causing the metal ball to expand (expansion caused by heating).

LESSON 6.3

THE THERMOMETER

PURPOSE:

To help students use the kinetic molecular theory to explain the expansion and contraction of liquids.

BACKGROUND INFORMATION:

Some students will correctly explain that glass expands when heated as well as the liquid. Although this is true, the glass expands much less than the liquid in a thermometer. Hence, the volume of the thermometer tube remains nearly unchanged while the volume of the liquid increases significantly when heated. This is why the column of liquid changes.

MATERIALS LIST:

For each group of students:
one thermometer
two plastic cups
hot and cold water

TEACHING SUGGESTIONS:

Some students may think that the liquid goes up the thermometer tube when the bulb gets warmer because "heat rises." To confront this misconception, encourage students to read the thermometer on its side and upside-down to see if it changes.

Discuss each part of the lesson fully to help students explain the changes in the thermometer.

After you finished reading in the Science Book, you may want to have students go back to questions in the Activity Book and change their answers to make them more complete.

LESSON 6.4

GASES AND THE DANCING DIME

PURPOSE:

To help students use the kinetic molecular theory to explain the expansion and contraction of gases.

ADVANCE PREPARATION:

Collect one large glass soda bottle that has a pry-off cap for each student group. Bottles with screw-tops tend to have necks too large to hold dimes on top. The bottles should be cold at the beginning of the activity. You can store them in the school refrigerator or in a stryofoam chest with ice.

MATERIALS LIST:

one large soda bottle, cold
one dime
one balloon for optional activity

TEACHING SUGGESTIONS:

The expansion of gases is often confused with convection currents, especially in the activities we use that seem to show hot air rising. Watch out for this conceptual confusion. Students are very familiar with the phrase "hot air rises," and it seems difficult to picture gases (or solids, for that matter) expanding. The activity in this lesson will help students get a visual image of air expanding, especially if the class talks specifically about the difference between "hot air rising" and air expanding (see Activity Book, Lesson 6.4, question 4, especially part c).

There is an Activity 6.4 and a Question Set 6.4.

Students should complete Activity 6.4: The Dancing Dime, at this time.

You may want to use Question Set 6.4: Lesson Cluster Review, as an assessment of student progress.

MATERIALS LIST

CLUSTER 6, LESSONS 6.1-6.4

Lesson 6.1:

two plastic cups
two pieces of hard candy
hot and cold water
Transparency 10
Poster 2

Lesson 6.2:

For this demonstration:
ball and ring apparatus
heat source such as propane burner or candle
Transparency 11

Lesson 6.3:

For each group of students:
one thermometer
two plastic cups
hot and cold water

Lesson 6.4:

one large soda bottle, cold
one dime
one balloon for optional activity

INTRODUCTION TO LESSON CLUSTER 7

EXPLAINING MELTING AND SOLIDIFYING

A. Lesson Cluster Goals and Lesson Objectives

Goals

Students should be able to explain melting and solidifying, by reference to the molecular structure of solids and liquids, and the motion of molecules in each state.

Lesson Objectives

Students should be able to:

7.1 Explain melting and freezing of water.

7.2 Explain melting and solidifying of other substances.

7.3 Explain that different substances have unique melting and solidifying temperatures.

B. Key Elements of a Good Description

There are three key principles involved in explanation of melting and solidifying:

1. Molecules of a substance move faster when the substance is heated, and slower when it is cooled.

2. The molecules of a solid are close together, arranged in a rigid array, vibrating back and forth. The molecules of a liquid are also close together, but move freely past each other.

3. There is a force of attraction between molecules of the same substance. This force of attraction is strong enough in solids to keep molecules tightly packed together.

When a solid is heated, its molecules begin to move faster and faster, until their motion overcomes the force of attraction between them. They move too quickly to be held in a rigid array--but not quickly enough to evaporate, or change into a gas, by escaping the attraction altogether.

When a liquid is cooled, its molecules move more slowly. At its freezing temperature, the force of attraction binds them together in a rigid array.

C. Students' Conceptual Learning

In Lesson Clusters 1 and 2, students learned differences among solids, liquids, and gases of substances in terms of the arrangements and motions of their molecules. The contents in Lesson Clusters 7, 8, and 9 are about how or why a substance changes from one state to another. In Lesson Cluster 6, students have learned that heating or cooling makes molecules move faster or slower. Thus, the students need to integrate scientific ideas they have already learned in understanding and explaining various changes of state in these last three lesson clusters. The specific example used is water in its three states, and the same explanation applies to other substances.

One additional conception that you should stress in the next three lesson clusters is that molecules attract each other. In solidifying and condensing, molecules slow down enough so that their attraction for each other "locks" them together in the solid or liquid state arrangement. In melting and evaporating, the increased motion of molecules allows them to overcome their mutual attractions, and change their molecular arrangement (from solid to liquid, or liquid to gas).

Lesson 7.1

At the macroscopic level, emphasize that matter is conserved when a substance changes from the solid state to liquid state. For instance, to many students, the solid state of water may appear to be heavier or have more "stuff" than the liquid state. However, water is conserved in all physical changes of state because the molecules of water remain the same from ice to liquid water, or vice versa.

Students may still be confused between observable properties of substances and properties of molecules themselves. Some common students' misconceptions are:

a. When ice melts, molecules themselves melt.

b. Molecules are different in ice and liquid water.

c. Molecules are hard or frozen in ice an begin to move when ice melts.

There is no change in individual molecules, but only in the arrangements and motions of molecules during changes of state.

Lesson 7.2

After learning how water melts and freezes, students should be able to explain how other substances melt and solidify. Most students are familiar with melting and freezing of water. But it is not always clear to students that wax, for instance, "freezes" or solidifies. They may say that it hardens or dries out, and not be able to account for the change in terms of molecules, even though they did for water.

Lesson 7.3

This lesson takes students on an imaginary voyage into very hot and very cold regions. Combining scientific ideas presented in the last two lessons, it describe how melting and solidifying of different substances occur at different temperatures.

D. Conceptual Contrasts

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

Issue	Goal Conceptions	Students' Conceptions
Conservation of matter	Matter is conserved in all physical changes.	Matter is not always conserved (e.g., ice weighs more than water).
Constant motion	Molecules are constantly moving.	Molecules may sometimes be still, especially in solids (e.g., molecules do not move in ice).
Visibility of molecular motion	Molecular motion continues independently of observable movement.	Molecules simply share in observable movements of substances (e.g., molecules begin to move when ice melts).
Same molecules in different states of same substance	Solid, liquid, and gas forms of the same substance are all made of the same type of molecules.	Molecules of the same substance are different in its different states (e.g., ice molecules).
Effect of heat on molecular motion	Molecules of hot substances move faster.	Molecules themselves can be hot or cold.
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules.	States of matter described only in terms of observable properties, or properties of state attributed to individual molecules (e.g., molecules are hard in ice).
Attraction of molecules	Molecules of one substance attract each other.	Molecules bounce around like billiard balls and do not attract each other.
Molecular explanation of changes of state	Heating and cooling cause changes of state by making molecules move faster or slower.	Heating and cooling make molecules "melt" or molecules begin to move when heated.

LESSON 7.1

MELTING ICE AND FREEZING WATER

PURPOSE:

To help students use the kinetic molecular theory to explain the melting and solidifying of water.

MATERIALS LIST:

Transparency 12: Why does liquid water change into ice when it gets cold?
Poster 3: Changes of state

TEACHING SUGGESTIONS:

Introduce this lesson by having the students read the first two paragraphs of the Science Book and discuss Activity 1.1: Changing Solid Water to Liquid Water--Fast. You might want to ask students to try to explain melting before you continue to read this lesson. Some of them may be able to bring together what they know about the motions and arrangements of molecules in solids and liquids with the idea that molecules move faster when they are heated. Most students will probably not be able to do this yet. The rest of this lesson discusses the explanation of melting ice.

Use the diagram and poster to stress the relationships among condensation, solidifying, melting, and evaporation (boiling).

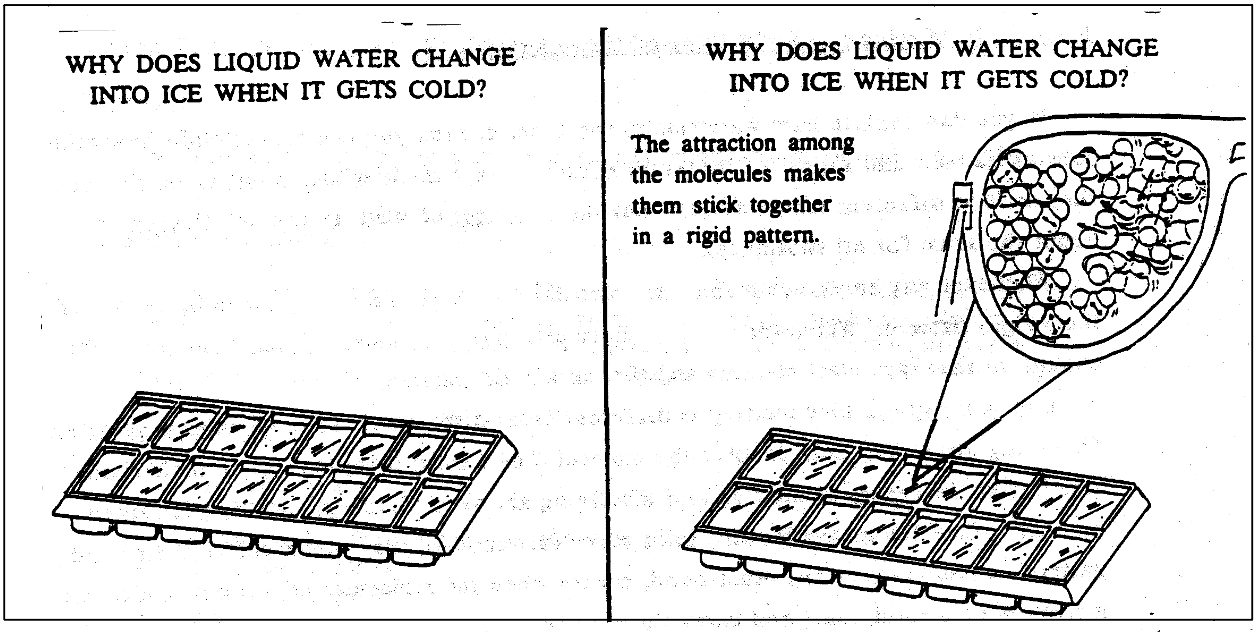
Many students believe that when water freezes, the molecules freeze or change into ice molecules. Emphasize that this is not true. When water changes state, the molecules remain the same. The only change is in the movement and position of the molecules.

This idea that the attraction between water molecules causes them to form into the rigid patter of a solid is important for explaining freezing. Attraction is not so important for explaining melting: One can simply say that when molecules move faster, they break out of the rigid pattern of a solid.

Some students want to bring into the explanations of melting the idea that when molecules move faster, they move farther apart, and therefore break out of their pattern. But this is not universally true. Molecules of water actually move a little closer together when ice melts. Since the explanation of melting is difficult enough as it is, "moving farther apart" should be left out of it.

The same is true with the explanation for freezing: some students want to say that when a substance is cooled, the molecules slow down, move closer together, and (therefore) the attraction between them becomes greater and they form a rigid pattern. This type of explanation is confusing, because the molecules are already very close together and the attraction between them always exists. What is important here is that the molecules slow down enough so that the attractive force can cause them to coalesce into a rigid pattern.

Use Transparency 12 here:



TRANSPARENCY 12: WHY DOES LIQUID WATER CHANGE INTO ICE WHEN IT GETS COLD?

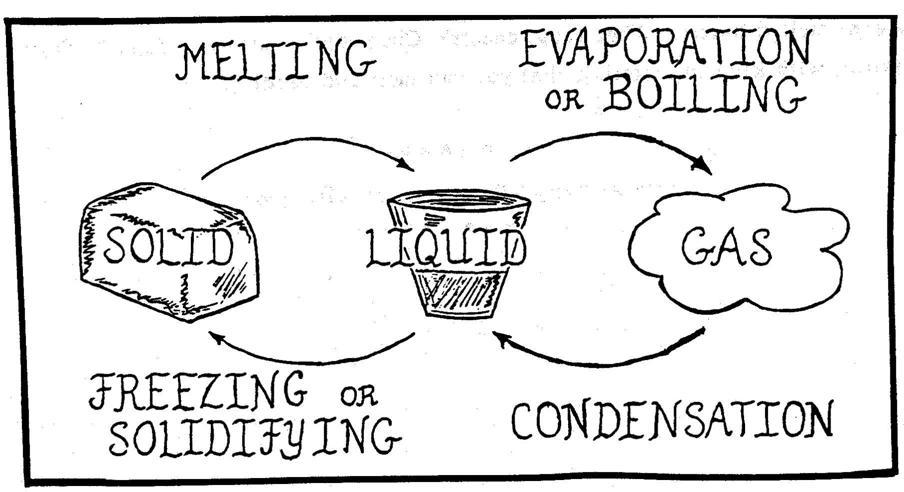
BOTTOM LAYER:

Many students will answer this question by saying, "the water freezes" and will not go any further in their thinking.

OVERLAY:

"The water freezes" is a correct answer at the macroscopic level, but it is important to get students to think in terms of molecules. When water molecules are in a liquid state, they are moving past each other and bumping into each other. As the water gets cold, the molecules begin to slow down, and the attraction among the molecules become stronger, making them stick together in a rigid pattern. This is ice.

Use Poster 3 here:



LESSON 7.2

MELTING AND SOLIDIFYING OF OTHER SUBSTANCES

PURPOSE:

To help students infer that almost all substances can be in either the solid or liquid state.

ADVANCE PREPARATION:

For this demonstration you will need to set up a hot place so you can heat water. You will also need ice so you can cool the four substances, which you can keep in the school refrigerator or in a stryofoam chest. You will also need the materials listed below.

MATERIALS LIST:

hot plate
two beakers
four test tubes
olive oil
shortening
chocolate
paraffin
test tube rack
ice

TEACHING SUGGESTIONS:

Read and discuss the lesson in the text with your class. Stress that almost all pure substances can be in the solid or liquid state by melting or freezing them, but some mixtures, as noted in the text, do not melt when heated.

Use this opportunity to review the differences between a pure substance and a mixture. Emphasize that a mixture is made of two or more pure substances. A pure substance has only one kind of molecule, but a mixture has two or more kinds of molecules.

It is important for students to realize the connections between the kinetic molecular theory and real life; therefore, you may want to discuss melting and freezing in the kitchen. Ask students about their experiences of those of their parents in the kitchen.

LESSON 7.3

ADVENTURES INTO THE HOT ZONE AND COLD ZONE

PURPOSES:

To help students infer that each substance has its own unique freezing or melting temperature.

To help students be cognizant of the wide range of temperatures in which substances melt or freeze.

TEACHING SUGGESTIONS:

This lesson is an imaginary flight into the heights and depths of temperature. Feel free to add visual aids by drawing pictures on the blackboard or on transparencies.

Encourage students to tell what they think the story is attempting to teach them (see Purpose above). The main point to get across to your students is that all substances can be solids at their unique freezing or solidifying points, and all substances can become liquids at their unique melting points.

Question Set 7.3 can be used as an evaluation tool if you want, or you may use it to review the major concepts of this lesson cluster.

Possible Extension Activities

1. Making ice cream illustrates freezing.

2. Making candles illustrates both melting and solidifying.

3. You may want to bring some dry ice to class (it is available at a convenience store).* Dry ice is solid carbon dioxide. It changes directly to gaseous carbon dioxide at -78.5^{0} C (or at higher temperatures). It can only exist as a liquid if it is in a container under pressure. The process of changing directly from a solid to a gas is called sublimation.

*We can provide dry ice on teacher request (at least one week notice).

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

MATERIALS LIST

CLUSTER 7, LESSONS 7.1-7.3

Lesson 7.1:

Transparency 12
Poster 3

Lesson 7.2:

one hot plate
two beakers
olive oil
shortening
chocolate
paraffin
four test tubes
test tube rack
ice

Lesson 7.3:

none

INTRODUCTION TO LESSON CLUSTER 8
Explaining Evaporation and Boiling

A. Lesson Cluster Goals and Lesson Objectives

<u>Goals:</u>

Students should be able to explain evaporation and boiling, both in macroscopic terms and in molecular terms.

<u>Lesson Objectives:</u>

Students should be able to:

8.1 Use the kinetic molecular theory to explain evaporation and boiling.
8.2 Use the concept of evaporation to explain the origin of water vapor in the air.
8.3 Use the kinetic molecular theory to explain rapid evaporation and boiling.
8.4 Use the kinetic molecular theory to explain smells and how smells travel.

B. Key Elements of a Good Explanation

Evaporation and boiling are both examples of liquids changing into gases. In boiling, the liquid changes into a gas at the bottom of the container, where the liquid is being heated, and forms bubbles of the substance in the gaseous state.

The change from liquid to gas is similar to the change from solid to liquid. In boiling, a substance is heated, molecules move more quickly and eventually move fast enough to change from a liquid to a gas. In evaporation, the substance is not being heated, but some molecules are moving fast enough to escape the surface of the liquid and mix with the air.

Smell is due to evaporation. A container of alcohol smells, for example, because some of its molecules are moving quickly enough to escape the liquid, mix with the air, and travel to our noses.

C. Conceptual Learning

At the macroscopic level, students should recognize two important ideas: when liquid water evaporates, it changes from the liquid state to the gas state (water vapor), and then this water vapor mixes with the air and stays there. Even though these two ideas have already been introduced in Lesson Clusters 1 and 3, many students may have difficulty putting them together. Some common students' misconceptions are:

a. When liquid water evaporates, it changes from liquid to <u>air</u>.
b. When liquid water evaporates, water molecules change into air molecules.
c. When liquid water evaporates, it disappears and is gone.
d. When liquid water evaporates, it goes to clouds or forms clouds (but not necessarily stays in the air).

Each of these misconceptions stem from the difficulty of understanding that there can be (and is!) invisible water vapor in the air.

At the molecular level, students should be able to explain how or why evaporation occurs. That is, molecules in the liquid state are constantly moving, but at different speeds. Faster moving molecules at the surface of a liquid break away from the attraction of the other molecules, and escape into the air. Furthermore, heating makes liquids evaporate faster because there are more fast moving molecules and, therefore, more molecules can escape.

Lesson 8.1: Where Did the Water Go?

To explain why the air is humid or dry, students should realize that there is water vapor in the air and that the amount of water vapor varies in dry versus humid air. Many students, however, may simply think that humidity has to do with temperature, that is, air is humid in hot weather like summer and dry in cold weather like winter. The teachers should help students realize that there is water vapor in air and that there is more water vapor in humid air than in dry air.

At the molecular level, students should know by now that molecules are constantly moving. Individual molecules are moving at slightly different speeds. Unless students understand that individual molecules in a liquid move at different speeds, they may wonder why some molecules escape from water but others do not; they may think that water needs to be heated to evaporate. Instead, heating simply speeds up evaporation by making molecules move faster.

Although the Science Book does not go farther in its explanation, there is more: As faster moving water molecules escape from a cup of water, the temperature of the water in the cup will decrease, and fewer molecules will have sufficient energy to escape, slowing down evaporation. However, this will happen only in a cup of water that is insulated from the rest of the environment. The external environment (i.e., the air, the cup itself, the desk the cup is on, etc.) will continuously provide enough heat to keep the water at a steady temperature and evaporation will continue.

Lesson 8.2: Where Does the Water in the Air Come From?

Students should understand that the process of water evaporating into the air does not just happen from cups of water or humidifiers. A very large proportion of water vapor evaporates from the oceans, lakes, streams, animals, and plants.

Students should be able to explain that water molecules are always escaping from any surface with water in it. One reason why plants and animals need to drink so much water is to replace water lost through evaporation.

Lesson 8.3: Fast Evaporation and Boiling

The teacher should help students distinguish between evaporation without heating, with heating, and boiling:

a. Evaporation occurs (without heating) when individual fast moving molecules escape from the surface of a container.
b. Heating speeds up evaporation by causing more molecules to move faster and more molecules to escape from the surface of a container.

c. Boiling occurs when molecules move faster and faster at the bottom of a heated container, and they eventually move fast enough to change to a gas at the bottom. Trillions of molecules of water vapor collect to form bubbles that rise to the top of the container.

Students also have difficulty with the notion of bubbles. Many students think that there is "air" in bubbles. Some students may think that heat from the hot plate goes through the container into the water and changes into bubbles. The teacher should emphasize that bubbles are a collection of molecules of water vapor. The teacher should also emphasize that heating is the cause of bubbles, but not the "source" of bubbles.

Lesson 8.4: Evaporation and Smells

Students have already learned about smells in Lesson Cluster 3: Smells are made of molecules of the substance that has escaped and mixed in with the air. This is a form of evaporation. Not all molecules that evaporate from substances are smelly, though.

Some students attribute smell to a "scent" that leaves the substance, but don't recognize that the amount of substance decreases as the "scent" leaves it. They most likely do not understand that the "scent" is actually molecules of the substance.

D. **Conceptual Contrasts**

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

ISSUE	GOAL CONCEPTIONS	STUDENTS' CONCEPTIONS
Conservation of matter	Matter is conserved in all physical changes.	Matter is not always conserved, especially in changes involving gases (e.g., water molecules change into air).
Water vapor in air	Air contains invisible water vapor (humidity).	There is no gaseous state of water in air.
Same molecules in different states of same substance.	Solid, liquid, and gas forms of the same substance are all made of the same type of molecule.	Molecules in different states of the same substance are different.
Effects of heat on molecular motion.	Molecules of hot substance move faster.	Molecules themselves can be hot or cold.
Molecular explanation of changes of state	Heating and cooling cause changes of state by making molecules move faster or slower.	Heating and cooling make molecules "evaporate."
Molecular explanation of evaporation.	Evaporation is caused by fast moving molecules escaping from liquid.	Molecules "evaporate" or disappear.
Molecular explanation of boiling.	Boiling occurs when molecules of a liquid move fast enough to change to a gas at the bottom of the container. Trillions of molecules of the gas collect to form bubbles that rise to the top of the liquid.	Boiling occurs when a liquid changes to air. The air carries some of the liquid out of the container.

Lesson 8.1: Where Did the Water Go?

Purpose:

To help students use the kinetic molecular theory to explain evaporation and humidity.

Materials List:

1. Paper towels and water
2. Transparency 13: Where does the water go when clothes dry?

Teaching Suggestions:

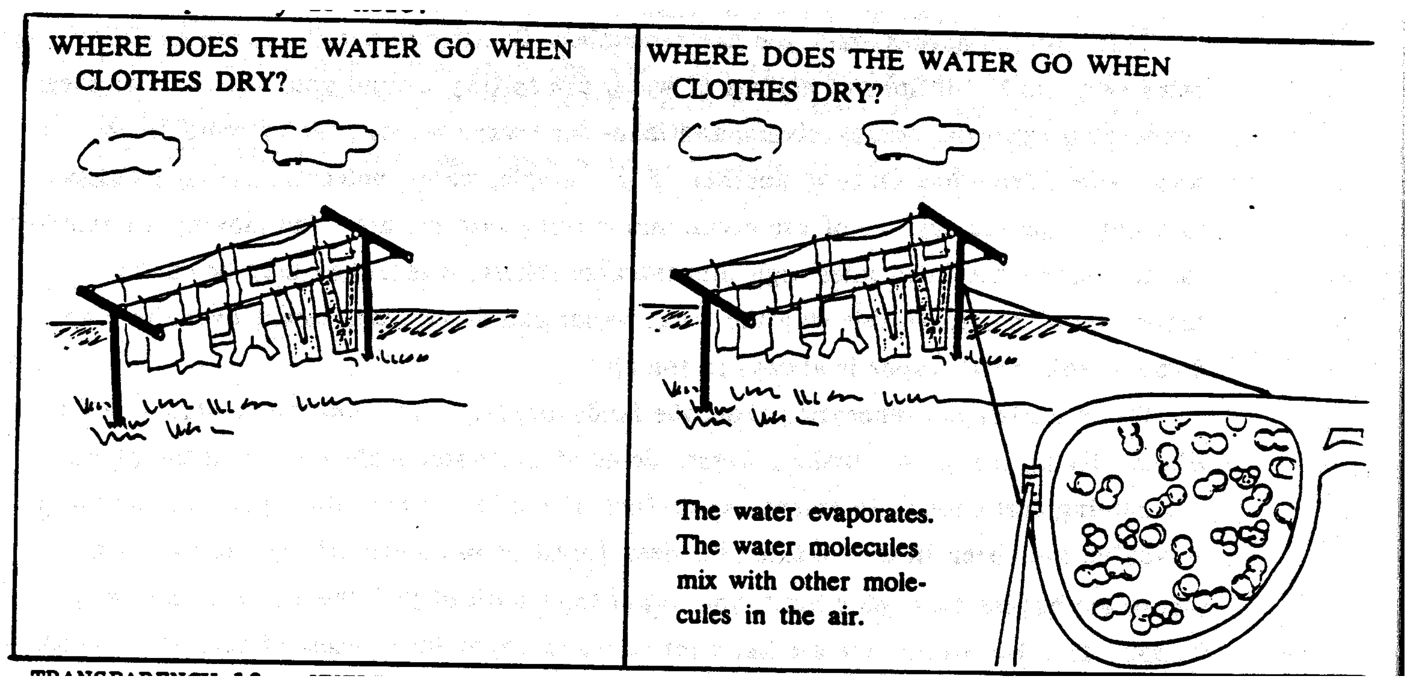
Begin this lesson by placing a spot of water on a paper towel and on the chalkboard. Discuss with your students the two questions at the start of Lesson 8.1. Students should easily recognize that the molecules on the paper towel are water molecules. Elicit as many responses to the question, "What happens to the molecules?" as you can. Some students may say that the water molecules "turn into air" or "just disappear." These are naive conceptions and are not adequate explanations.

You may want to discuss with your students the question, "What do we mean when we say the air is humid?" when you come to it in the text. Many students are familiar with the term "humid," but they do not really understand what it means. They do not associate water vapor in the air with humidity. Most students will talk about the effects of humidity, that is, "we feel uncomfortable" or "we sweat a lot." Encourage students to explain why they may feel uncomfortable or sweat more. Have them use the model of a good explanation presented in Lesson Cluster 4.

Unless students understand that individual molecules in a liquid move at different speeds, they may wonder why some molecules escape from water but others do not; they may think that water needs to be heated to evaporate. Instead, heating simply speeds up evaporation my making molecules move faster.

Although the Science Book does not go farther in its explanation, there is more: As faster moving water molecules escape from a cup of water, the temperature of the water in the cup will decrease, and fewer molecules will have sufficient energy to escape, slowing down evaporation. However, this will happen only in a cup of water that is insulated from the rest of the environment. The external environment (i.e., the air, the cup itself, the desk the cup is on, etc.) will continuously provide enough heat to keep the water at a steady temperature and evaporation will continue.

Use Transparency 13 (WHERE DOES THE WATER GO WHEN CLOTHES DRY?) here:



Bottom Layer

Students have a variety of conceptions concerning this phenomenon. Some students will say that the water "just disappeared." Others will say that "it soaks into the clothes." Still others will say, "it evaporated."

Overlay

Of all the above conceptions, only the last is correct. The water does evaporate but this is not specific enough. Students should also understand what is happening in terms of molecules. Some of the water molecules in the drying clothes are moving fast enough to escape the surface of the clothes. These molecules mix with the molecules of the air and become part of the air.

Lesson 8.2: Where Does the Water in the Air Come From?

Purpose:

To help students use the kinetic molecular theory to explain evaporation as the source of water vapor in the air.

Advance Preparation:

You may want to have a world map or a globe to discuss the relationships of the amount of water and land on the earth.

Teaching Suggestions:

It seems to be very difficult for many students to believe that there is invisible water vapor in the air at all times. Even those who understand that water goes into the air when it evaporates from puddles or drying clothes seem to have difficulty with this idea of "humidity" when no source of water vapor is near by. This is an especially important conception, though, for the explanation of condensation given in the Lesson Cluster.

Lesson 8.3: Fast Evaporation and Boiling

Purposes:

To help students use the kinetic molecular theory to explain rapid evaporation and boiling. To describe what is inside the bubbles of a boiling liquid.

Advance Preparation:

For the activity, you will need to measure 2-ml portions of alcohol.

Materials List:

1. For each student, 2 ml of alcohol
2. Transparency 14: What's Inside the Bubbles of Boiling Water?

Teaching Suggestions:

Begin this lesson by discussing the first paragraph in the Science Book. Ask students if they know of any good ways to make the process of evaporation go faster. When you have gathered a list of possible responses, proceed to the activity.

After you have given ample time to the activity, discuss what happened with your students and read the next four paragraphs aloud. Take a moment to talk about the clothes dryer example. This is an everyday application of the kinetic molecular theory, and it is important for students to see the connection between science and real life.

It is important for students to understand that the bubbles in boiling water are water vapor. If you were to boil alcohol, the bubbles in boiling alcohol are gaseous alcohol. They are not made of air or anything else. The bubbles are not individual molecules. You should draw out these misconceptions through discussion and confront them directly.

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.

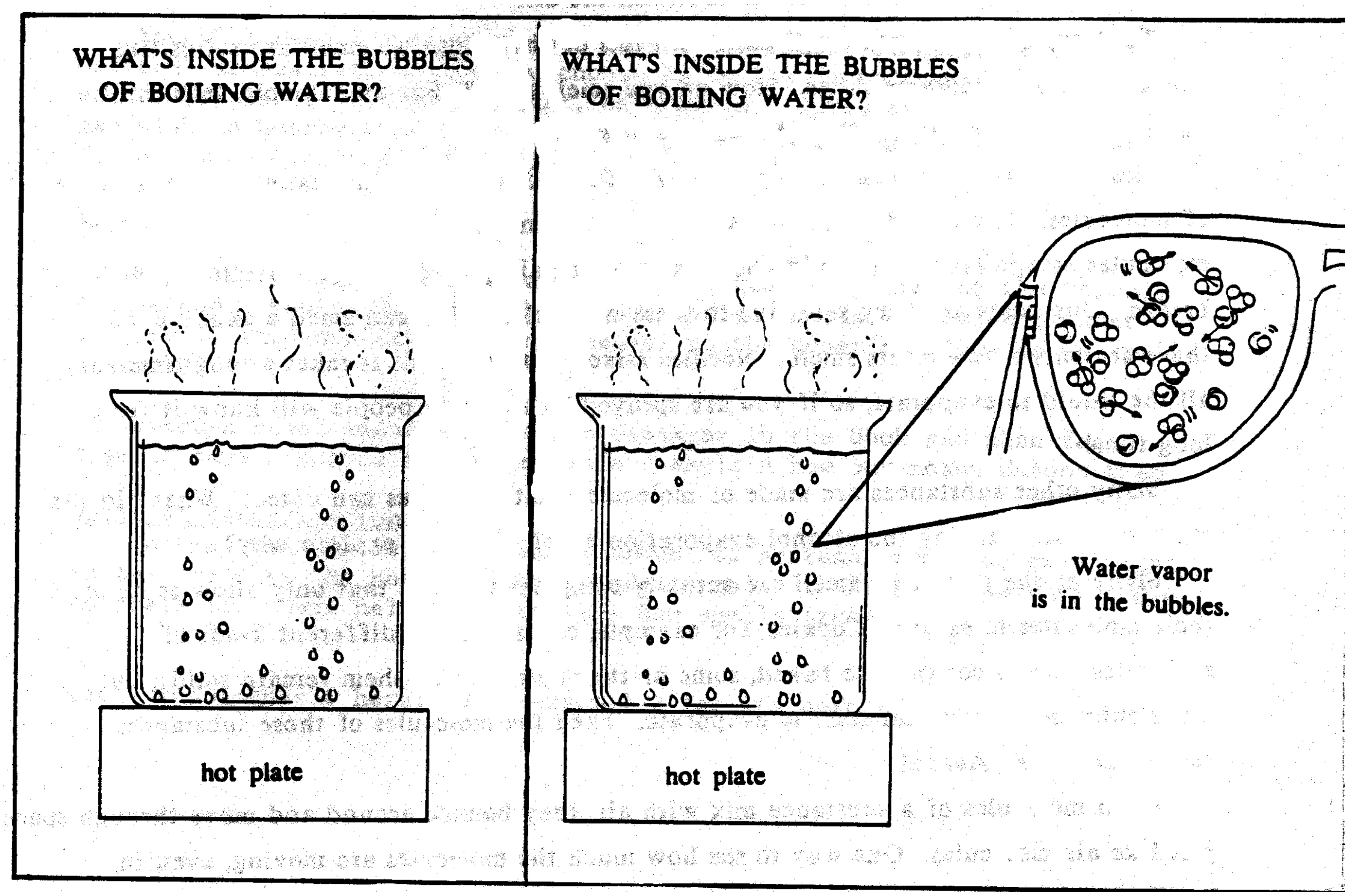
3. Students should include the following ideas in their responses: Alcohol molecules in liquid alcohol slide around and bump into each other. Some of the molecules are moving fast enough to escape from the surface of the liquid, thus, the liquid changes to a gas. The alcohol molecules mix in with the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

$$C_2H_5OH + 3O_2 \qquad 2CO_2 + 3H_2O$$

Finally, make sure students understand the difference between evaporation and boiling. You can select individual students from the class to explain the difference in their own words, or you may want them to write the differences and similarities down.

Use Transparency 14 (What's Inside the Bubble of Boiling Water?) here:



Bottom Layer

Although students will come up with a variety of answers to this question, their most common answer will probably be that there is air inside the bubble.

Overlay

The bubbles do not contain air. This is an important misconception to counter. They contain invisible water vapor. Under each bubble which forms at the bottom of the container are molecules that are moving fast enough to move very far apart (so that the liquid changes) directly to a gas. These molecules have clustered together to form these bubbles which then rise to the surface and pop, releasing water vapor into the air.

Lesson 8.4: Evaporation and Smells

Purpose:

To help students use the kinetic molecular theory to explain smells and how smells travel.

Advance Preparation:

You will need Transparency 6: What is the Smell of Baking Cookies? Optional demonstration: If you choose to do the demonstration, you will need a bottle of perfume, vinegar, or ammonia. Optional activity: You may wish to borrow a copy of "Bartholomew and the Oobleck," by Dr. Seuss, for use with Question Set 8.3 in the Activity Book.

Teaching Suggestions:

Begin by having students read the first two paragraphs of the Science Book aloud. Remind students that they studied smells in Lesson Cluster 3. See if students can think of answers to the question, "How do we smell a skunk?"

Discuss other scents. Read the passages in the book and also feel free to have students choose smells and explain how our noses detect them.

Optional Demonstration:

You may want to release a small amount of perfume, ammonia, or vinegar in the front of the room and have students raise their hands as they begin to smell it. This helps students see how smells travel.

Use Transparency 6 here. See Lesson 3.2 for its description.

When most students understand smells, let them do Question Set 8.4. This is a cluster review, so you may choose to use it as an evaluation tool.

MATERIALS LIST

CLUSTER 1, LESSONS 8.1-8.4

Lesson 8.1:

paper towels
water
Transparency 13

Lesson 8.2:

world map or globe (optional)

Lesson 8.3:

For the activity: (for each student)
2 ml of alcohol

For the demonstration:
You will need a pre-heated hot plate and 2 beakers, one with 2 ml of alcohol, the other with a larger amount so that students can view the bubbles. Caution: There should be no open flames in the room when you boil alcohol.

Transparency 14

Lesson 8.4:

Transparency 6
For demonstration: (optional)
bottle of perfume, vinegar, or ammonia

Bartholomew and the Oobleck by Dr. Seuss (optional)

INTRODUCTION TO LESSON CLUSTER 9
Explaining Condensation

A. Lesson Cluster Goals and Lesson Objectives

Goals:

Students should be able to explain condensation of water vapor on cold objects and how condensation fits into the water cycle.

Lesson Objectives:

Students should be able to:

9.1 Explain condensation as part of distillation or when liquids boil in open containers.

9.2 Explain condensation from evaporation.

9.3 Continue explanation of condensation from evaporation.

9.4 Explain condensation when the source of water is not evident (in the open air, and as part of the water cycle).

9.5 Explain various forms of precipitation.

9.6 Describe how water is recycled over and over again through evaporation and condensation in the water cycle.

B. Key Elements of a Good Explanation

The explanation of condensation is similar to that of solidifying or freezing. When air is cooled, (by coming into contact with a cold surface, for instance), molecules of water vapor slow down. If they slow enough, the attractive forces between them hold them together when they collide, and they coalesce into tiny droplets.

The distinction between the molecular structures of liquids and gases is important for this explanation. In gases, molecules are far apart and move freely. When they collide, they are moving fast enough so that the intermolecular forces cannot hold them together--they bounce off each other. In liquids, molecules are held closely together, but they are moving fast enough so that they slide past each other, moving from one place to another.

C. Conceptual Learning

At the macroscopic level, students should recognize two important ideas in order to understand condensation of water: There is water vapor in air, and water vapor changes into liquid water on a cold object. First, the teacher should help students remember the presence of water vapor in the air. By now, most students would not have difficulty with this. Then, the teacher should stress how cooling affects water vapor to change into liquid. The teacher should also stress how condensation is related to boiling or evaporation: they are reverse processes. This will help students recognize how the processes of evaporation and condensation continue over and over again.

At the molecular level, the teacher should stress that when molecules of water vapor hit something cold, they slow down and move closer together. The closer the molecules become, the more they attract each other, and they cluster together to form a liquid.

Finally, some students may not recognize that cooling is necessary for condensation. The teacher should emphasize that condensation occurs only when water vapor is cooled by hitting something cold. That is why students use cold containers in the experiments. Related to this, the teacher should make the distinction for students between the cause (i.e., coldness) and the source (i.e., water vapor) of condensation.

Lesson 9.1: Boiling and Condensing

This lesson uses the distillation apparatus again to illustrate condensation. Some common misconceptions are:

a. Bubbles in the boiling water are air, and air changes back to liquid.
b. Condensation occurs when hydrogen and oxygen in the air combine to form water.

The teacher should stress that water does not change into air, and vice versa. Instead, the bubbles contain water vapor and water vapor mixes in the air. The teacher should also stress that the chemical reaction of $2H_2 + O_2 \quad 2H_2O$ does not occur in the air because there is virtually no H_2 in the atmosphere.

Many students also have difficulty with the identity of water vapor and the word "steam." They may think that the visible "steam" above boiling water is water vapor. Some students may think that "steam" is hot air or heat rising off water. The teacher should help students with their learning difficulties by emphasizing the scientific idea that water vapor produced by boiling is invisible. The visible "steam" is droplets of water which have already condensed from water vapor. (Scientists use the word "steam" to indicate the invisible water vapor produced by boiling. We put the word in quotation marks to indicate colloquial rather than scientific usage.)

Lesson 9.2: Purifying Water Without Boiling

The evaporation-condensation cycle occurs when water evaporates as well as when it boils. Evaporation--from oceans, lakes, etc.--is the process that puts most of the water vapor into the air around us. Evaporation of salt water produces pure water when it condenses. This lesson demonstrates and explains the purification of water as a result of evaporation.

A three-stage process of evaporation, spreading of water vapor, and condensation, explains the movement of water in the purification process.

Lesson 9.3: Evaporating and Condensing

This lesson continues the discussion of how distillation occurs through evaporation and condensation. It begins with viewing the "solar still" episode of "Voyage of the Mimi."

The teacher should remind students of the difference between boiling and evaporation from Lesson Cluster 8. As in the last lesson, the teacher should stress how evaporated gases mix with and stay in the air and how they condense on cold objects in molecular terms.

Lesson 9.4: Condensing in the Open Air

In the last two lessons, students could see water vapor condense into liquid water in containers (i.e., closed systems). In this lesson, condensation on a cup of cold water sitting in the open air is explained. Students should realize that there is always water vapor in the air. Students who do not recognize the presence of water vapor in the air may have difficulty understanding where the liquid water on the outside of the glass comes from. Some students' misconceptions are:

a. Air outside the glass changes into liquid water.
b. Water inside the glass seeps through the outside of the glass.
c. Coldness comes through the glass.

Since there is no visible source of liquid water, students may wonder where water vapor in the air comes from. The teacher should help students recognize various sources of water vapor, such as oceans, lakes, tree leaves, etc.

Lesson 9.5: Condensation and Precipitation

In the last lesson, different forms of precipitation were explained as various processes of condensation in the open air. This lesson focuses on the three step process of: (1) evaporation, (2) spreading, and (3) condensation as a detailed explanation of all forms of precipitation. Students may have problems in explaining the seemingly unrelated phenomena of fog, dew, rain, snow, or hail until they can see how each is a result of the same processes (evaporation and condensation) but under slightly different circumstances.

Lesson 9.6: You Drank the Water that George Washington Used to Wash His Boots

This lesson uses a catchy example to illustrate the water cycle. The important idea in the water cycle is that water that is on the earth remains almost the same, and is only recycled over and over again through evaporation and condensation.

D. <u>Conceptual Contrasts</u>

The chart below contrasts common patterns in student thinking with scientific thinking about some of the important issues for this lesson cluster.

ISSUE	GOAL CONCEPTIONS	STUDENTS' CONCEPTIONS
Conservation of matter	Matter is conserved in all physical changes.	Matter not always conserved, especially in changes involving gases (e.g., water outside a glass comes from nowhere, or is hot air or heat).
Water vapor in air	Air contains invisible water vapor (humidity).	Water vapor is visible (e.g., in "steam" or fog as water vapor).
Condensation	Water vapor in air condenses on cold objects.	Condensation is "fog"; is formed by a reaction between heat and cold; or no concept about cooling.
Same molecules in different states of same substance	Solid, liquid, and gas forms of the same substance are all made of the same type of molecule.	Molecules of liquids are different from molecules of gases.
Effects of heat on molecular motion	Molecules of hot substances move faster.	Molecules themselves can be hot or cold.
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules.	States of matter described only in terms of observable properties; or properties of state attributed to individual molecules (e.g., molecules are in drops).
Attraction of molecules	Molecules of one substance attract each other.	No concept about how cooling causes attraction of molecules.
Molecular explanation of changes of state	Heating and cooling cause changes of state by making molecules move faster or slower.	Heat and cooling make molecules evaporate or condense.
Molecular explanation of evaporation	Fast-moving molecules escape from liquid.	Molecules evaporate or disappear.

Lesson 9.1: Boiling and Condensing

Purpose:

To help students use the kinetic molecular theory to explain the processes of condensation and distillation.

Advance Preparation:

For Demonstration 9.1 in the Activity Book, you need a distillation apparatus set-up as pictured in the Activity Book. The "dirty water" is a mixture of water, salt, and food color.

Materials List:

You will need the distillation apparatus, which consists of:

1. hot plate
2. Erlenmeyer Flask
3. glass tubing
4. test tube
5. water, food coloring or dye, and salt

You will also need Transparency 15: What is the Steam Above Boiling Water?

Teaching Suggestions:

Be sure to start heating the distillation apparatus before you come to the demonstration so that you have enough time.

When you get to the demonstration, describe the contents in the Erlenmeyer Flask (a mixture of water, salt, and food coloring). Tell them you are going to separate the water from the other substances.

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 leat ten minutes.)

   c. Clear or uncolored liquids

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.

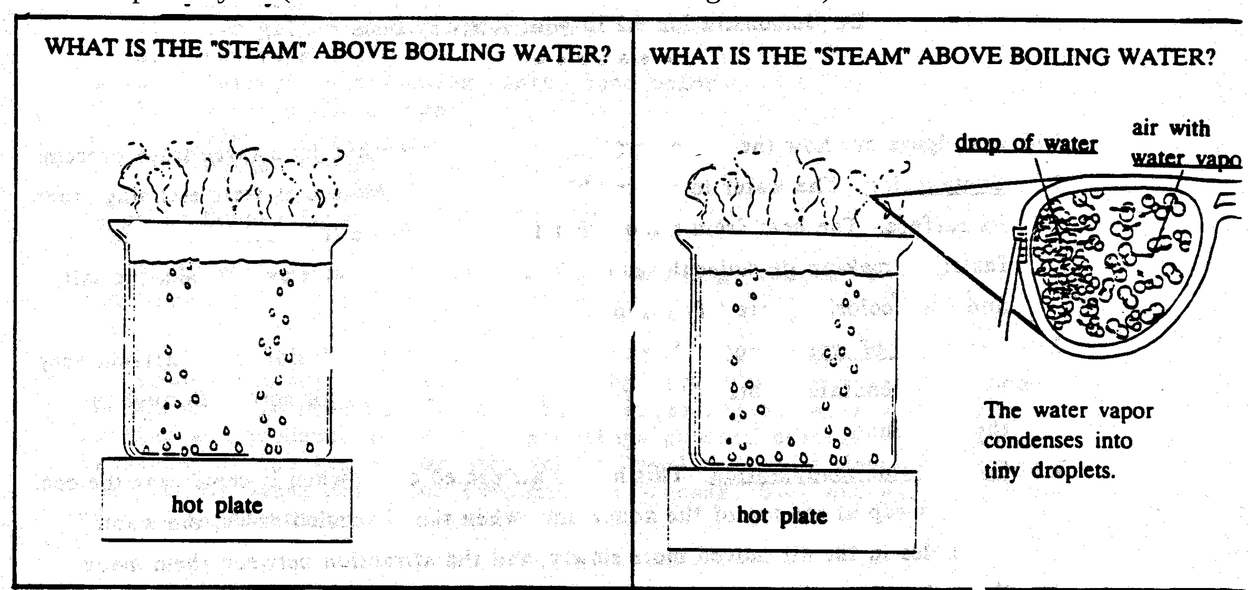
   b. Invisible water vapor must be passing through the glass tubing because water vapor is condensing to liquid water in the test tube. Water vapor is invisible because water molecules are too small to see and they are far apart and moving freely through the tube.

   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.

It is important for students to note that they can see examples of condensation in their everyday life. Read the paragraph about what we often call "steam" and put up the transparency "What is the "steam" above boiling water?" Be sure to remind students that we cannot really see steam, and show them that what we call "steam" is really tiny drops of water.

Another everyday example of condensation is the "fog" that forms when we breathe out on a very cold day. Water vapor in our breath turns to tiny droplets of water when it is cooled by very cold air.

Use Transparency 15 (What is the Steam Above Boiling Water?) here:



Bottom Layer

Many students believe that the visible "steam" above boiling water is a gas. They will probably say that is is a "fog" or a "white cloud."

Overlay

Be sure to elicit students' ideas about the state that the steam is in. Although students will often say that the "steam" is a "fog" or "cloud," which is correct, they often believe that the fog or cloud is a gas, which is incorrect. Actually, the invisible water vapor, which has escaped from the boiling water, cools rapidly and condenses into tiny droplets of liquid water. This is what we see as the fog or "steam."

Lesson 9.2: Purifying Water Without Boiling

Purpose:

To help students use the kinetic molecular theory to explain condensation after water evaporates from a nearby container.

Advance Preparation:

Follow the illustration in the Activity Book (Demonstration 9.2) to set up the apparatus. You will need to start this experiment early in order for the overhead projector to have time to heat the water. Also, the older style overhead projectors work better than the new ones which do not get as hot.

Materials List:

1. overhead projector
2. two gallon aquarium/terrarium
3. two cups
4. "dirty" water - water, salt, food coloring
5. clear plastic wrap
6. rubberband
7. weight (coin)

Teaching Suggestions:

Begin the demonstration early in the morning, and let it run continuously.

Students should be able to follow the path of water molecules through the three-stage process of evaporation, spreading of water vapor, and cooling and condensation. The three-stage process describes what is happening on the visible or macroscopic level. When students can trace the path of water molecules through this process, they are explaining the process at the molecular level.

Lesson 9.3: A Solar Still

Purposes:

To help students use the kinetic molecular theory to explain evaporation and condensation.

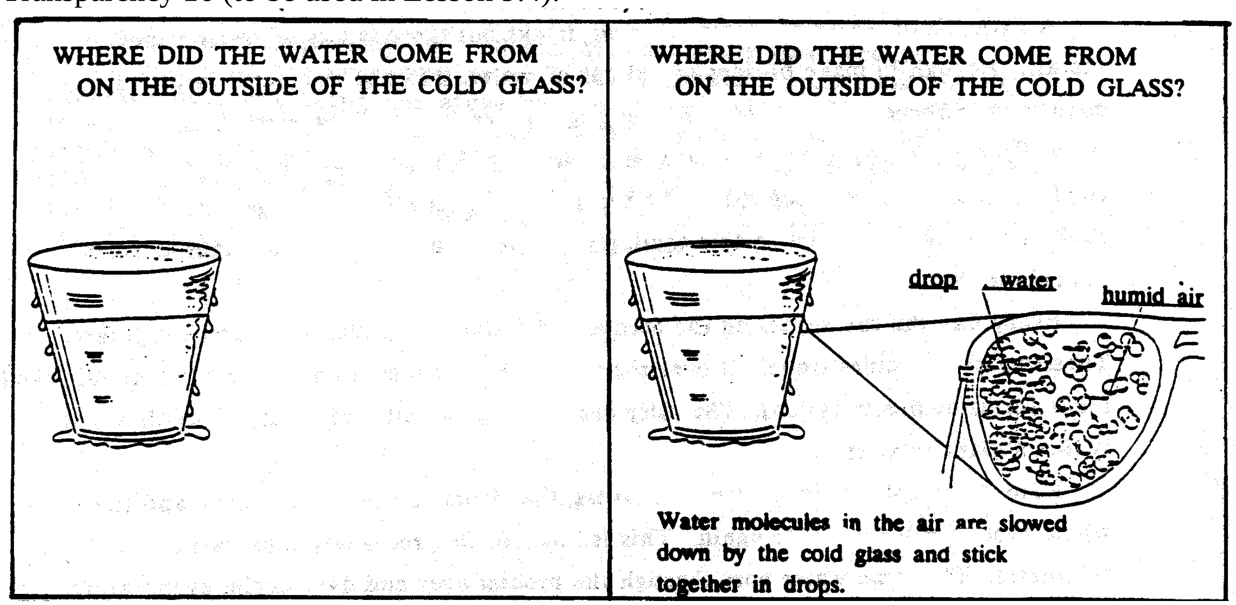
Advance Preparation:

You will need the videotape episode entitled "Making Dew" from the series "The Voyage of the Mimi" from Bank Street College of Education. Order these materials from the Science Resources Center. It may be checked out for a 3-4 day period.

Teaching Suggestions:

Begin this lesson by showing the Solar Still Episode of "The Voyage of the Mimi." The "Voyage of the Mimi" is a series from PBS. This fifteen minute episode is titled "Making Dew." The crew needs drinking water to survive on an uninhabited island. They set up a solar still to separate pure water from salt water. The still illustrates, in miniature, the water cycle: evaporation, spreading, and cooling & consensation.

Transparency 16 (to be used in Lesson 9.4):



Bottom Layer:

Students often respond to this question by saying that the water on the inside of the glass can somehow seep through to the outside of the glass. Even students who know about condensation may say that the water evaporated from the glass, not recognizing that there is always water vapor in the air.

Overlay:

It is important to contrast these ideas with the more scientific idea. Students should know that there is always water vapor in the air. The water vapor in the air cools when it comes in contact with the cold glass. This makes the molecules of water vapor slow down and cluster together to form water drops on the glass.

Lesson 9.4: condensing in the Open Air:

Purpose:

To help students use the kinetic molecular theory to explain the process of condensation when the source of water is not visible or nearby, and to explain the water cycle.

Materials List:

1. Transparency 16: Where did the water come from on the outside of the cold glass?

2. Glass and ice water

Advance Preparation:

Before class, you should prepare a glass of ice water and set it where the students can see it.

Teaching Suggestions:

Begin the class by showing the glass of ice water you have prepared. There should be water on the outside of the glass; make sure all your students get a chance to view it closely.

Then use transparency 16: "Where did the water come from?" Elicit student responses to this question before letting the students view the overlay. There will probably be a variety of ideas from students about where the water comes from. Many will say that it evaporated from the glass, moved around the side, and then condensed. You can ask them what they think might happen if the glass was covered with a lid. Since there is always water vapor in the air, water would still condense on the cup.

Lesson 9.5: Condensation and Precipitation

Purpose:

To help students be able to explain in more detail the everyday phenomena of different kinds of precipitation--rain, fog, dew, and snow--in terms of the processes of evaporation, spreading, and condensation.

Materials:

Transparency 17: What do all forms of precipitation have in common?

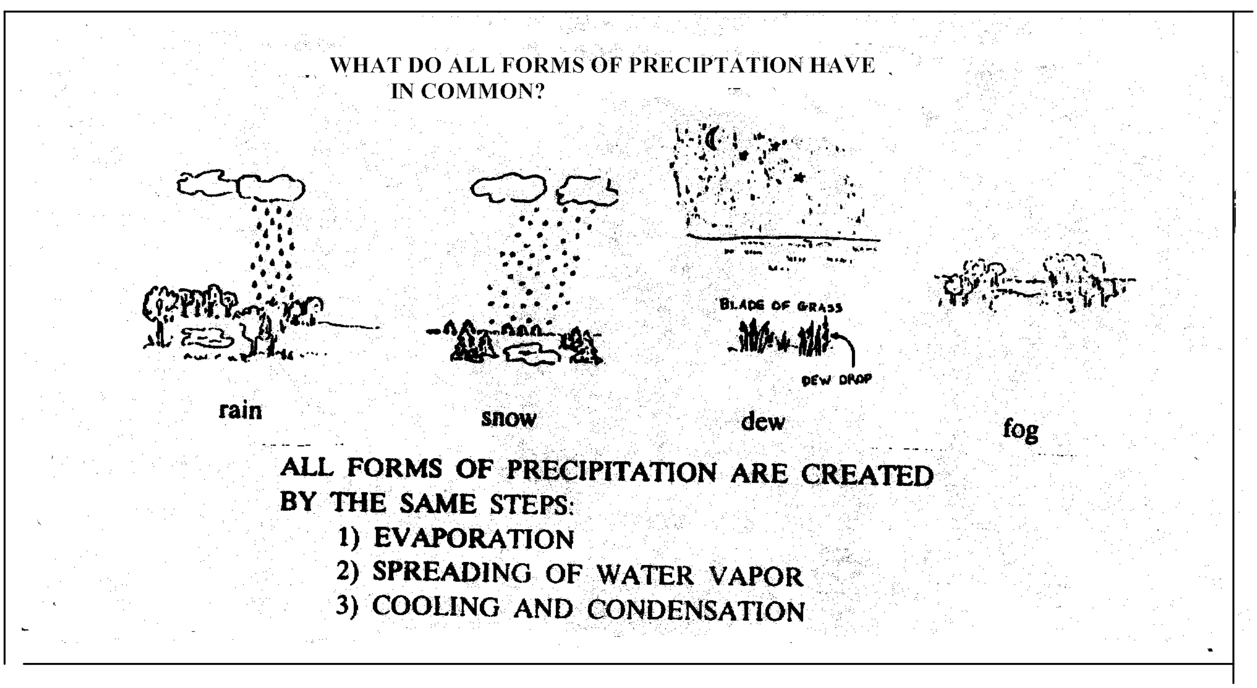
Teaching Suggestions:

You may want to begin the lesson by first eliciting from the students all of the different kinds of precipitation they have experienced recently and listing them on the board. Then begin reading the lesson.

Before discussing what clouds are, you may want to challenge student thinking by asking why it doesn't rain on sunny days. What is missing when the sun shines: (clouds) What do clouds have to do with rain?

As students read the rest of the lesson, take time to discuss each kind of precipitation (rain, snow, sleet, hail, dew, fog) in terms of evaporation, spreading, cooling and condensation.

Use Transparency 17 here:



Bottom Layer: Most students know the various forms of precipitation, but they may not know that all forms are created by the same steps.

Overlay: Stress that all forms of precipitation are created by the same steps: evaporation, spreading, cooling and condensing. You should encourage students to explain the three steps for at least form of precipitation, in terms of molecules.

Students should answer Ques. Set 9.5 in their Activity Book at this point.

Lesson 9.6: You Drank the Water that George Washington Used to Wash His Boots

Purpose:

To help students comprehend that the water we use in everyday life is water that has been recycled over and over again through the processes of evaporation and condensation.

Teaching Suggestions:

After you finish reading the story, discuss it with your students. Creative students may wish to add to the story.

When you are through discussing, have students complete Question Set 9.6. This question set is a cluster review, and it can be used as an evaluation tool.

Question Set 9.6 is the cluster review, and can be used as an evaluatory tool.

MATERIALS LIST

CLUSTER 1, LESSONS 9.1-9.6

Lesson 9.1:

Distillation apparatus:
hot plates	Erlenmeyer flask	glass tubing	test tube
water	salt
food coloring or dye	Transparency 15

Lesson 9.2:

overhead projector
two gallon aquarium/terrarium
two cups
"dirty water" -- water, salt, food coloring
clear plastic wrap
rubber band
a weight (coin)

Lesson 9.3:

Videotape: Episode "Making Dew" from "The Voyage of the Mimi"
To obtain, contact the Science Resources Center, 839-2428.

Lesson 9.4:

glass and ice water	Transparency 16

Lesson 9.5:

Transparency 17

Lesson 9.6:

None