INTRODUCTION TO LESSON CLUSTER 8
Explaining Evaporation and Boiling

A. Lesson Cluster Goals and Lesson Objectives

Goals:

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

Lesson Objectives:

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 air.
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:

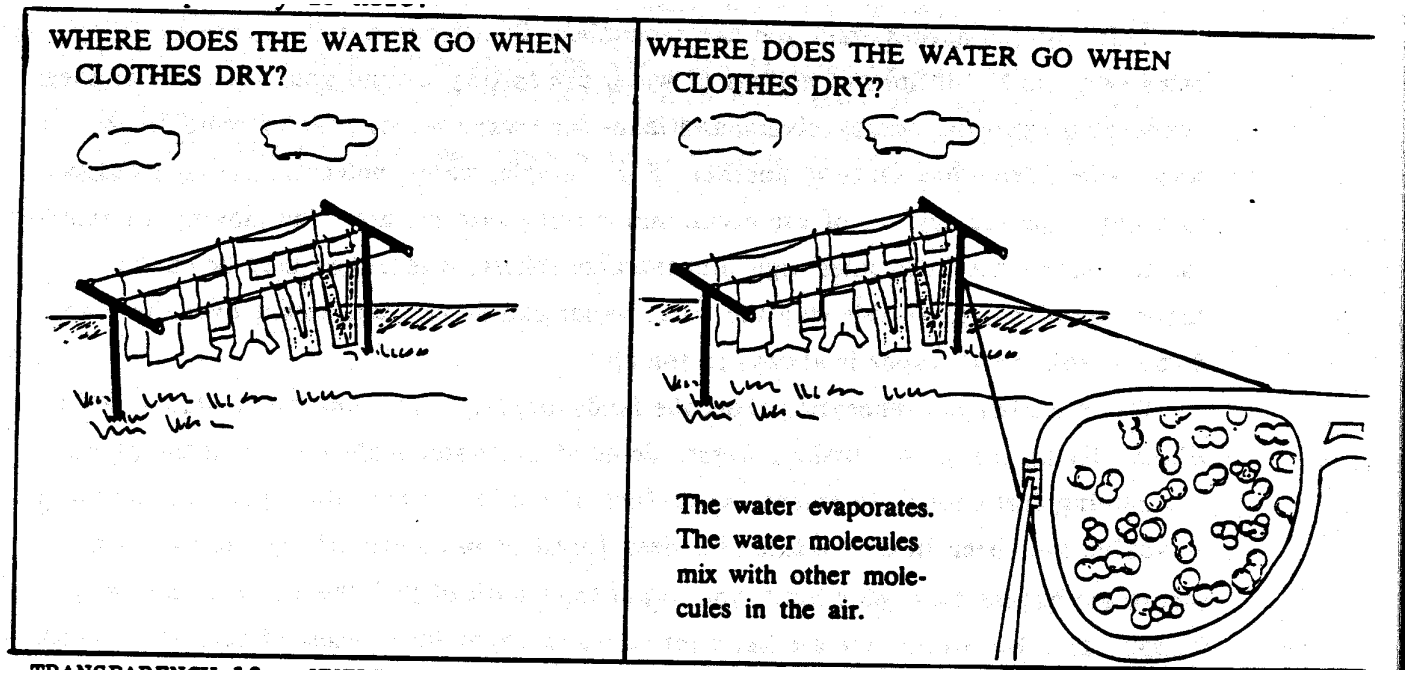
Begin this lesson by placing a spot of water on a paper towel and on the chalkboard. Discuss with your students the two questions at the start of Lesson 8.1. Students should easily recognize that the molecules on the paper towel are water molecules. Elicit as many responses to the question, "What happens 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.

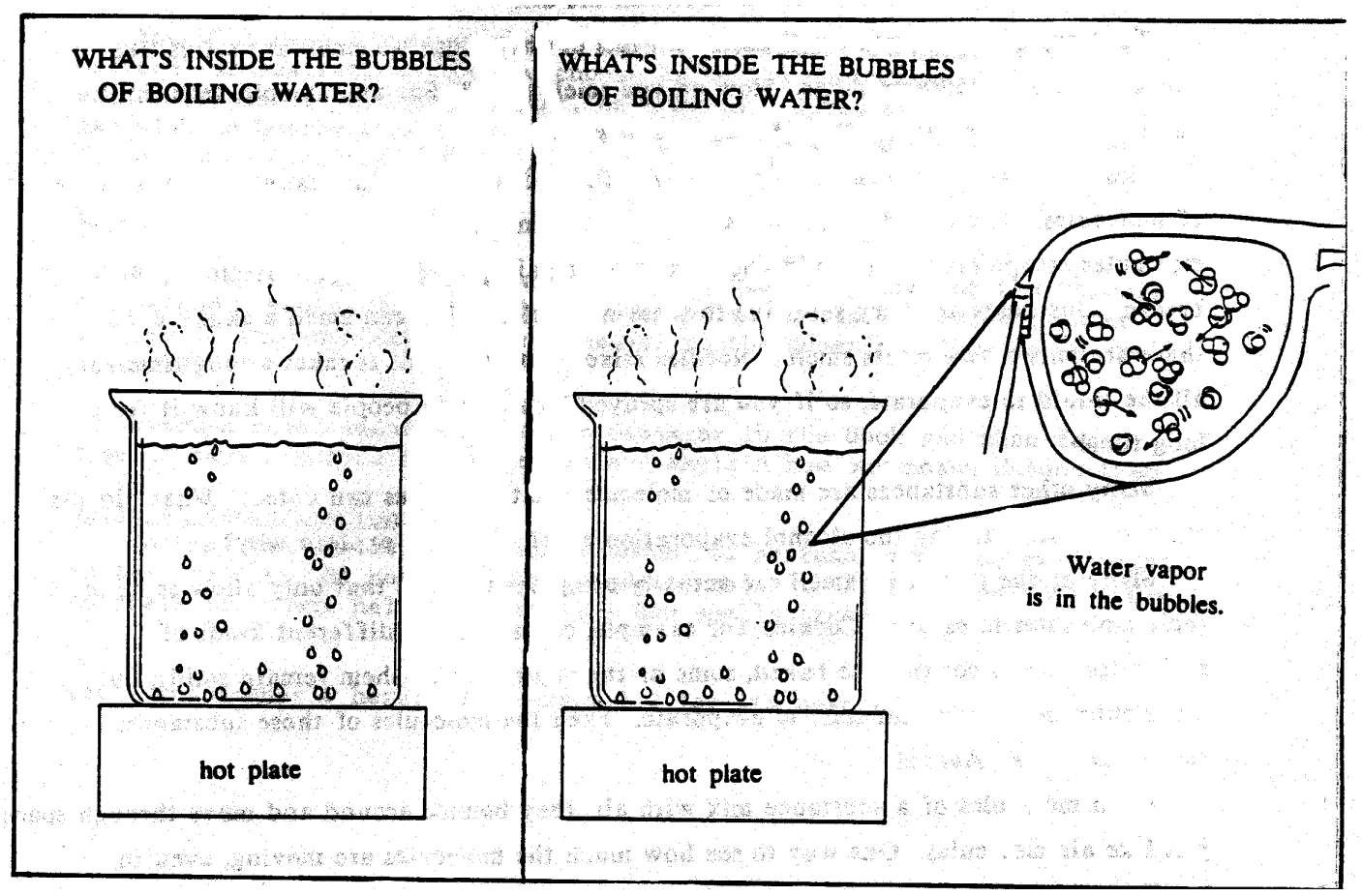
3. Students should include the following ideas in their responses: Alcohol molecules in liquid alcohol slide around and bump into each other. Some of the molecules are moving fast enough to escape from the surface of the liquid, thus, the liquid changes to a gas. The alcohol molecules mix in with the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

$$C_2H_5OH + 30_2 \qquad 2CO_2 + 3H_2O$$

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)