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. 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 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.

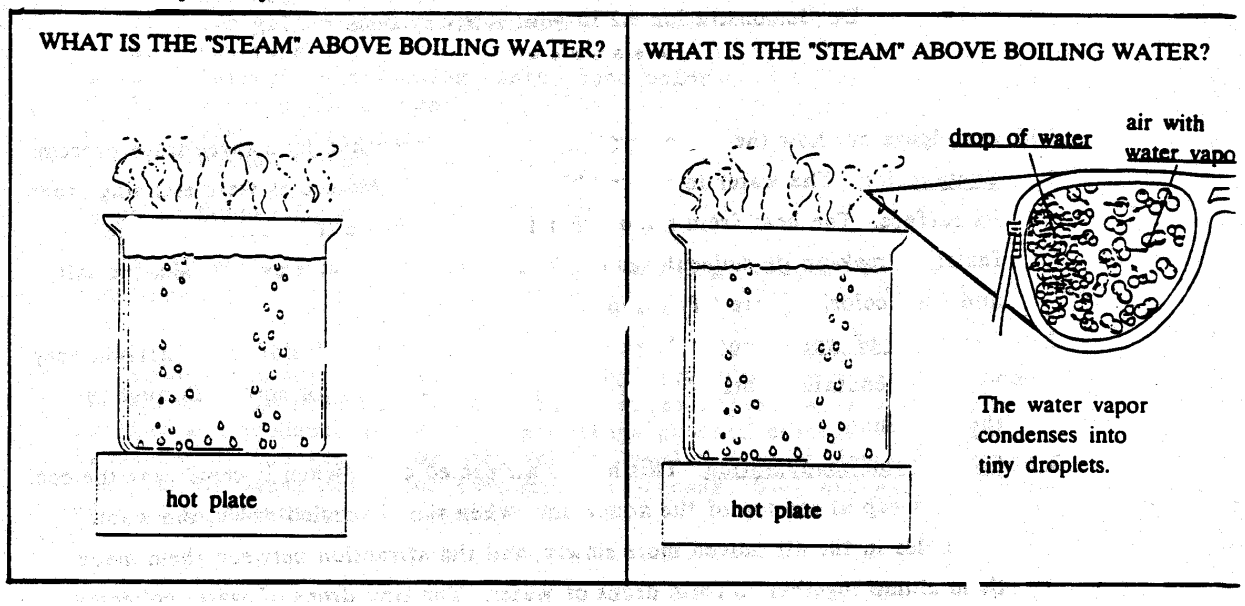
   b. Invisible water vapor must be passing through the glass tubing because water vapor is condensing to liquid water in the test tube. Water vapor is invisible because water molecules are too small to see and they are far apart and moving freely through the tube.

   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.

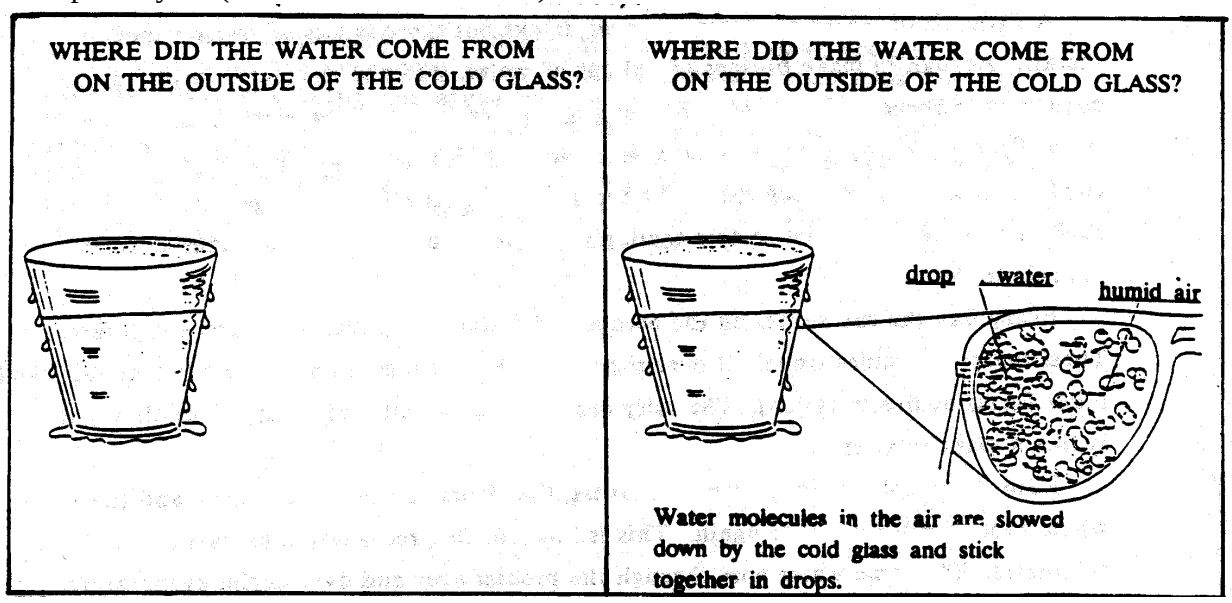
Advance Preparation:

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?

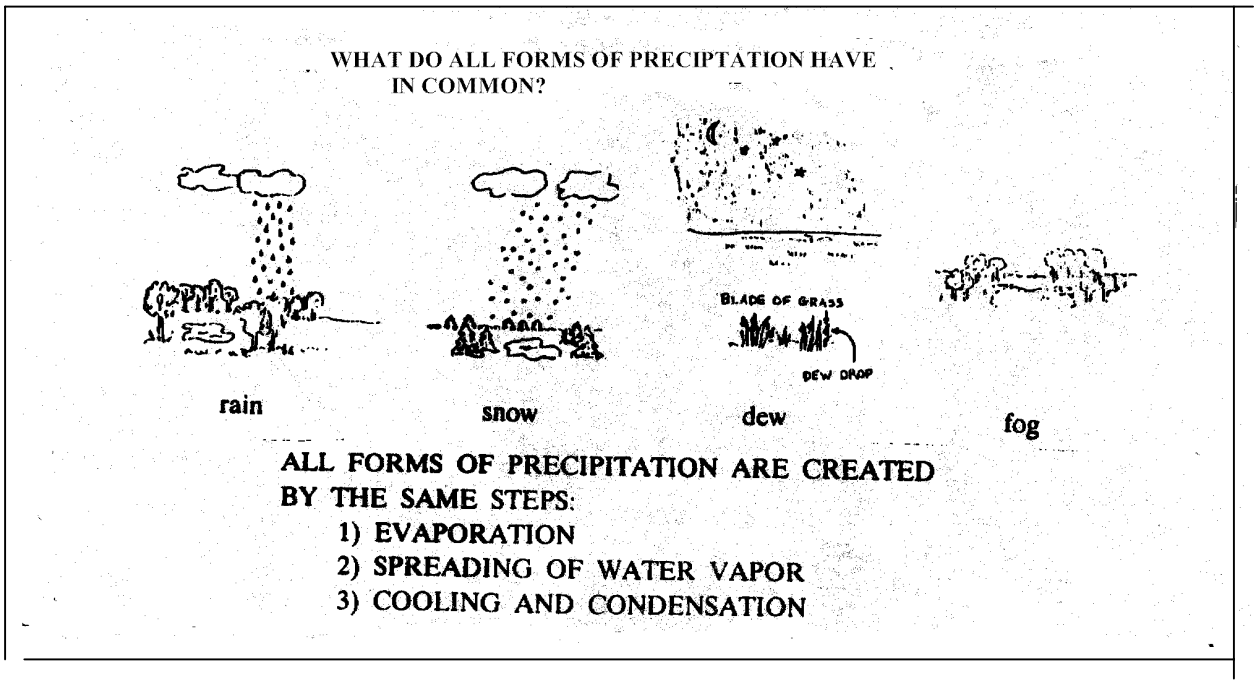
Teaching Suggestions:

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