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.

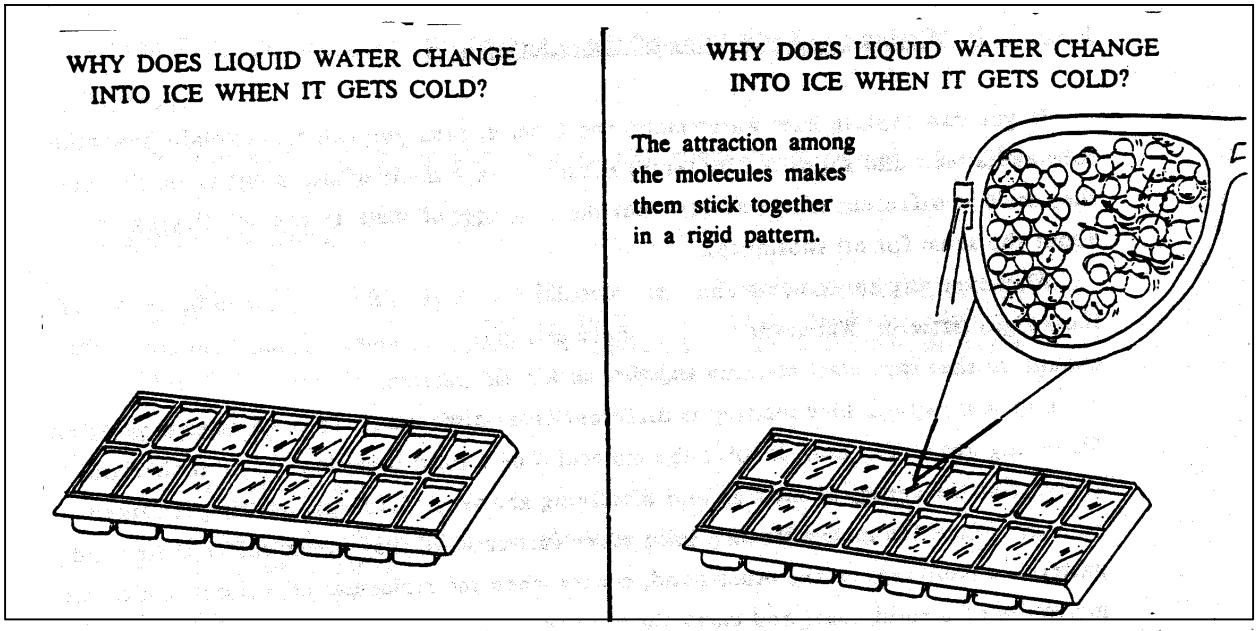
This idea that the attraction between water molecules causes them to form into the rigid patter of a solid is important for explaining freezing. Attraction is not so important for explaining melting: One can simply say that when molecules move faster, they break out of the rigid pattern of a solid.

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?

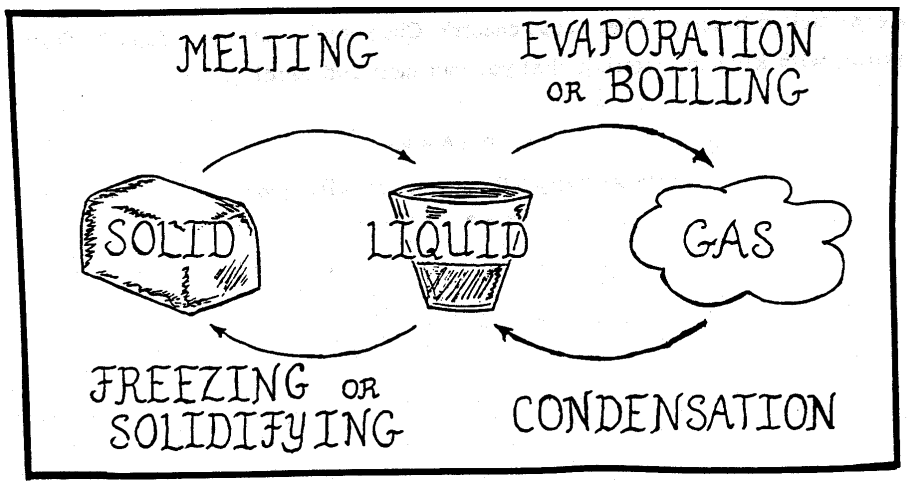
BOTTOM LAYER:

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