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.

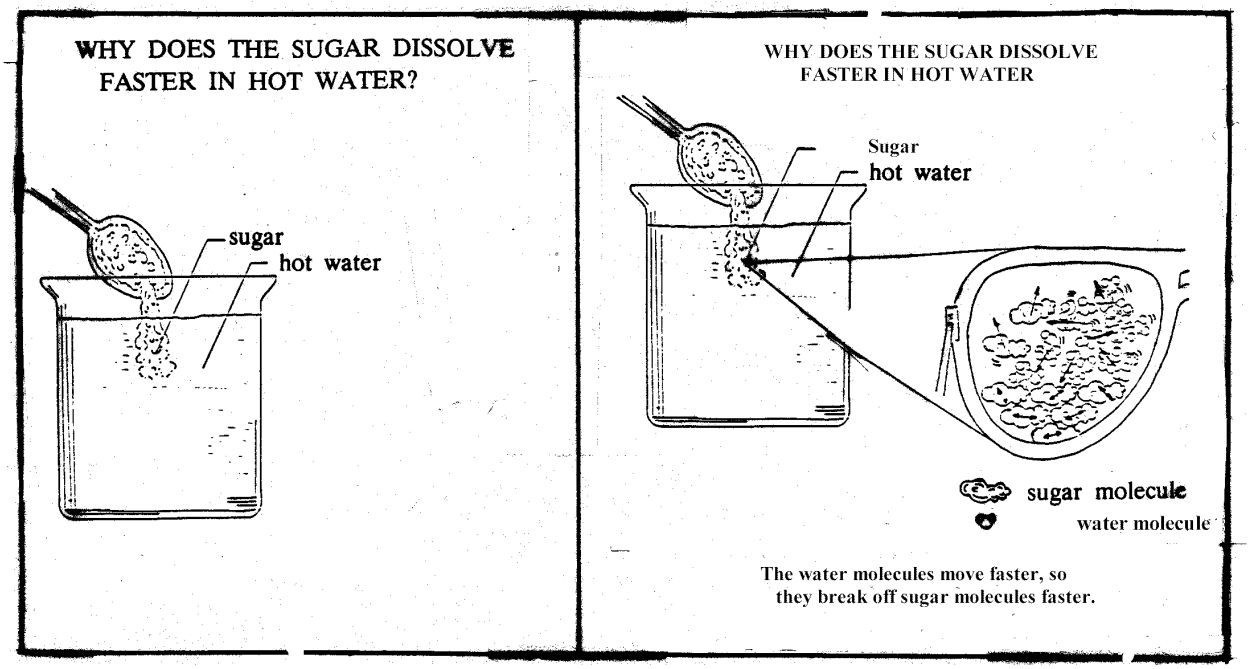
MATERIALS LIST:

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:

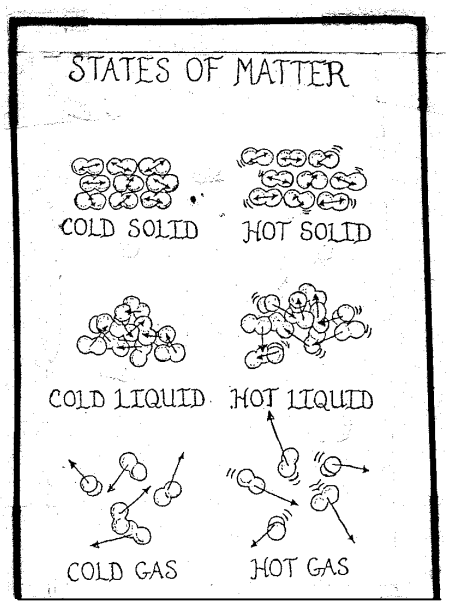


TRANSPARENCY 10: WHY DOES THE SUGAR DISSOLVE FASTER IN HOT WATER?

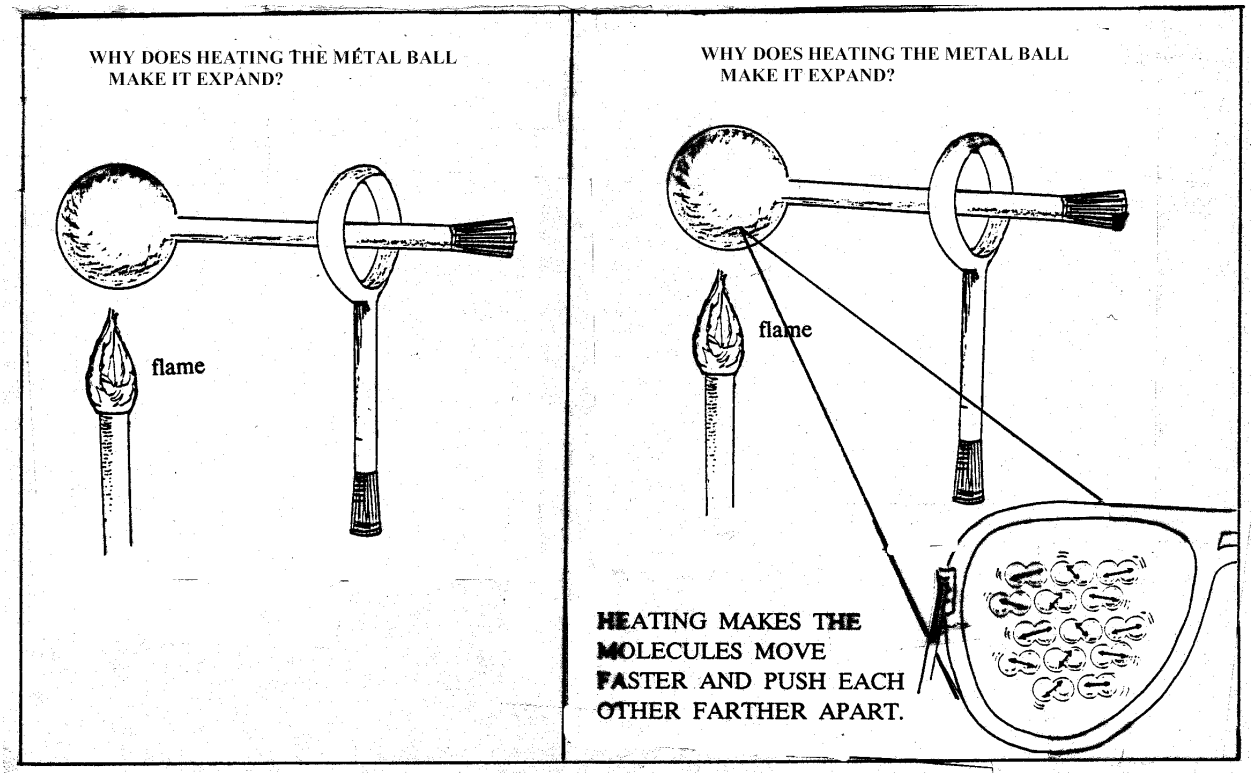
Bottom Layer
Students often answer this question by saying, "heat causes faster dissolving" or "molecules get hotter and so they move faster and dissolve faster." These are elements of the explanation but not an adequate explanation.

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.

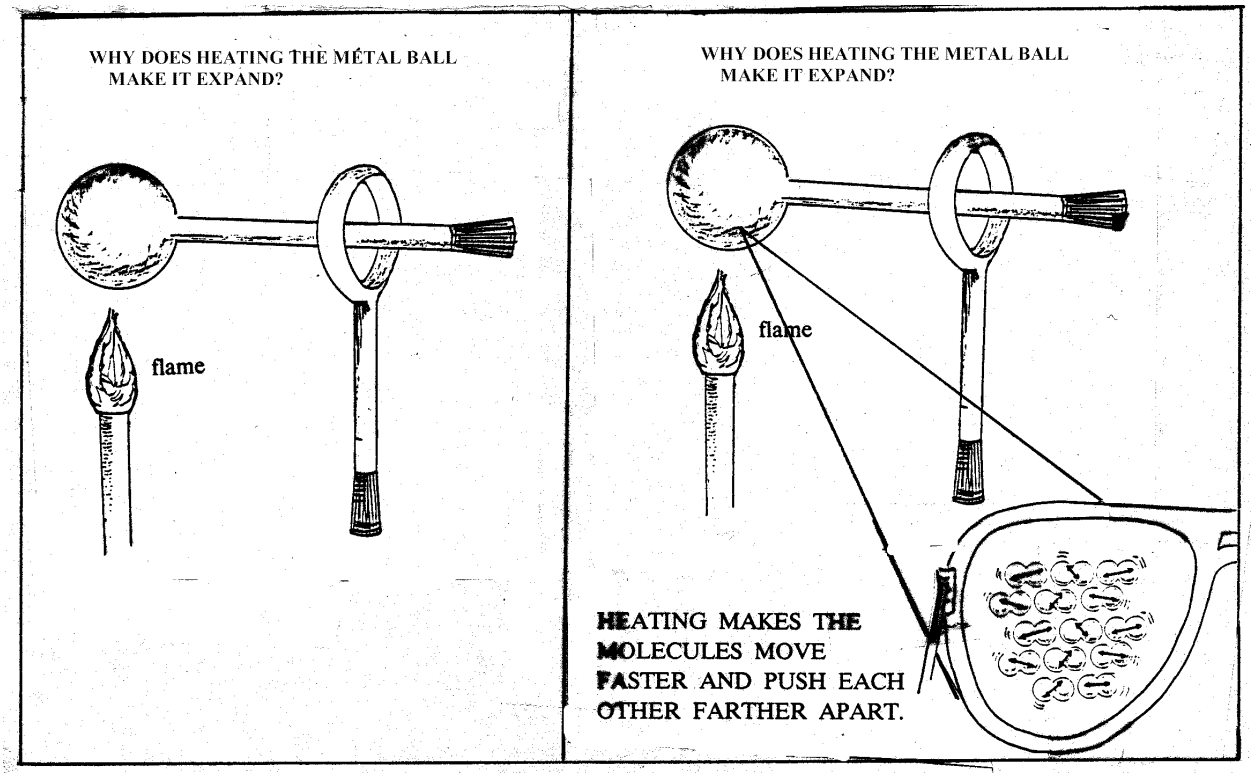
1. Begin with Activity 6.2 Heating and Cooling Solids--The Ball and Ring Demonstration.

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