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. Students' Conceptual Learning

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:

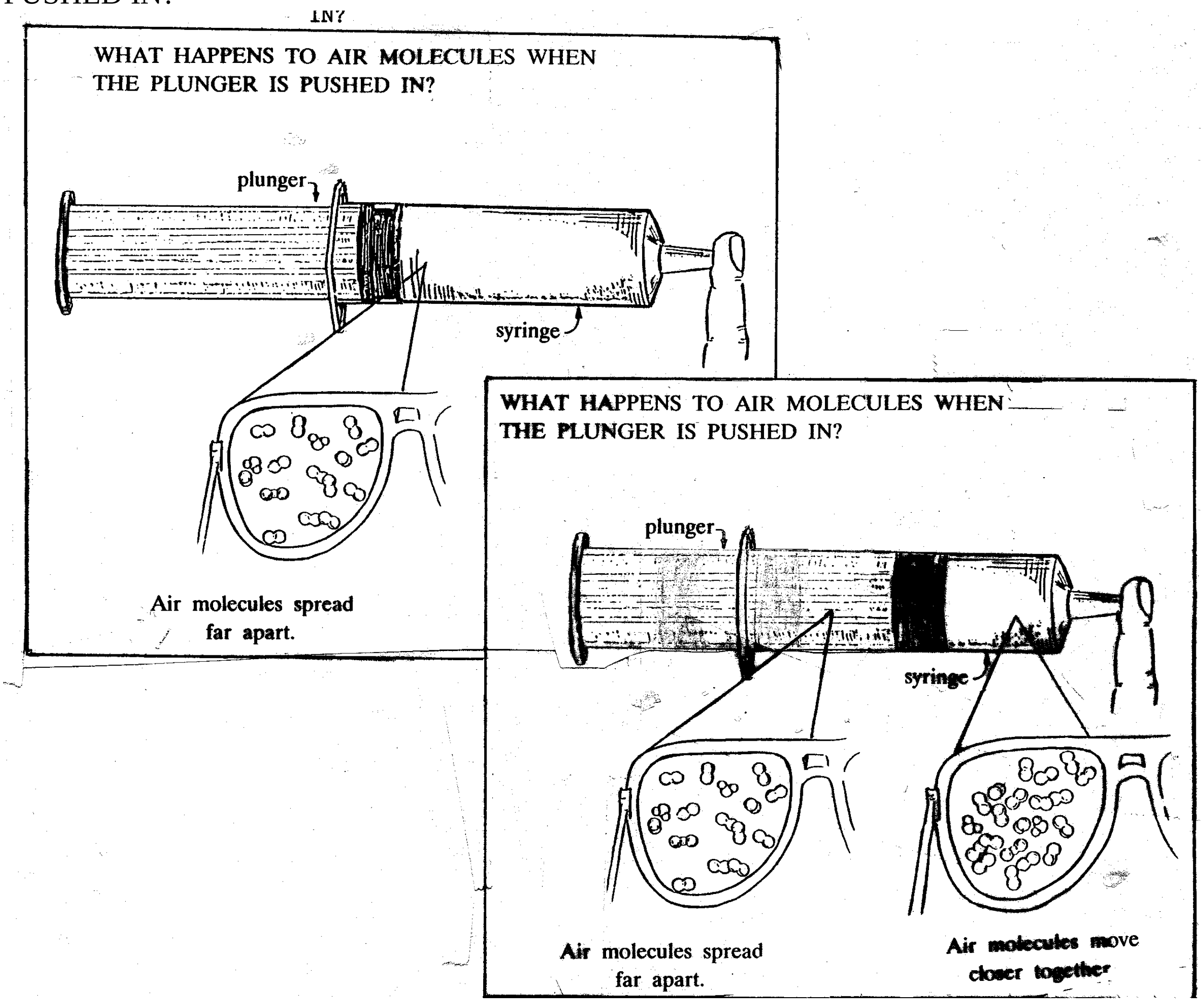
If you anticipate that the students will use the syringes for water fights do not distribute the water until it is needed.

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.

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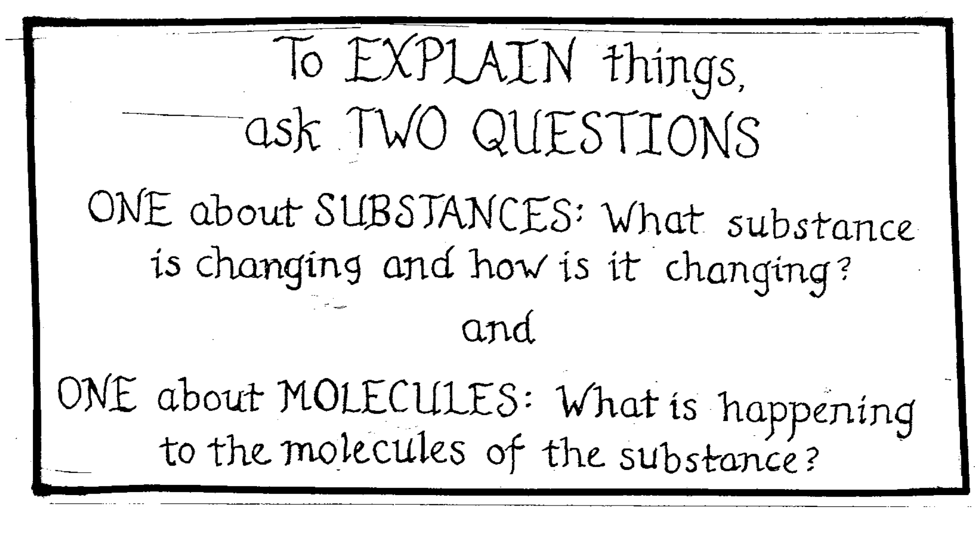
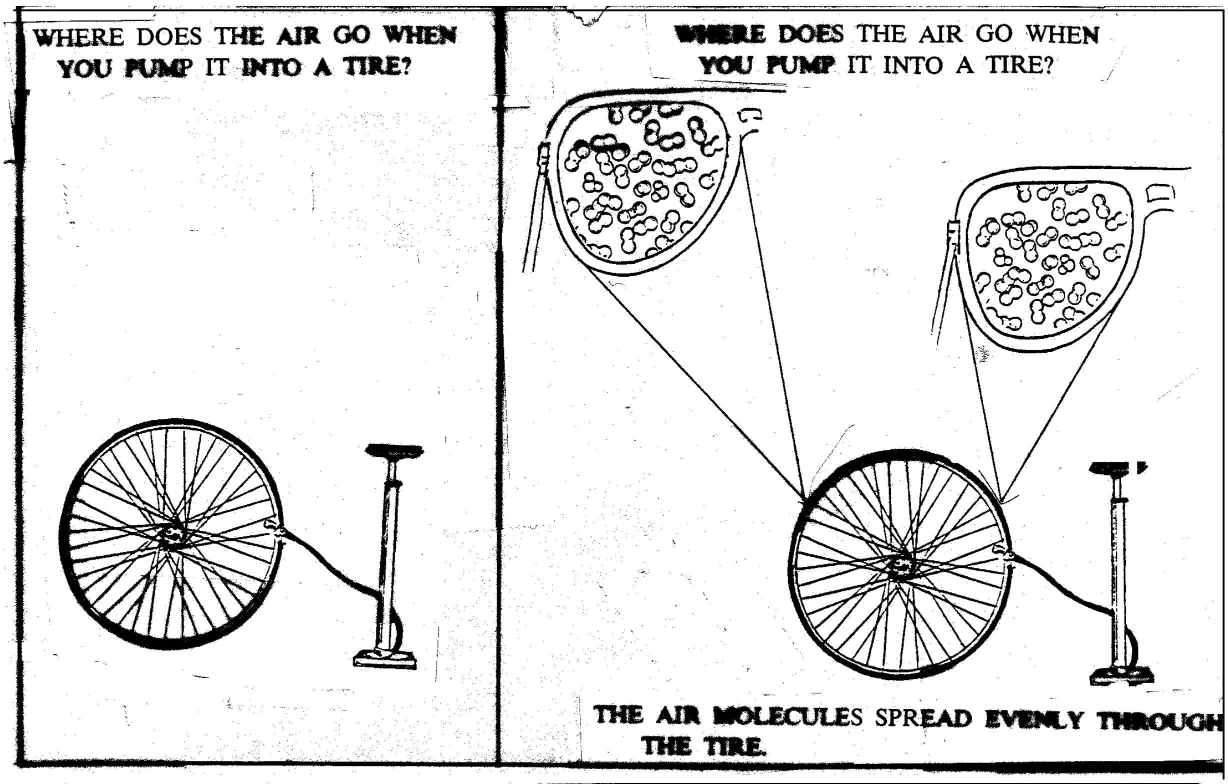


Use Transparency 8 here:



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