Category IV Physical Science Examples

Demonstrating use of knowledge

Matter and Molecules

An important goal of *Matter and Molecules* is "helping students *use* [emphasis added] scientific knowledge to develop their own personal descriptions and explanations of real-world phenomena, and thus to appreciate how interesting and useful scientific knowledge can be" (*Science Book*, p. **T-6**). Throughout Clusters 4-9, the *Science Book* demonstrates how knowledge about the arrangement, motion, and interaction of molecules can be used to explain everyday phenomena (pp. 28s, 32s, 35s, 36s, 41s, 42s, 44s, 48s, 54s, 57s, 60s). Most explanations provided are step-by-step (e.g., pp. **44s**, **48s**, **54s**, **60s**), are identified as demonstrations (e.g., pp. 41s, **44s**, 48s, **54s**, **60s**), and include running commentary about important aspects of the explanation (e.g., p. **41s**, **32s**). This is in stark contrast to most middle school science textbooks which either never explicitly show students how to link ideas to real world phenomena or provide incomplete explanations. Both the teacher's guide and student text point to criteria for judging explanations of macroscopic phenomena that can be explained in terms of molecular arrangement and motion (e.g., *Science Book*, p. **32s**).

students alienated from science, and unaware of the power and the beauty that scientific knowledge can hold.

Therefore, our final goal is to help students use scientific knowledge to develop their own personal descriptions and explanations of real-world phenomena, and thus to appreciate how interesting and useful scientific knowledge can be.

Using this Unit to Teach about Matter and Molecules

Achieving the goals described above is not easy. Students (and sometimes teachers) must work through a difficult process of conceptual change in order to achieve each goal. Because the process of conceptual change is so difficult and complex, there is no simple way that students can work their way through it. A variety of different, complementary approaches is necessary. Therefore, the Matter and Molecules unit includes several different components, each designed to help students in a different way. Each of these components, its purposes, and recommendations for teaching strategies that will help make it more effective are described below.

The Science Book: Reading with understanding. The first part of this unit is the Science Book, or student text. This text is written to explain the important ideas about matter and molecules discussed above in a way that will help students learn with understanding. Reading about the kinetic molecular theory with understanding, however, is a difficult task for most students. They can truly understand only if they successfully work through the process of conceptual change; that is, they must actively integrate the information in the Science Book with their own previous ideas, sometimes realizing that their previous ideas were incorrect and changing them accordingly.

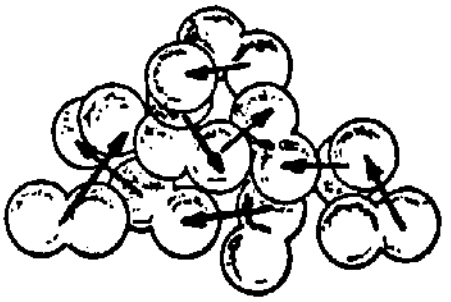
Both our research and the work of other researchers indicates that no matter how well a textbook is written, many students normally fail to read it with understanding. The reason is that many students do not normally process the information in the text in an active way. Teachers can make a great deal of difference in how students read and process textbooks. By helping your students to ask the right questions and think actively about what they read, you can help them understand the Science Book much better than they otherwise would.

In particular, we recommend a set of teaching strategies based on the work of Annemarie Palincsar and Ann Brown, who have found that student comprehension can be greatly increased if students engage in the following activities as they read:

1. Summarizing: developing brief summaries of the passage that they just read.

2. Generating questions: suggesting questions that address important ideas (as opposed to minor details) in the passage they just read.

3. Clarifying: identifying statements or ideas that are unclear or confusing to them and asking questions that help them resolve their difficulties.

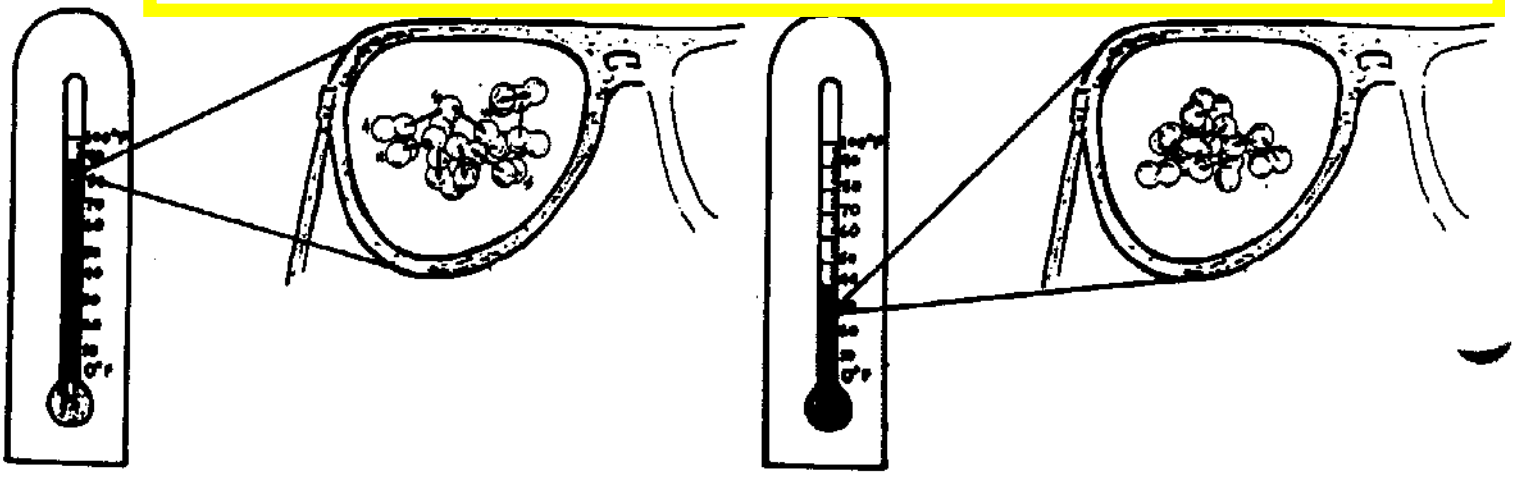


Cooling slows down the molecules of a liquid
and they move closer together

Now we can explain how the thermometer works. Compare the explanations below to the ones you wrote in your Activity Book. Did you answer the questions about substances and the questions about molecules in the same way as the explanations below?

When you place the bulb of the thermometer in hot water, the molecules of the colored liquid move faster and push each other farther apart. This causes the colored liquid to get larger or expand. The colored liquid expands up through the thermometer tube which gives a higher temperature reading.

When you place the bulb of the thermometer in cold water, the molecules of the colored liquid move slower and come closer together. This causes the colored liquid to get smaller or contract. The contraction makes the column of colored liquid move down toward the bulb. This gives a lower temperature reading.



When ice is warmed it melts into liquid water. The water molecules in ice are locked into a rigid pattern, but as they vibrate faster they break out of that rigid pattern and begin sliding and bumping past each other. Solid ice has melted into liquid water!

(Did the explanation above answer both the question about substances and the question about molecules? Check it and see!)

Ice melts when the water molecules vibrate fast enough to break out of their rigid pattern

Water freezes when it is cooled down and the water molecules move slower. To completely explain how water freezes there is one other thing you need to know about molecules. Water molecules are attracted to each other. This attraction makes the molecules stick together in a rigid pattern if nothing breaks them apart.

But the attraction between molecules keeps them stuck in a rigid pattern only if the molecules are moving slowly. When water molecules are moving fast, their motion keeps them from sticking together. They jiggle apart rather than settling into a rigid pattern. When water gets cold, though, the molecules slow down. Then the attraction between them makes them stick together in a pattern. Liquid water has changed into ice!

Water is not the only substance that melts and solidifies. You will learn about some other substances in the next lesson. First, though, try answering some questions about what you have learned.

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Do Question Set 7.1 in your Activity Book

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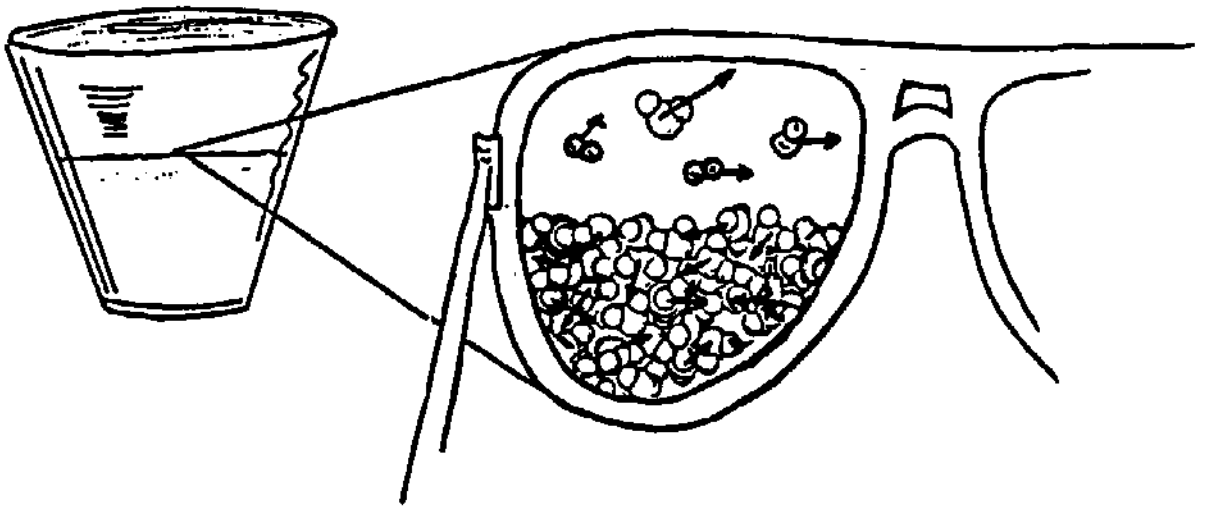
In the wintertime, there is usually less water vapor in the air, and we may become uncomfortable because water is evaporating too fast from our skin, causing our skin to feel dry. To become more comfortable, we may add water vapor to the air. That is why many furnaces have a humidifier, which adds water vapor to the air when the air is very dry. This makes us feel more comfortable.

How does evaporation happen? Let's try explaining it in terms of molecules. You know that the molecules in liquid water are constantly moving. In a liquid, though, the attractive forces between molecules keep them close together. What you might not know is that the molecules in a liquid move at different speeds. Some molecules are moving very fast, while other molecules are moving more slowly.

What do you think would happen if a fast-moving molecule reached the surface of a drop of water? Yes, it would escape! It would break away from the strong attraction of the other water molecules and become a molecule of water vapor in the air. If all the water molecules escape in this way, we say that something has "dried out." The liquid water has turned into water vapor in the air, and the water vapor makes the air more humid.



Evaporation occurs when fast-moving molecules of liquid water escape into the air

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Do Question Set 8.1 in your Activity Book

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LESSON CLUSTER 9
Explaining Condensation and the Water Cycle

Lesson 9.1: Boiling and Condensing

You have been studying changes of state for quite a while now. You have studied melting, freezing or solidifying, evaporation, and boiling. That means there is only one change of state left to study: condensation.

You know that if a liquid is heated enough, it turns into a gas. The molecules of the liquid move fast enough to escape from the attractive forces that hold them together and begin moving freely through space.

What do you suppose happens if we slow down the molecules of a gas by cooling the gas? The slow-moving molecules begin to stick to each other and form clumps. Clumps with lots of molecules make up drops of liquid. This process, where a gas turns back into a liquid, is called condensation.

Sometimes it is possible to use boiling and condensation to purify dirty liquids. Your teacher will show you how.

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Do Demonstration 9.1 in your Activity Book

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Let's explain what happened.

When you heat the flask, the liquid water changes to water vapor at the bottom of the flask and rises to the surface as bubbles. This, of course, is called boiling. The hot water vapor goes through the tube into the bottom of the cold test tube. When the water vapor hits the cold test tube, the molecules slow down and move closer together. When the molecules slow down enough, the attraction among them makes them stay close together. They cluster together to form a liquid.

The dye and other substances in the flasks are made of molecules that do not boil as easily as water. When the water boils and goes through the glass tubing, the dye and other substances stay behind in the flask.

Now let's try using these ideas to explain why the candy dissolved faster in hot water. We will talk about the cold water, then the hot water. We will answer the question about substances and the question about molecules for each temperature of water.

In the cold water the candy (substances) dissolved slowly because the water molecules were moving slowly as they knocked off molecules from the pieces of candy.

In the hot water the candy dissolved faster because the water molecules were moving faster and hit the candy more often. That made them knock the molecules off the pieces of candy more quickly.

Did the explanation about hot water answer both the question about substances and the question about molecules? Find the parts of the explanation that answer each question.

When molecules are moving faster they make substances dissolve faster. Fast-moving molecules cause other effects, too. You will learn about one of those other effects in the next three lessons.

Lesson 4.4: Bicycle Tires

Up to this point in this cluster, you have seen that air can be compressed. We explained air compression by saying that air molecules are normally very far apart, with lots of empty space between them, and they can be pushed closer together.

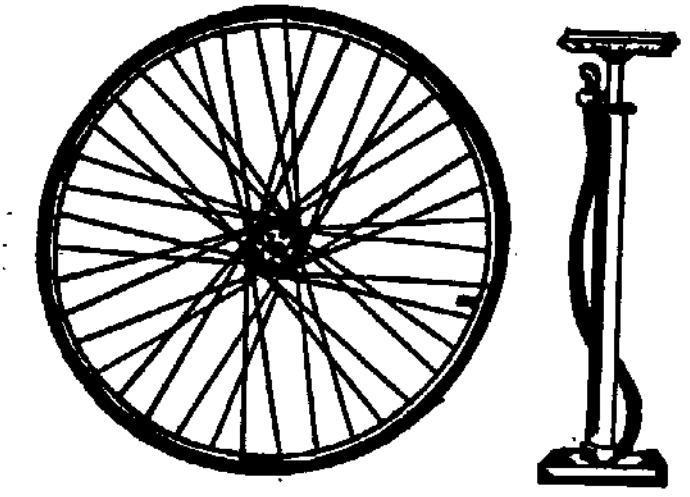
You have also learned something about scientific explantions. To make a good explanation, you often need to talk about molecules. You need to talk about the way molecules move and the way they are arranged in solids, liquids, and gases. You also need to know what kind of molecules you are talking about. You need to identify the substance that is changing and tell how it is changing.

In other words, a good explanation answers at least two questions:

1. A question about substances: What substance is changing and how is it changing?
2. A question about molecules: What is happening to the molecules of the substance?

Let's think about the explanation of air escaping from an air tank and see if it answers those questions. We said that air (substance) comes out of the tank and expands into the room because the molecules of air inside the tank are pressed very close together, and they move farther apart. That explanation answers both the question about substances and the question about molecules.

Now let's try to explain something else: What happens when you fill a bicycle tire with air? This is a little more complicated than the scuba tank or the syringe, but it will help you learn more about air molecules and how to make good explanations.



What happens when you fill a bicycle tire with air?