Category II Summaries for Physical Science Examples

Alerting teacher to commonly held ideas

Matter and Molecules

Research indicates several difficulties students typically have with ideas related to the particulate nature of matter and the kinetic molecular theory:

- Students have difficulty appreciating the **intrinsic motion** of particles in solids, liquids, and gases (American Association for the Advancement of Science [AAAS], 1993, pp. 75, 337; Driver, Squires, Rushworth, & Wood-Robinson, 1994, pp. 92, 93).
- Students **attribute macroscopic properties to particles** (such as hardness, hotness/coldness, expansion, physical state, etc.) (AAAS, 1993, p. 337; Driver et al. (1994), p. 92).
- Students have problems in **conceptualizing forces between particles** (AAAS, 1993, p. 337; Driver et al., 1994, p. 9).

Matter and Molecules alerts the teacher to all these student difficulties and commonly held ideas and represents research findings in an accurate way. In the beginning of each lesson cluster the *Teacher's Guide* (a) provides a chart of "conceptual contrasts" that compares the scientific view with students' misconceptions on the ideas in the benchmark (see pp. **T-14**, T-27, T-40, T-48, T-61, T-69, T-80, T-90, T-100), and (b) describes common misconceptions related to the ideas to be developed (see pp. **T-13**, T-38, T-49, T-60, T67-T69, T-79). The contrast between the student ideas and the scientific ideas makes it likely that teachers will better understand where the problem lies in student ideas. For example, pages **T-13**, **T-14**, and T-80 alert teachers to students ideas related to the intrinsic motion of molecules; all pages alert teachers to student ideas related to attributing macroscopic properties to particles.

In addition to alerting teachers to commonly held ideas related to this benchmark, the *Teacher's Guide* alerts teachers to student difficulties specific to the activities used in the material to teach the benchmark ideas. For example, when learning about liquid expansion, students put a thermometer into warm water and observe what happens to the column of the colored liquid. In the Teaching Suggestions, page **T-74**, teachers are alerted that "some students may think that the liquid goes up the thermometer tube when the bulb gets warmer because 'heat rises.'

Lessons 3, 4 and 5:

At the invisible or molecular level, you will probably find that many of your students haven't heard of the word "molecules." Even if some students have heard of it, their understanding is likely to be substantially different from the ideas conveyed in this unit. Furthermore, although many students might have heard of the term atoms, their understanding may not be scientific. Their acquaintance with the term atoms may even interfere with the new term molecules.

The size of molecules is one characteristic that is difficult for students to understand because it lies outside the realm of their normal experience. Although students think of molecules as small, it is hard to convey just how small they are. Many students think of molecules as similar in size to other tiny objects that they are familiar with, such as specks of dust, bacteria, or cells. Even if they say that molecules are smaller than these objects, they may still think that they can see molecules with a microscope. In reality, a typical human cell contains perhaps 100 trillion molecules; a dust speck, even more. Thus, molecules are too small to be seen.

Students also have difficulty in understanding that molecules are constantly moving. Molecules are always moving, even in substances such as ice where no motion of the substance is visible. Many students think that molecules are moving in liquid water because liquid water is flowing, but molecules are not moving in ice because ice is not moving. The constant motion of molecules is difficult for students to believe, both because it seems to contradict the evidence of their senses and because they have never encountered objects that, like molecules, are so tiny that they are unaffected by friction and thus never come to a stop.

Students are confused between observable properties of a substance and properties of the molecules themselves. Many students may believe, for instance, that molecules of water become hard and cold when the water freezes, rather than simply becoming locked into a rigid arrangement and motion in their places. Some students may even think that when water changes into ice water, water molecules change into ice molecules.

Many students believe that there are molecules in substances rather than the substances are made of molecules. For example, they think that water contains molecules (like blueberries in a muffin) rather than consisting of molecules and nothing else (like grains of rice). Students may think there is "air" or "water" between water molecules. Thus, it needs to be strongly emphasized that water is made of only molecules and there is nothing between water molecules.

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 disappears when it is heated).
Water vapor in air	Air contains invisible water vapor.	Water in air is visible (e.g., fog, "steam"). There is no gaseous state of water.
Molecular constitution of matter	All matter is made of molecules.	Molecules are in substances (e.g., water has molecules in it, with water between the molecules).
Size of molecules	Molecules are too small to see, even with a microscope.	Molecules may be comparable in size to cells, dust specks, etc. Molecules can be seen with a microscope.
Constant motion	All 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 (e.g., molecules do not move in ice because ice is frozen).
Molecular explanation of states of matter	States of matter are due to different arrangements and motions of molecules: - solid: vibrate in rigid array. - liquid: random motion within limits. - gas: random motion, no limits.	States of matter described only in terms of observable properties of the state attributed to individual molecules (e.g., water molecules are hard in ice).

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:

1. One thermometer
2. Two plastic cups
3. 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.