Category II Summaries for Physical Science Examples

Alerting teacher to commonly held ideas

Chemistry That Applies

Research indicates that, typically, students have several difficulties with the ideas that serve as the basis of the *Chemistry That Applies* analysis:

- Students have difficulty understanding the **particulate nature** of matter. For example, they may think that particles (atoms or molecules) are *in* substances and/or that there is something (e.g., air) between the particles, rather than that substances are *made of* molecules (American Association for the Advancement of Science [AAAS], 1993, p. 336; Driver, Squires, Rushworth, & Wood-Robinson, 1994, pp. 92–94).
- Students may have a general notion of "heaviness" and not distinguish between **weight and density** (Driver et al., 1994, p. 78).
- Students have difficulty grasping that **weight is conserved** in reactions in which a gas is absorbed or has evolved (AAAS, 1993, p. 337; Driver et al., 1994, pp. 88–89).
- Students may see chemical changes as the **disappearance of original substances and the appearance of new substances** (and, hence, not expect weight to be conserved) until they can interpret "combination" at the molecular level (Driver et al., 1994, p. 86).
- Students may have other misconceptions about **chemical changes**, seeing them as translocations (i.e., the product materials must be contained in the starting materials somehow) rather than as the combination and recombination of atoms (Driver et al., 1994, p. 86).
- Students may not appreciate that in a change involving two or more materials, there is **mutual interaction**. For example, students may see oxygen as "enabling" a combustion reaction rather than as one of the reacting substances (Driver et al., 1994, p. 88).

The module alerts teachers to several of these common student beliefs, typically in the descriptions of the clusters (pp. viii–ixt) or in the *Teacher's Guide* in brief sidebars along the student text (pp. 16t, 23t, 26t, 27t, 36t, 39t, 40t, 41t, 49t, 76–77t). For example, cluster 2 warns teachers about confusions that students have with density: "Many students confuse density with weight so they think that compacted steel wool weighs more" (p. **16t**) and "A common misconception is that the weight increases because a solid [is] formed, and solids weigh more than liquids. Many students will be surprised to find that there is no change and will find it hard to accept this fact even after they have done the experiment" (p. **26t**). And teachers are cautioned about students' common misconceptions regarding the particulate nature of matter in cluster 3, as the recombination of atoms that make up molecules is needed to account for the conservation of mass (p. **49t**).

In most cases, students' widely held beliefs are explained in terms of their likely responses to questions or tasks in the unit, rather than in the abstract (e.g., p. **28t**). These descriptions may not be adequate to give teachers a real sense of what students' difficulties are and to appreciate the significance of these misconceptions. It would have been helpful to give teachers a more coherent perspective on students' difficulties at the beginning of each cluster, so that teachers could take account of them in their planning. Then, the brief notes in sidebars could have served as helpful reminders during the lessons.

Cluster by Cluster

This unit is composed of four clusters, each building toward a comprehensive story of how changes in matter relate to atoms and molecules and energy—one of the key questions in the Framework of the Michigan Essential Goals and Objectives for K-12 Science Education. As a unit, these materials put the goals for Michigan science education into practice (see the Michigan Essential Goals and Objectives for K-12 Science Education, page 1, Philosophy and Rationale).

How the unit works:

To develop a broadly-connected understanding of how new substances form, this unit applies ideas about atoms, molecules, chemical reactions, and energy changes to four relatively simple reactions: burning, rusting, the decomposition of water, and the "volcano" reaction of baking soda and vinegar.

Students will, in general, have studied changes of state (melting, freezing, evaporating, condensing) and other physical changes (dissolving, crushing, coloring, etc.) prior to doing this unit. They usually will not, however, have studied the properties of many everyday substances (such as gasoline, baking soda, bleach, metals, bread, wood, paper, etc.) or the chemical changes that take place with them (burning, rusting and other oxidation reactions, baking, the effects of acids, etc.)

In Cluster 1, students are asked to develop descriptions of various substances and changes that occur in those substances, with the purpose of eventually being able to recognize when chemical reactions have occurred—that is, when new substances are produced. This is often difficult because students typically use the language of physical changes to talk about what scientifically literate people recognize as chemical changes. For example, students may say that rust is nothing more than discolored or flaky metal, or that when an egg white cooks it goes through a phase change from liquid to solid, or that gasoline goes through a phase change from a liquid to a gas when it burns. They fail to understand that chemical changes produce new substances or how those substances form. Students learn to write more accurate descriptions of reactants and products and use their descriptions to find evidence for the formation of new substances.

Cluster 2 asks whether the weight of substances changes during physical and chemical reactions. Students make predictions about weight changes and then actually weigh the starting substances and the ending substances to check their predictions. They learn to account for the invisible gases either as reactants or as products and are eventually led to the Law of the Conservation of Matter. Many students think that solids weigh more than liquids, that gases have no weight, and that burning makes things disappear. They often have great difficulty letting go of these misconceptions even when experimentation has shown them otherwise.

In Cluster 3, students construct explanations for both the formation of new substances and the Law of the Conservation of Matter. These concepts are explained and understood in terms of the rearrangement of atoms in molecules during chemical reactions. The cluster introduces molecules as a way to distinguish between substances and as a way to account for what happens during chemical reactions. It presents chemical equations as a way to account for and conserve atoms and to show how new substances form. It poses many questions that extend students' thinking to similar situations in the world around them.

Cluster 4 explores the energy changes that take place between reactants and products and uses separate energy equations to express these changes. It then focuses on reactions that require a “booster” to get started, either in terms of energy or chemical substances that remain after the reaction (catalysts).

Throughout the entire unit, students conduct their own research of a chemical substance. They apply the concepts learned in each cluster to their specific substance as they learn its chemical name, physical properties, history, uses, chemical composition, disposal method, and energy requirements. At the conclusion of the unit, students make presentations using formats they have chosen.

Cluster 2—Lesson 4

A. This lesson is designed to start students thinking about weight gain or loss in reactions involving several kinds of physical changes, and to allow teachers to become aware of student thinking along with any misconceptions they have. Most of this should be a review of what students already know. However, many students still think that weight is lost when steel wool is compacted or when ice melts or sugar dissolves. Many students confuse density with weight so they think that compacted steel wool weighs more. Try not to get into any detailed discussion of density as this is a difficult and confusing concept to most students and is not relevant to the understanding of the Law of the Conservation of Matter which is what we are preparing for here.

B. This is NOT THE TIME TO TRY TO CHANGE OR INFLUENCE STUDENTS' THINKING. They must be allowed to become aware of how they think in order to discover discrepancies in their thinking and then construct new knowledge which will lead to conceptual change. The rest of this cluster is designed to do that. If this process is not allowed to occur, students will revert to their former way of thinking the minute they walk out the door.

Lesson 4: DOES THE WEIGHT CHANGE?

Hardly a minute goes by that we don't witness changes, both physical and chemical, in the world around us. The snow that fell on the ground this morning has melted into puddles of slush. Trash picked up at the curb is compacted by the garbage truck into a much smaller volume. Soda pop is cooled down by ice, meat cooked on the stove turns from red to brown, medicines change the condition of our bodies, cars rust, hair turns grey. The list is endless.

(A) In Cluster 1, you observed many changes and wrote detailed descriptions of the starting and the ending substances. In some of these changes, only the size, shape, the space it occupied or temperature of the material changed while the material itself stayed the same. But in other changes you observed, the material seemed to lose its character, and something with entirely new properties appeared. All of the changes that produced new substances with new properties involved chemical reactions. Other changes —where only the size, shape, space it occupied or temperature, changed—are lumped into the category of physical changes.

(B) Which of the changes above are ones where the material itself stays the same? Ice melting into snow? Which others? What other changes can you list where the size, shape or temperature of the material changes, but not the substance itself?

Which of the changes above are ones where the material itself actually changes into a new substance? Can you name other changes like this?

Chemical changes are not easy to understand simply by asking whether the material changes into a new substance. That is not always easy to tell. To get a deeper understanding of chemical reactions and the making of new substances, you are going to consider another question—how the weight of materials changes as they change in all these different ways.

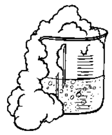
LESSON STATEMENT: Students will observe physical changes in matter and make predictions about weight changes involved. They will discuss and debate their predictions in groups and then share their predictions with the class.

PURPOSE: Students will observe reactions involving physical changes such as crumpling, melting, dissolving and boiling; they will explore and discuss their thinking about the weight changes that occur.

APPROX. TIME: 1 class period.

A. Students are allowed to observe the reaction and make predictions about weight change. They design an experiment to test their hypothesis and use their findings to prove or disprove their predictions. Through group discussions, students construct the explanation that no matter entered or left the system. Therefore, the weight did not change.

B. A common misconception is that the weight increases because a solid formed, and solids weigh more that liquids. Many students will be surprised to find that there is no change and will find it hard to accept this fact even after they have done the experiment. In the discussion, they should give reasons why they think what they do, and they should become aware of any discrepancies in their thinking.



TRY THIS

YOU WILL NEED

- 2 stoppered test tubes containing solutions to be combined
- 100 ml beaker and stirring rod
- balance

A. Obtain two stoppered test tubes that contain each of the solutions to be mixed. Examine the properties of each of the solutions and write them in your journal. Save your solutions for later use.

(A) B. Your teacher will combine solutions of the two substances together and stir for several minutes. Watch carefully and write any observations in your journal.

C. Your teacher will give each group a small portion of the product to examine. Examine the properties and record your observations in your journal. Compare these properties to those you observed before the reaction. Record whether you think a new substance was formed, and why you think so.

(B) D. Make a prediction. Did the weight increase, decrease or remain the same during this reaction? Write your prediction in your journal. Then write all the reasons why you think this.

How can you verify your predictions for this reaction?

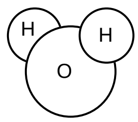
E. Before you begin, plan out the experiment carefully, by following these steps for conducting the experiment.

- Plan, as a group, how to conduct your experiment. Write out your plan in steps.
- Think about each measurement you need to make and provide a clearly identified place on your data sheet for it.
- Think carefully about what might happen during your experiment that might make your measurements inaccurate, and plan ways to correct for those possible inaccuracies.

A THINK AND WRITE

1. Write what you remember about **molecules** in your journal.

Chemists have come to understand that common substances in our environment—really all substances, common or not—when they are magnified millions of times, are composed of different kinds of molecules. Water, for example, has its own kind of molecule, which we often refer to as H_2O.



a water molecule

Sugar has its own kind of molecule.

Vinegar is made up of its own special kind of molecule.

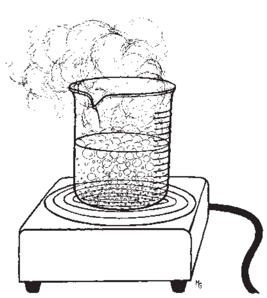
Oxygen is made up of still another kind of molecule.

Carbon dioxide is composed of molecules different from oxygen.

So are aluminum, and iron, and copper, gold and many, many, many other solids, liquids and gases.

Take a chunk of ice. Magnify it millions of times, and you would see water molecules joined together into sort of a cage-like structure, jiggling a little, but staying in the same place. Solids are made of molecules that are close together in neat, orderly, regular arrangements.

When ice gets warmer, it becomes liquid water. The molecules jiggle faster as the ice gets warmer, until they break free from the forces that hold them together as solids. As a liquid, the molecules are moving freely within the container, sliding around past each other. *But nothing about the individual molecules has changed.* They are still H_2O.



When water is heated, it boils and becomes water vapor. The molecules are given increased speed by the heat, and fly off the surface of the water, into the air. As gaseous water vapor, molecules are very far apart. But they are still H_2O molecules.

Whether a substance is in the solid, liquid or gaseous phase has only to do with how the molecules are

A. 1. This question is intended not only to get students to think about what they know, but also to help teachers become familiar with students' thinking on this subject and become aware of any misconceptions. Some students will know more about molecules than others. One typical misconception is the idea that molecules are in substances, rather than making up the substance—e.g., that there are molecules inside an ice cube, perhaps between the water, or that the molecules in liquid water are similar to germs, floating around in the water. Underlying this misconception is the general notion that substances are continuous, not made up of discrete particles—that water is a continuous liquid, or that solid aluminum is a continuous substance, not actually composed of discrete, individual particles.

If possible, show models of solids, liquids and gases. The solid should be a rather rigid, orderly arrangement of molecules. Be careful that the models you use represent molecules, not atoms which students haven't learned about yet. Since the models should represent entire molecules, marbles or styrofoam balls work well. Marbles or styrofoam balls moving freely in a dish make a good model for a liquid. Blowing ping-pong balls around in space with a hair dryer is a good model for molecules of gaseous substances.

Cluster 2—Lesson 7

A. This lesson allows students to explore their own thinking about weight gain or loss in reactions involving gases as products. It also allows teachers to become aware of their students' thinking about gases and of any misconceptions they have. Because the gases produced in these activities are invisible, many students are not even aware that they are being formed and given off. Most students do not know what bubbles are and they certainly do not think of them as pockets of gases that were formed as the reaction occurred. Many students think the bubbles contain air. Another common misconception is that these gases have no weight and are not matter, so they take no account of them in their predictions. Students are frequently very surprised when the cork pops off the vinegar and baking soda reaction. Some students think something is being formed and given off but may think it is energy.

B. This is NOT THE TIME TO TRY TO CHANGE OR INFLUENCE STUDENTS' THINKING. During the rest of this cluster, students will discover their misconceptions and discrepancies and construct new knowledge so that conceptual change can occur. If students are not allowed to go through this process, they will probably revert to their former way of thinking the minute they walk out the door.

Lesson 7: WHAT'S INSIDE THE BUBBLES? INVISIBLE PRODUCTS

(A) You just finished comparing the weight of the reactants (starting substances) to the weight of the products (ending substances) in a reaction that could happen in a closed and sealed jar; very interesting chemical reaction. Now you will compare the weights of the reactants and products of two other reactions that get a little trickier.

KEY QUESTION

What does it mean when bubbles are formed in a reaction? What happens to the weight in a reaction if bubbles are formed?

(B) You have observed both of the following reactions (vinegar with baking soda and Alka-Seltzer with water) many times before, but have you ever taken the time to observe what is really happening? Have you ever thought about or wondered what's in the bubbles? And what happens to the weight after the reaction compared to the weight before the reaction? Let's see how good your powers of observation are!

TRY THIS

YOU WILL NEED

- test tube about 1/3 filled with vinegar fitted with a stopper
- about 1/2 teaspoon of baking soda
- 250 ml Erlenmeyer flask and balloon that fits over the neck of the flask
- Alka-Seltzer tablets

LESSON STATEMENT: Students will observe two chemical changes where gases are produced in the reactions. They make predictions about weight changes as reactants form products and give reasons for their predictions.

PURPOSE: To provide opportunities for students to observe chemical reactions that form bubbles of invisible gases as products of the reactions; to think about whether any weight changes occurred.

APPROX. TIME: 1 class period.