Chemistry That Applies
The module provides numerous activities to assist teachers in identifying their own students' ideas. For example, questions and tasks help teachers check for:

- possible confusions about weight and density—students are asked to predict (a) how the weights of regular versus teased-apart steel wool compare (p. **19s**), (b) what happens to the weight when sugar is dissolved in water (p. 19s), and (c) what will happen to the weight when two liquids react to form a solid (p. **26st**).

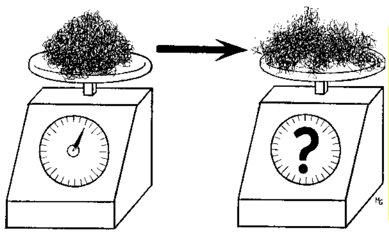
- possible misconceptions about whether gases have mass—students are asked to predict (a) how the weight would change if water were boiled in a beaker for 10 minutes (p. 19s), (b) what happens to the weight when vinegar reacts with baking soda (p. 29s), and (c) what happens to the weight when Alka-Seltzer is mixed with water (p. **29s**).

- what students know about the particulate nature of matter—several questions are posed (pp. **49–50s**, Think and Write, questions 1, 2), and tasks involve students in making predictions about familiar phenomena (rather than asking about abstractions) and are likely to be comprehensible.

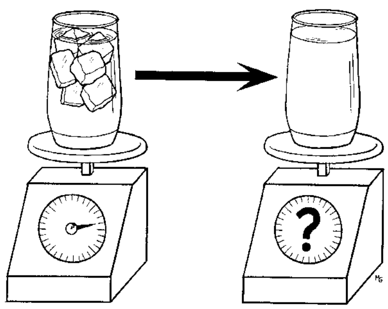
Teacher notes make clear that the purpose of these questions and tasks is to probe students' ideas, and they instruct teachers not to provide answers at this point (e.g., pp. **2–4t**, **12t**, 16t, 28t, 36t).

Students are asked to make and justify their predictions (e.g., pp. 20s, 26s, **30s**), and/or design an experiment to test them (e.g., pp. 26s, **31st**). For example, after students make predictions about the weights of compact versus teased-apart steel wool, unmelted versus melted ice cubes, undissolved versus dissolved sugar, and water before and after boiling for 10 minutes, they are asked to (a) share and debate their predictions in their team; (b) make any changes in their predictions or reasons; (c) share their predictions and reasons with the class, noting differences of opinion and reasons; and (d) revise their predictions or reasons if they find others more compelling (p. **20s**).

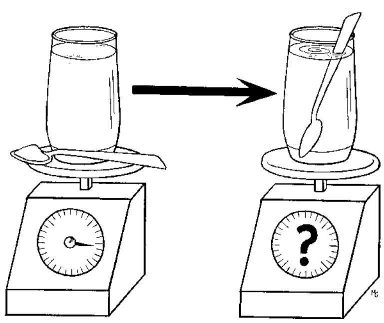
Nevertheless, no suggestions are offered on how teachers can probe beyond their students' initial responses, nor are they told that they should do so. While students may reveal more about their ideas when they justify their predictions, teachers are not asked to listen to, or read, their responses.



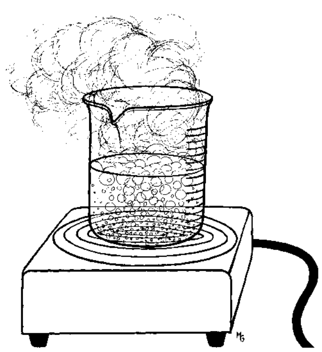
DEMONSTRATION 1: Which weights more, a tightly wadded ball of steel wool or the same steel wool stretched and pulled apart?



DEMONSTRATION 2: How does the weight of a glass of water with an ice cube in it change as the ice cube melts and eventually disappears?



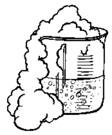
DEMONSTRATION 3: Observe a teaspoon with sugar and a glass of warm water. Then stir the sugar into the glass of warm water until it has all dissolved. How does the initial weight of the teaspoon of sugar and the glass of water compare to the weight of the dissolved sugar and water?



DEMONSTRATION 4: How would the weight change if you boiled a beaker of water for 10 minutes?

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)

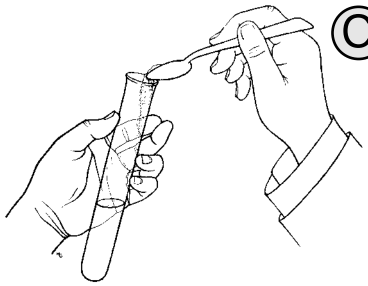
D. Make a prediction. Did the weight increase, decrease or remain the same during this reaction? Write your prediction in your journal. Then write all the reasons why you think this.

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.

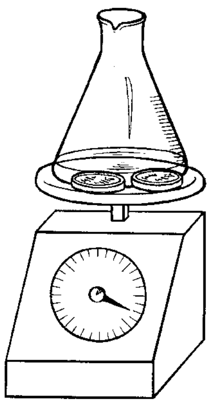
- Plan, as a group, how to conduct your experiment. Write out your plan in steps.
- Think about each measurement you need to make and provide a clearly identified place on your data sheet for it.
- Think carefully about what might happen during your experiment that might make your measurements inaccurate,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

C



ACTIVITY 1

Obtain the largest test tube you can find. Fill it about 1/3 full of vinegar and then place about 1/2 teaspoon of baking soda in it. Observe the reaction. Then make a prediction. Did the weight of the test tube, vinegar and baking soda before the reaction weigh more, less or the same as the test tube and its contents after the reaction? Write the reasons why you think this in your journal.



ACTIVITY 2

Obtain a 250 ml Erlenmeyer flask and put a small amount of water in it—enough to fill it about 1/2 inch. Add an Alka-Seltzer tablet to it. Observe the reaction. Make your prediction. Did the weight of the flask, water and Alka-Seltzer before the reaction weigh more, less or the same as the flask and its contents after the reaction? Write the reasons why you think this in your journal. Share your predictions and reasoning for each of the above reactions with the other members of your group. Try to understand what the other students in your group think about each reaction. If there are differences in the predictions or reasons in your group, discuss and debate these differences and try to come to a consensus. If you want to change anything you wrote in your journal, write these changes after you have finished the discussion.

Now continue with the next two similar activities.

D

ACTIVITY 3

Repeat the procedure in Activity 1 above, except this time put a stopper on the test tube very securely. Observe the reaction. Does this change what you thought in Activity 1 above? Make a new prediction for Activity 1 if you want to and write the reasons for your new prediction in your journal.

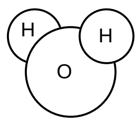
C. ACTIVITIES 1 & 2: Even though it is recommended that students try to come to a consensus in the group, it is not necessary. Allow students to hold their own beliefs if they have not been convinced otherwise, and they could not bring the group to their way of thinking. You will probably find groups where, even though the students have a correct prediction, they cannot give a reason for the prediction (This is really just a guess.), or the reasons they have are not correct. This will all come together at the end of the next lesson when the focus is on constructing new knowledge.

D. ACTIVITIES 3 & 4: Probably the cork will pop off the test tube with some force so be sure that it points toward the ceiling or wall, not toward themselves or another student. Hopefully, the popping of the cork will help the students realize that the bubbles that form have something in them that creates a force, and maybe it is matter and has weight. But, once again, remember—no help from the teacher. Let the students figure it out in their discussions.

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.

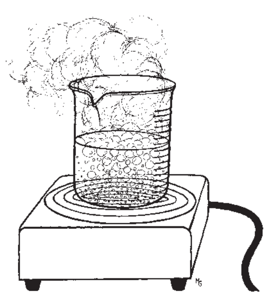
Oxygen is made up of still another kind of molecule.

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.

2. Students pictures should show the arrangement and distance between molecules—that the spacing in solids is close and very orderly. The spacing in liquids is very close and in gases the molecules are very far apart. Only distance and arrangement (orderliness or randomness) are changing. In this question, students are drawing molecules as a single particle and atomic representation is not expected. Students should use different symbols, such as circles and squares, or different color circles, or size for different kinds of molecules.

In preparation for understanding the difference between chemical and physical changes, it is important that students recognize that the molecules stay intact during physical changes.

The molecules don't change in any way during melting, freezing, etc.

If students draw pictures of ice cubes that contain molecules, rather than being made up of molecules, you might ask them to describe what the other stuff in the ice cube is.

3. a. You would heat it, for example, bring an ice cube to room temperature or put it in the sun. You could heat water on the stove.
b. You would cool it, for example, gases in the air change to liquid on the outside of a glass of cold pop. Lakes freeze in the winter time.
c. Yes, but in the case of a metal, you would have to get it very, very hot.

4. Fruits dry out when the water in them evaporates. See the fruit is still there, just less water. Think about grapes to raisins. The molecules of water in the fruit leave it by flying off into the air.

5. Can't be a change of state, since you add heat to make it seem more solid (adding heat usually melts things). It must be some other kind of change. (It's actually a chemical change, where the heat affects the proteins in the egg.)

arranged and how they move. If you heat a solid, it changes to a liquid and, if you heat it more, the liquid changes to a gas. The opposite is also true. If you cool a gas, it changes to a liquid and, if you cool it more, the liquid becomes a solid. The molecules themselves are the same in all three forms. They have simply gone into different arrangements because of the increased speed (when heated) or decreased speed (when cooled.) And because the molecules are still the same, **no new substances are formed.**

2. Draw a picture of what you think pure ice, water and water vapor would look like if magnified millions of times.
3. a. How could you get a solid to change to a liquid or a liquid to a gas? Give an example of each.
   b. How could you get a gas to change to a liquid or a liquid to a solid? Give an example of each.
   c. Would your methods work for butter? for chocolate? for a metal such as aluminum? Explain.
4. All the food we eat (fruits, vegetables, milk, juice, meat, bread, etc.) contains large amounts of water. If fresh fruits or vegetables are left around for a while, they begin to wither and dry out. What kind of change is this? Use molecules to explain why you think this.
5. When an egg white is cooked, it goes from sort of a liquid to some sort of a solid. Is this a change of state or some other kind of change? (This is really a tough one, so here's a hint. If water changes from liquid water to solid ice, do you heat it or cool it? When the egg white changes from liquid to solid, do you heat it or cool it?)

DIFFERENT KINDS OF MOLECULES

A gold ring can be melted into liquid gold, and then poured into a mold to make a new ring. Its gold molecules never change in this process. But if you poured water into the ring mold, and froze it, would it come out as gold metal? Why not?

? ? ? ? ? ?

Cluster 1—Lesson 1

A. Many questions are posed in this unit simply to stimulate class discussion. Questions marked with numbers are ones for which students should write answers. We recommend that students use a notebook or a "science log" for writing answers to questions, so they can refer back to their earlier ideas when appropriate. They can also use the journal for recording observations and data from lab activities.

B. The KEY QUESTIONS in this unit are the "objectives" for each cluster or lesson. When they are first presented in the cluster or lesson, they are for stimulating discussion, activating students' prior knowledge, and giving an idea of what's ahead. Don't ask for or give definitive answers at this time—they will be developed during the cluster. But do ask students to voice their present ideas. This will give you some insight into their thinking, and perhaps stimulate some initial debate and questions that will carry through the cluster.

C. This lesson is designed to get students to explore their thinking about changes in matter and to allow teachers to become familiar with their students' thinking. This is not the time to correct errors in their perceptions of changes in matter. No explanations of the reactions are expected in this lesson. Students do, however, observe and describe the reactions as they are demonstrated, and they share their descriptions with other students.

Lesson 1: MIXING IT UP

Each morning we begin our day by mixing things. It may be our favorite cereal and milk, toast with butter, or cream and coffee. It doesn't end there. As the day continues, we use a wide array of mixed substances such as foods, hair sprays, liquid soaps, fertilizers for plants, gasoline and oil for the lawn mower, glue, detergents for washing clothes, and the flour, eggs, sugar, and baking powder for making cakes. The list continues until bedtime when you decide to mix a glass of hot milk and chocolate to help you go to sleep.

Mixing substances together is something we do (or have done for us) all the time. Asking questions about these mixtures will help us to look more closely at what is happening when things are mixed.

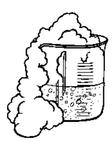
(A) Can you think of any things you mixed before coming to class today, or any mixtures you used today? How many combinations can you think of?

(B)

KEY QUESTION

What happens when some ordinary household substances are mixed?

(C)



TRY THIS

In this activity you will mix a variety of commonly used household substances and observe and think about what happens. You will work in groups assigned by your teacher.

YOU WILL NEED

One kit (containing a few commonly found household substances) per group.

Chemistry That Applies—Michigan Dept. of Education **2**

LESSON STATEMENT: Students combine some common, everyday household substances and observe and describe what happens. Some of the substances undergo chemical reactions, while others just mix. Students select their most interesting combination, demonstrate it for the class and share their observations with others in the class.

PURPOSE: To provide students with opportunities to explore, observe and describe some reactions involving common substances without providing scientific explanations.

APPROX. TIME: 1 1/2 class periods.

DO, OBSERVE, AND RECORD:

A. Prepare a data chart similar to the one below on which to record your observations. Use your paper the long way and use the full width of the sheet of paper in order to provide sufficient room for your descriptions. Each student should have a separate chart.

B. Work as a team. Examine your kit of materials and make a list of all possible combinations of two substances in your journal. Then make a list of all possible combinations of three substances.

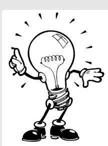
STARTING SUBSTANCES			DESCRIPTION OF WHAT HAPPENED	DESCRIPTION OF ENDING SUBSTANCES
	COMMON NAME	DESCRIPTION		
SUBSTANCE #1				
SUBSTANCE #2				
SUBSTANCE #3				

C. Mix each combination and check it off as you do it. Make a note of anything interesting that happens when you mix the substances.

D. For your most interesting combination (choose only one), record on your data chart in the appropriate columns:

- The common name and a description of each substance you started with.
- What you observed happening when you mixed your substances.
- A description of each substance you ended with. If you think you know the names of any of these substances, write them also.

Since people see things differently, it is important that your observations and ideas are shared, explained and validated by others. You will now have the opportunity to share your demonstration with the entire class as well as observe and describe reactions they will perform.



SAFETY!

Handle all chemicals with care, even ones that are found around the house. Avoid spills and contact with your skin. Never taste any substance unless told to do so by your teacher.

D. Teachers should talk with the lab groups about the descriptions they are writing. If they are having difficulty, ask them questions about color, odor, state (liquid or solid), etc. You don't need to go into too much detail since students will get more practice and much more direction for writing good descriptions in the next lesson.

The purpose here is to get the students started thinking about changes in matter and to help teachers become aware of students' thinking.

E. One way to handle the group discussions of each demonstration is to have the performing group write their descriptions on the blackboard or on an overhead transparency and have the class critique it or add to it. Alternately, the class could come up with a description and compare it to the descriptions of the performing group.

F. Ask students in the class whether they have anything to add to the performing group's description. Write any new descriptions on the blackboard. Then ask the class whether there are any parts of the description that they wish to challenge or to be clarified.

G. QUESTIONS 1 & 2. These questions are for students to speculate about and to explore their own thinking about changes in matter. Do not correct or give them answers at this point. They will construct their own solutions as the cluster progresses.

(E) E. Prepare to repeat this experiment for the entire class. Use the following guidelines as you prepare for the demonstration:

- Try to involve each member of your group in the presentation.
- Allow the class to observe and examine the starting materials and write short descriptions of each one.
- Allow the class to observe and examine the ending substances and write short descriptions of each one.
- Compare your descriptions with those of your classmates.

(F) F. After each demonstration you should:

- Add the new reaction to your data chart. Use the same one you used earlier. Be sure to number each new reaction. Write a description of the starting and ending substances and what you observed happening when the substances were combined.
- Share your descriptions with the class and compare your observations and descriptions with those of the other students.
- Revise your data chart to show any new information gained from the class discussion.

(G)

THINK AND WRITE

Use the descriptions you have written to answer the following questions. You may want to discuss these questions in your group before you write answers in your journal.

1. Do you think any of the demonstrations DID NOT produce new substances? How can you tell?
2. Do you think any of the demonstrations DID produce new substances? How can you tell?

evidence as a clear indication of a chemical change (such as a gas produced, a new color, etc.). Any of these changes can also be the result of a physical change (gas is produced during boiling; a dark color solution becomes lighter colored when water is added). Nevertheless, students should begin to look for this kind of evidence, and add it to other things they may learn as indicators that chemical changes have occurred.

2. Reaction #2: The formation of bubbles and the fizzing is an indication that gases were formed. This is evidence that a new substance could have been formed.

Reaction #3: The butane is disappearing as is evidenced by the weight change. But what is happening to it? Although there were gases produced, these are invisible, and most students will not have them in their descriptions. Some students may think that the butane was vaporizing and turning to a gas.

Reaction #4: Again, gases were formed and released as bubbles formed at each electrode; this change is evidence that a new substance could have been formed. They did not test the properties of these gases though, so they cannot be sure. Many students have no clues about what the bubbles are or what is in them. They may think that air was inside the bubbles or, perhaps, that electricity was inside the bubbles, and the water just sort of went off the end of the wire. Some may think that water vapor was inside the bubbles.

3. Answers will vary. Let students speculate! Do not attempt to explain this here. Explanations will come later. This is just an opportunity for students to make use of their prior knowledge and for you to see what they think.

As you probably just found out, it is sometimes very difficult, if not impossible, to tell if new substances were formed. And if new substances did form, where did they come from? Was anything lost or gained in the process? In Cluster 2, you'll investigate how the weight of the starting substances compares to the weight of the ending substances and in Cluster 3 you'll find out where new substances come from.

REMEMBER TO SAVE ALL YOUR DATA CHARTS FOR REFERENCE IN CLUSTER 3.

ACTIVITY 4

Repeat the procedure from Activity 2 above, but, immediately after dropping the Alka-seltzer into the flask, fit a deflated balloon securely over the flask. Observe the reaction. Make a new prediction for Activity 2 if you want to and write your reasons for this prediction in your journal.

In your group, discuss any changes you made in your predictions and your reasons. Try to reach a consensus, if possible. After the group discussions, one member from each group should present your group's prediction and reasons to the entire class. At the end of the presentations, discuss any differences among the groups. In your journal, make any changes or additions you want and then get ready to see how your predictions compare to real data.

Verifying your predictions for these experiments is not very easy, but there is a very clever way to do it. We'll save that for the next lesson. But first, try answering the KEY QUESTIONS from the beginning of this lesson. Discuss them in your group before you write your answers. Here are the questions again.

Ⓔ THINK AND WRITE

1. Were there any invisible substances formed in these reactions? Why do you think this?
2. Is anything inside of bubbles? If so, what do you think it is?
3. Where did the bubbles in this reaction come from?

Ⓕ SPECULATE ABOUT THESE

- Are air and other gases substances? How could you find out?
- Do they have weight? How could you find out?

In the next lesson, you will find out if you are correct.

Chemistry That Applies—Michigan Dept. of Education **30**

E. These questions are posed simply so that students will think about them and write their ideas. Student answers will vary Do not correct or explain answers at this point. Answers will develop during the next two lessons. Answers are given below for teacher information only.

1. Yes, there are gases inside the bubbles. Evidence for the formation of the gases is the cork popping off the test tube and the balloon filling with something.

2. Answers vary.

3. Some students may just say "I don't know." That's OK. Do not discuss or answer this question at this time. However, some students might recognize that the invisible gases are new molecules.

F. These are speculation questions. Students do not yet have the evidence they need to answer the questions. They should answer it based on the knowledge they have so far and then pose ways they could test their predictions.

Lesson 8: DO GASES HAVE WEIGHT?

The last lesson asked some interesting questions but didn't offer any definite answers to the big questions. What are the big questions?

KEY QUESTION

Do gases have weight? How can you find out? How does the weight of the starting substances compare to the weight of the ending substances when gases are formed and given off in a reaction?

Ⓐ By the end of the last lesson, you probably decided that all the little bubbles that formed in the two reactions contained some kind of invisible gases. As the bubbles broke, the gases escaped to the surrounding air.

If you knew for sure whether these gases have weight, then you would know how to make your predictions. How could you design an experiment that would test this out?

TRY THIS

The most sensitive method by which to compare two weights is a balance. You'll use a meter stick suspended from the middle with weights hung at both ends. The weights for this experiment are 2-liter soda bottles with a small amount of water in the bottom used to dissolve Alka-Seltzer tablets. The bottles are hung from the ends of the meter stick by strings or wires. Coat hangers, bent to fit around the neck of the bottle at one end and bent into a hook on the other end to hang over the meter stick, work quite well. They should be taped in place so they do not move during the experiment. Two Alka-Seltzer tablets, are broken in half, tied together and suspended above the water inside one of the bottles with a string and tape.

A. Have the class, as a whole or in small groups, try to design an experiment to test these predictions. Students should come to the idea, or you should introduce it when appropriate, that the reaction must be done in a way that can capture the gases and weigh the products, and then release the gases and weigh the products again. This demonstration is very powerful in helping students understand that gases have weight. Allow them to watch the demonstration and come to their own conclusions. As always, they will first predict what will happen to the weight and then check their predictions against experimental evidence. Do not give clues when students are making their predictions. Let them see for themselves!

LESSON STATEMENT: Students will observe a chemical reaction, which forms a gas as a product, in an open and a closed system. They will see changes in weight between the systems when the gas is trapped inside the bottle and when it is allowed to escape.

PURPOSE: To provide visual, experimental evidence that gases have weight and to help students begin to construct a conceptual understanding of the Law of the Conservation of Matter.

APPROX. TIME: 1 class period.

D. After making their predictions and discussing them as a class, allow students to write new thoughts or change their predictions if they have been convinced otherwise.

E. Have the class discuss how they could verify their predictions. If time permits, you may want to begin the next lesson by having students write their plans for performing the experiments.

THINK AND WRITE

After all the demonstrations:

- Share and debate your predictions in your team.
- Make any changes you want in your own predictions or reasons. Your predictions don't have to be the same as those of the other team members.
- (D) Share the predictions and reasoning of the team with the entire class. You may do this by selecting one spokesman for each team or by having all members of the team share. Make sure you tell the class if not everyone agrees on any of your predictions or reasons.
- Get a class tally for each of the predictions. Find out how many students think the weight would increase, how many think it would decrease and how many think it would stay the same.
- (E) Revise or rewrite your predictions or reasons any time you feel that a different prediction or reason makes more sense to you. Don't be persuaded by others' predictions just because "they always get A's" or anything like that, though. That's not what science is about.

Look at the class tally. Are there disagreements among students in your class? How could these disagreements be settled? How could you test your predictions, and prove or disprove them? You'll do this in the next lesson.