Category V Physical Science Examples

Encouraging students to explain their ideas

Chemistry That Applies
Students are asked consistently to clarify, justify, and/or represent their thinking about the key ideas. For the many physical changes and chemical reactions that they observe, they make predictions about whether or not new substances will be formed (e.g., pp. **4s**, **11–12st**) and what happens to the mass (pp. **22-24st**). Then, they observe what happens and attempt to explain it. Such tasks ask students to use the ideas that substances may combine with other substances to form new substances with different characteristic properties and that when substances interact with one another in a closed system, mass is conserved. Students are asked repeatedly to explain their ideas about atoms and their relationship to mass conservation in end-of-lesson questions (e.g., p. **62s**). Students are asked to answer similar questions about the other chemical reactions observed, such as rusting iron (p. **67s**), baking soda reacting with vinegar (p. **73s**), and burning butane (pp. **76–77s**). They also are asked to make drawings of what is going on with the atoms and molecules in each of these reactions and to use them to "account" for the mass.

In most cases, each student is expected to respond to questions and tasks. Teacher notes explain the role of group work and the need for students to write individual answers to questions "so that those [students] who do not contribute strongly or learn well from group discussions have opportunities to articulate their own ideas in writing" (p. **xit**).

Suggested responses to questions give guidance to teachers on how to provide feedback to students. The answers in the teacher notes contain the correct answer (always), suggest limits to the expected answer (when appropriate), indicate how students might answer the question (occasionally), and provide questions to probe the student's answer further (only once). For example, suggested responses to questions and tasks on pages **23-24s/t** do all but the last.

The text also provides feedback to students, typically by demonstrating how to explain a phenomenon that they have just considered. For example, after observing that the reaction of Alka-Seltzer and water loses weight and attempting to explain their observations, the text provides an explanation: "Here's how scientists think about this reaction. . ." (p. **33s**).

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 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?

G. Place the tips of both pencil leads into the water of the petri dish. The leads should not touch each other.

H. Observe each substance being formed and write complete descriptions of these substances in the appropriate spaces on your data sheet. Be sure to use at least three good, descriptive words for each. Refer to the board for help if you need it.

I. Share all of your observations and descriptions with your group. Make any changes or additions you want on your data sheet.

(D) Now, you might be wondering if any of the ending substances were actually new substances, or if they were just some form of the old substance? How can you tell? Try to figure it out!

(E)

THINK AND WRITE

1. Review the description of the beginning and ending substances in the first reaction. Is there any evidence for a change? There aren't any hard and fast rules for finding new substances, but some things to look for might be a color change, a new smell, a change in taste **(CAUTION: DON'T TASTE ANYTHING IN THIS UNIT)**, the formation of a gas or a new solid or heat. Often, you must use several or all of these to help you decide. Look for any evidence for a change in the substances. Circle all the evidence you can find Then write a statement about this reaction that starts with "I think a new substance did (or did not) form because…"
2. Repeat question 1 for each of the other 3 reactions.
3. If you think that new substances were formed in any of the reactions, how could this be explained? Where would the new substances come from?

D. Each of the reactions in this lesson is a chemical change. Students describe the reactants and products as a preparation for recognizing chemical changes later. Be sure to focus on these descriptions and do not try to get students to name and identify any of the reactants or products (although some will spontaneously mention some products like rust), since this causes them to lose the focus of the lesson. Many students will describe the substances being formed simply as "bubbles." They will not think about what is inside the bubbles. You may want to ask them this question: "What do you think is inside the bubbles?" Many will say water or, maybe, electricity. Just get them to speculate now and write down what they think. Don't try to teach them yet that oxygen is in the bubbles at one electrode and hydrogen is in bubbles at the other.

E. Be sure to emphasize the "could have been formed" in all of these answers since visual evidence is very unreliable. Do not attempt to explain chemical reactions here or give explanations. Each of these reactions will be done again, and further explanations will be given as the unit develops.

1. Reaction #1: The color change is evidence that a new substance could have been formed. It is also flaky and brittle rather than in strands. This is evidence that a new substance could have been formed.

In this lesson, students are looking for evidence for new substances. Do not talk about chemical change yet although that is occurring. Avoid using the traditional approach to teaching students about when a chemical change has taken place, that is, labeling certain types of 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.

EXPERIMENT 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?

EXPERIMENT 3: How does the weight of a teaspoon of sugar and a glass of warm water before they are mixed compare to the weight after stirring the sugar into the warm water until it has all dissolved?

EXPERIMENT 4: How does the weight change if you boil a beaker of water for 5 minutes?

After you have collected all the needed data, your group should prepare to present your findings to the class. Be sure to include the following points in your presentation:

(B)
- Whether your results helped to prove or disprove your predictions.
- If your group still believes in the reasons you gave for your prediction.

After all the experiments have been done and reported to the class, try as a class to answer to following question:

(C)
- What must happen during any change for the weight of the materials to increase or decrease?

If you're having trouble coming to a good answer to this question, think about these questions:

(D)
- In which of the experiments did the weight decrease significantly?

(E)
- What was different about that experiment from the others where there was no weight change?

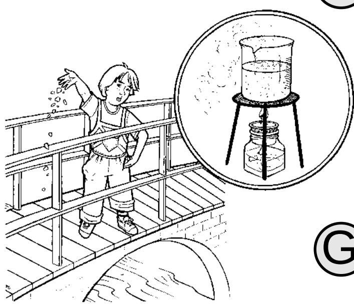
B. If students predicted that the weights would decrease, they should have some lively discussions as they try to construct explanations that account for their observations. Through the class discussion, students should construct a molecular picture of what is going on that would cause the observed results. Students find it very difficult to change their thinking from their original misconceptions. Allow plenty of discussion time while they construct new ideas.

C. • Something must be gained or lost—like putting quarters into your pocket or tossing them out.

D. • The weight of the boiled water decreased.

E. • Some of the water actually left the beaker and went into the air.

F



Here's how scientists would explain this. The last experiment—the one with boiling water—was different from the rest because as the water boiled, steam, which is a form of water, left the beaker. As the steam left the beaker, there was less water in the beaker, so it weighed less. It's like standing on a bridge, taking something heavy out of your pocket, and throwing it over the side. You now weigh less than before. As water boils, water molecules are going into the air, thus leaving fewer water molecules behind. Therefore it weighs less than it did before boiling.

G

THINK AND WRITE

Now try to answer the following questions in your journal:

1. What are all substances made up of? Use as much detail as you can.
2. What must happen to the substances involved in order for the weight of the materials to increase? to decrease?
3. Using this same sort of logic, how could you explain why a newly painted car would weigh more?
4. a. Did the steel wool change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   b. Did the water and ice cube change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   c. Did the sugar and water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   d. Did the boiling water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules in your experiment. Include bubbles in your picture and show what's in them.

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F. Ask students what they know about steam. See if they know what is inside the bubbles. Many think that the bubbles contain air but they have no explanation for how the air got there. Some think there is nothing in the bubbles. Others simply have no idea of what is in them.

G. When the water heats up, bubbles form in the water. Each bubble contains some molecules of water. As the water gets hotter, the bubbles rise to the top, break and the water molecules fly off into the air.

1. All substances are made of molecules. Students have probably heard of molecules before so take a few minutes to see how their thinking about molecules relates to these substances. If students are not comfortable with the concept of molecules, take some time to discuss the concept. It is sufficient here if students understand that all substances are made up of particles and that these particles are called molecules. The concept of atoms and molecules are developed much more in Cluster 3 so there is no need to go into any detail here—especially, do NOT discuss atomic structure or formulas.

2. Some of the substance must be added to or taken away from the system—like throwing quarters out of your pocket or putting some quarters into your pocket.

3. The paint adds weight to the car.

4. a. No. The number of molecules stayed the same whether the steel wool was stretched or compacted. Nothing left the system when compacting the steel wool. Picture should depict molecules spread out and far apart, possibly lined up in strands. The compacted picture should show the molecules much closer together possibly still in strands. Be sure students show the same number of molecules for each in their pictures.

4. b. No. The number of molecules did not change as the ice melted and changed to water. They simply went into a new arrangement. The water and ice cube picture should show water molecules as random and disordered while the ice cube molecules are neat and orderly floating in the water. When melted, all the molecules should show the same randomness and disorder. Be sure that the number of molecules stays the same in the ice cube

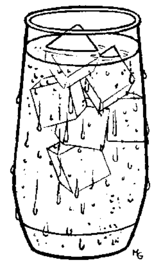
before and after melting. An important point to emphasize is that the ice and water molecules are identical. Be sure that students don't represent water molecules differently than ice molecules such as squares and circles. They should either be all square or all circles. Do not get into atomic structure here.

4. c. No. The number of molecules stays the same. When the sugar dissolves, the molecules separate and spread throughout the water molecules. The sugar should show a pile of ordered molecules as crystals of sugar (possibly square to show that they are different from water) and the water molecules (possibly round) should be random, disordered molecules in the glass. After dissolving, the sugar molecules (possibly square) should be equally dispersed into the water (round) molecules in the glass. None are lost in the process. Be sure that student drawings show no change in the number of molecules.

4. d. Yes. Bubbles filled with water molecules rise to the surface and burst, releasing some water molecules to the air. In the boiling water, as the water boils some of the molecules are leaving the beaker, spreading out and going into the air as water vapor. Since there are fewer molecules in the beaker, the water now weighs less.

5. a. All four reactions are physical changes.

5. b. Observing the changes reveals no new properties. Steel wool is still steel wool. Melted ice cubes and dissolved sugar taste the same. If you condense steam from boiling water on a spoon or lid of a pot, it is still water. Therefore, these are probably physical changes. Help students understand that observation alone is frequently not enough to tell if a change is physical or chemical.



5. a. Are these changes physical or chemical changes?

   b. How do your observations help you figure this out? Can you be sure?

   c. How do molecules help you figure this out? Why is this a problem?

6. Try these problems:

   a. Predict what would happen to the weight of a cold glass of water on a humid summer day? Explain your prediction.

   b. Predict what would happen to the weight of a car that gets very rusty over several years. Explain your prediction.

7. Can you think of any other examples of a change where weight would stay the same?

8. Can you think of any other examples of change where weight would increase or decrease?

We will use these ideas about weight change to understand more about that other kind of reaction, chemical reactions. The next lesson will give you more insight into chemical reactions as you make predictions about weight changes in some chemical reactions.

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5. c. At the molecular level, the molecules are still the same kind of molecule. But since you can't see individual molecules, this is not a practical way to detect physical changes. You need sophisticated instrumentation to figure out whether the molecules have changed or not.

6. a. It becomes very moist on the outside of the glass as it picks up water vapor from the air. It has added more matter so it will weigh more. Students have difficulty with this question. Some think that the water seeps through the glass. That doesn't make much sense to them, but they do not have a better explanation.

6. b. There are several plausible answers for this—the car gets lighter because metal rusts and falls off; the car gets heavier because the iron combines with oxygen from the air and forms a heavier molecule; there is no change in weight since rust is just the same iron discolored. Accept any reasonable explanation. Do not give answers here as this reaction is explored in lessons that follow.

7. Examples are chocolate melting, water freezing, bending metal, etc.

8. Answers will vary.

I. Students should write the balanced equation by thinking about their models and looking at the pictures of the models that they drew. If they write the correct formula first and then "how many," they should not have trouble figuring out where the numbers go. Don't use abstract ideas to explain equations.

QUESTIONS:

The following questions should be used for discussion in small groups. Students should use this opportunity to work out any discrepancies in their thinking as well as "fine tune" their thinking. After group discussions, students should be given time to write their answers on the back of their data sheet.

1. Boiling: The gas given off is water vapor, which has the same molecules as water. No atoms are rearranged to form new molecules in boiling.

2. a. Any substance that contains only hydrogen and/or oxygen atoms are possible products. There are no chlorine atoms available and no carbon atoms available.

b. Yes, these molecules only involve atoms that are available in water. Students may need some help in understanding that the individual products formed do not need to use every different atom from the reactants.

3. The subscripts tell how many atoms are in a molecule. They are like the "recipe" for making a molecule. The coefficient tells how many "whole" molecules are involved. If students have trouble with this, have them go back and look at the pictures of the models they drew.

This is the Law of Conservation of Matter, or the Law of Conservation of Mass. No weight is lost or gained in chemical reactions. No mass is lost or gained. No matter is lost or gained. Why? Because no ***atoms*** are lost or gained during chemical reactions.

CHEMICAL EQUATIONS

Chemists use a shorthand to write about this reaction. They show the starting substances on one side of an equation, and the ending substances on the other side, to show how their weights are equal. They use an arrow instead of an equal sign, to show that the left side reactants change into the right side products. The formula for this reaction is

$$2\ H_2O \rightarrow 2\ H_2 + O_2$$

The 2 in front of the H_2O means that two molecules of water were used in the reaction. The 2 in front of the H_2 means that two molecules of hydrogen gas were formed. No number in front of the O_2 means that one molecules of oxygen gas was formed.

K. Write the formula for this reaction on your chart.

THINK AND WRITE

1. When water boils a gas leaves its surface, and the level of the water goes down. When water is chemically decomposed, like in this experiment, it forms gas and the level of the water also goes down. What's the difference between boiling and decomposing water? Talk about the different gases that are formed in your explanation.
2. a. Could chlorine gas, Cl_2 be a product in this reaction? What about carbon dioxide, CO_2? Explain why you think this.

   b. Do you think it would be possible for ozone, O_3 to form as a product in this reaction? What about hydrogen peroxide, H_2O_2? Explain why you think this.
3. Find a partner and explain the difference between the two number 2's in 2 H_2O. Use your models to help you. Then write your explanation.

Can you use this discovery to answer the question about weight changes?

Ⓑ I. To write a balanced equation for this reaction, write the correct formula under each kind of molecule. Then show how many molecules of each kind were involved in the reaction, by putting a number in front of the formula for the molecule (for example, 2 Fe).

The balanced equation should look like this, with numbers in front of each molecule:

$$\_\_ \; Fe + \_\_ \; O_2 \rightarrow \_\_ \; Fe_2O_3$$

THINK AND WRITE

1. You have a friend who doesn't know the first thing about chemistry. He thinks that rust just starts somehow and then "eats" away at cars or pipes—sort of like termites eat wood—and this makes holes in the car or the pipe. You must explain to him what is really going on. Tell him what the reactants are and where they come from. Explain what product is formed and how this happens.
2. Is rust just the same thing as iron, only brown? Explain.
3. A friend of yours says that she left a shovel outside during the winter and it got rusty. She says that if you scrape off the rust with a steel brush, the shovel will be as good as new. To test her knowledge of chemical reactions, you ask her if it will weigh the same after the rust is scraped off as when she bought it. She says she's not sure, but it seems like it should—after all, rust just grows on the shovel like moss on a tree or mold on stale bread.

   Do you agree? Explain. Use atoms and molecules in your explanation, too, if you can.
4. Some cars and trucks get so rusty that holes start to form in the metal. How can this happen?

B. Students should write the balanced equation by thinking about their models and looking at the pictures of the models that they drew. If they are having difficulty, remind them to write the correct formula first and then "how many."

QUESTIONS:

1. Students should explain that the iron in the car body combines with oxygen from the air to form the rust. The rust is a reddish-brown color, and is flaky—significantly different in color and texture from the original iron (this is why this unit stresses student observation and description of products early on). The rust can fall away from the car.

2. No. It's a new substance. This can be seen by its properties—it is quite different from iron.

3. Since rust is a combination of some of the iron from the shovel with oxygen from the air, if the rust is scraped away the shovel loses some of its original iron and therefore wieghs less.

4. Rust starts when iron is exposed to the oxygen in the air and reacts with it. The iron has not disappeared, but is present in a new form in the rust that formed. It has chemically combined with the oxygen to form iron oxide which is rust. Since the iron is actually involved in the reaction (it is reacting to form a new substance), there will eventually be a hole in the original substance.

THINK AND WRITE

Discuss each question below in your group. Then write the answers on the back of your data sheet.

1. Sometimes when you do this reaction, after all the bubbles have popped (and the fizz settles down) you can add more vinegar and start the reaction going again. What does this tell you about the baking soda?
2. Design an experiment to show that carbon dioxide is actually what's inside the bubbles.
3. The change that you observe when baking soda and vinegar are mixed is a chemical reaction. The reaction produces bubbles with carbon dioxide in them. When water boils, bubbles are also produced. Is this a chemical reaction? Explain.
4. a. For each of the following changes, tell if you think new substances formed. Tell why you think as you do.
    1. Hydrogen and oxygen gas are ignited with a spark and explode to form water.
    2. Copper jewelry tarnishes (turns green after being exposed to air and water for a long time).
    3. An iron nail is magnetized by rubbing it against a magnet.
    4. Salt is stirred into water until it all dissolves.
    5. An egg is cooked, turning from a drippy liquid to a rubbery solid.

    b. Which of the above were you unsure of? What information would you need in order to make a correct decision?
5. Think about all the reactions you have done in this cluster, including the mixing you did in Lessons 1 and 2 of common household substances. Write a short paragraph telling what happens when new substances form. Be sure to tell both what you would observe with your eyes and what happens to the atoms and molecules which your eyes cannot see.

You are now ready to explore what happens when butane burns.

2. Yes, because of significant change in color and texture of the tarnish.

3. No, the nail is still the same and can be used as a nail in exactly the same way. Nothing new was seen forming.

4. No, the salt is still there as is evidenced by the taste. Also, the water could be evaporated and you would have salt and water. So they were just mixed together. Students often think that dissolving is a chemical change because the solid "changes into a liquid." They usually know that it did not melt but they do not know what is happening. Tell them to think about the properties of the substance, especially taste. Ask them what would happen if they evaporate the water?

5. Yes, the egg is different in color (the egg white) and taste. Most people don't eat raw eggs. This is confusing because we call both the cooked and the uncooked egg an egg so students often say "it is still an egg." Sometimes students say that it was liquidy and it went to solid as in a physical change but remind them that heat was added to cook the egg and when liquids change to solids (water to ice), the substances must be cooled.

4. b. Answers vary. You need to know the chemical formulas for the reactants and the products to see if they are the same or different.

5. Important points to include are:

- the properties that you can observe with your senses change, usually in an obvious way but sometimes in a less discernible way.
- the reactant molecules come apart and then go back together again in new arrangements.
- the total number of atoms in the reactants and in the products does not change.

QUESTIONS:

The following questions should be used for discussion in small groups as students refine their thinking. After group discussions, students should write the answers on the back of their data sheet.

1. 13

2. $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$

3. You can't burn trash up and get rid of it. This violates the Law of the Conservation of Matter. When burning trash, the trash and the oxygen it needs to burn change into new forms, much of it being gases which are given off into the atmosphere, including carbon dioxide and water vapor. Other gases can be produced, depending on what is burned; some of those gases contribute to air pollution. (Butane does not release other gases, as can be seen from the chemical equation; it is therefore a "clean" fuel. See note below.) Students frequently have the misconception that when things burn up, they weigh less. They fail to realize that the total weight of all the ash and the gases formed is exactly equal to the weight of the trash before it burned.

4. a. The gasoline in cars reacts to form carbon dioxide and water vapor and a few other products which are also mostly gases. These are given off into the atmosphere. The total weight of these products is less than the weight of the gasoline alone but it is exactly equal to the weight of the gasoline and the oxygen in the air needed to burn the gasoline. Nothing disappears or is lost.

THINK AND WRITE

Discuss each question below in your group. Then write the answers on the back of your data sheet.

1. How many molecules of oxygen did you need to react with the two butane molecules?
2. Write the balanced equation for the reaction in the appropriate place on your data sheet.
3. Charlie has been hearing a lot recently about all the trash that we are making and the problem of getting rid of it. He just had a brainstorm! Just burn it all up and it will be gone! What do you think about his brainstorm? Will it work? How would you explain this problem to a friend. Write your explanation in your journal.
4. The gasoline in your car is a fuel very similar to butane. When it enters the engine, it combines with oxygen in the cylinders and a spark makes it explode!
   a. What products are formed when gasoline is burned? (Hint: The products are the same as the products you got when your burned butane.) Would these products weigh more, less, or the same as the gasoline your started with? Where do these products go? Tell why you think this.
   b. Explain why you eventually run out of gasoline: What happens to the gasoline?
5. Your friend doesn't believe that butane or gasoline needs an invisible reactant to make them burn. Design an experiment to prove the invisible reactant is needed.
6. Some homes use bottled gas for their stoves, or for heating water for the shower, or for drying clothes. Some houses in cities get their gas from a pipe connected to their house, just like water and electricity come into your house. Other people, often those who live out in the country, get their gas from a tank in their back yard.

In all of these cases, a pipe takes the gas from the tank into the house and then to the stove or water heater or furnace or dryer. When you turn on the stove, the gas

A note about burning: Many substances burn (chemically react with air, releasing a great deal of heat), including gasoline, paper, wood, butane, coal, oil, natural gas, kerosene, charcoal, candle wax. These substances are all composed of carbon and hydrogen atoms, like butane; many also have oxygen atoms, nitrogen atoms, sulfur atoms. When each substance burns, it chemically changes into carbon dioxide and water; but in most cases (not butane) other substances are produced as well. Burning wood, paper and wax can produce smoke (small particles like dust) and comes out, and a small flame called a pilot light (or, in newer furnaces, an automatic, sparking electronic device) ignites the gas.

a. Every few months, a truck has to come to the houses in the country and fill up the tank. Why?

b. If you said that the gas is used up or burned up, what do you mean? Does it just disappear leaving nothing behind? Use the idea of molecules to answer these questions? For instance, are there molecules in the gas tank? Is there anything other than molecules in the tank? What happens to those molecules when the gas is burned?

7. Miguel knows that people drown in water because they don't have any oxygen to breathe. But now he also learned that water is made up of oxygen and hydrogen. How can it be that a person drowns because of lack of oxygen but water is made up of partly oxygen? Can you help Miguel with this dilemma?

8. Natalie's problem is similar to Miguel's. She knows that fire needs oxygen in order to burn. She also knows that water, which is made up partly of oxygen, is used to put fires out, not to help them burn. What is going on in this world of chemistry anyway? Help!

b. Cars eventually run out of gasoline because it is chemically changed into carbon dioxide, water vapor, and other products. It does not disappear!

5. One design of an experiment would be to put a butane lighter in a flask with a balloon on top and observe what happens to the balloon as the oxygen is used—the balloon will be sucked into the flask, just as with the rusting steel wool. Another design would put a butane lighter in a vacuum chamber where the air could be sucked out; the butane lighter would stop working as the oxygen decreased.

6. a. The tank has to be filled up because the propane is reacting and forming carbon dioxide and water (and releasing heat in the process). The carbon dioxide and water vapor float off and mix with the air. The amount of gas in the tank decreases as it reacts (burns).

b. Nothing ever disappears. So it means that although the gas was no longer there, the products formed from it are still around somewhere.

7. Even though water molecules have oxygen atoms as a part of their make-up, water as a substance is not oxygen. Oxygen, as a substance, has a molecule made of two oxygen atoms combined. Humans and other animals cannot separate the oxygen atoms from the water molecules and make oxygen molecules in their lungs: this requires a chemical process, similar to the decomposition of water activity done earlier. (There is, of course, oxygen as a substance dissolved in water. This is why fish can extract oxygen from water in their gills. Fish do not change water into oxygen.)

8. Water as a substance is not any kind of mixture of oxygen and hydrogen gases. It is its own substance, totally distinct from oxygen gas or hydrogen gas. Even though the water molecule is made from oxygen atoms, water as a substance has no characteristics of the substance oxygen.

The ideas used in these last two questions have to do with the distinction between elements and compounds, which is not discussed explicitly in this unit. Here's the distinction: There are 92 naturally occurring types of atoms in our world. These 92 can make their own substance (called elements), or they can combine with each other to make zillions of other substances (called compounds). Elements are therefore made of only one kind of atom, although sometimes the molecule of an element is made from more than one of the same kind of atom. For example, the element oxygen is made from two oxygen atoms. The element carbon, in some forms, is made from 8 carbon atoms. Some elemental substances, like iron and sulfur, are crystals, or long structures of connected atoms.

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ashes. Some of the products are hazardous, in different ways. The carbon monoxide produced when gasoline, kerosene, or charcoal burn can suffocate people who burn them in closed areas. The sulfur dioxide produced from burning coal or oil can change to sulfuric acid in the air, returning to the ecosystem as acid rain. Other air pollutants come from burning fossil fuels. While burning reactions are all similar at a basic level—producing carbon dioxide and water—each has its own additional products.

Working in Groups

The activities in this unit are written to be done in small, collaborative groups, where students have distinct responsibilities for various tasks in the activities. We suggest that you assign students to groups—rather than letting students choose their own groups—to ensure diversity of thinking and action-orientations within the group. Be observant of how groups operate together, and restructure them if anyone is dominating a group or anyone is allowing others to do their work.

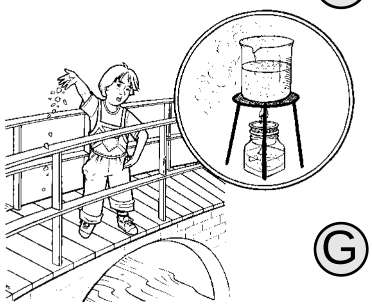
Many questions are also developed for discussion in students' small groups. These discussions are ones where students debate with each other in a collaborative effort to find solutions to problems. Students should still be responsible for writing individual answers to questions, so that those who do not contribute strongly or learn well from group discussions have opportunities to articulate their own ideas in writing.

Classroom Environment

Even though different teachers have different personalities and different approaches to helping students learn, what is common in classrooms where students are really making sense of science is student *activity*—students working, students thinking, students explaining. "Hands-on, minds-on" means that *doing* and *thinking* are linked together in developing scientific literacy.

Classrooms where students really make sense of science and learn to use its key ideas and habits of mind in their daily lives have a culture where students are continually trying things out, discussing their ideas, debating solutions to problems, being critical as well as open-minded, listening and thinking. Whether they are learning how to explain why something works, or how to describe a natural system in detail and show the connections of its parts, or how to use information to make predictions, or how to design and build a tool or a system, students have to be allowed to try out their ideas and explain their reasoning.

And teachers have to value students' thinking, both for the insight it provides to further a student's development and because it is the product of the student's honest efforts to grapple with the important questions being raised in the class. In this environment of working, thinking, and listening to others, students learn that their ideas are important and valued and that science is not authoritarian, dogmatic, and esoteric.



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Here's how scientists would explain this. The last experiment—the one with boiling water—was different from the rest because as the water boiled, steam, which is a form of water, left the beaker. As the steam left the beaker, there was less water in the beaker, so it weighed less. It's like standing on a bridge, taking something heavy out of your pocket, and throwing it over the side. You now weigh less than before. As water boils, water molecules are going into the air, thus leaving fewer water molecules behind. Therefore it weighs less than it did before boiling.

THINK AND WRITE

Now try to answer the following questions in your journal:

1. What are all substances made up of? Use as much detail as you can.
2. What must happen to the substances involved in order for the weight of the materials to increase? to decrease?
3. Using this same sort of logic, how could you explain why a newly painted car would weigh more?
4. a. Did the steel wool change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   b. Did the water and ice cube change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   c. Did the sugar and water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules.

   d. Did the boiling water change weight? Why or why not? Use molecules in your explanation. Then draw a picture that shows what is happening to the molecules in your experiment. Include bubbles in your picture and show what's in them.

F. Ask students what they know about steam. See if they know what is inside the bubbles. Many think that the bubbles contain air but they have no explanation for how the air got there. Some think there is nothing in the bubbles. Others simply have no idea of what is in them.

G. When the water heats up, bubbles form in the water. Each bubble contains some molecules of water. As the water gets hotter, the bubbles rise to the top, break and the water molecules fly off into the air.

1. All substances are made of molecules. Students have probably heard of molecules before so take a few minutes to see how their thinking about molecules relates to these substances. If students are not comfortable with the concept of molecules, take some time to discuss the concept. It is sufficient here if students understand that all substances are made up of particles and that these particles are called molecules. The concept of atoms and molecules are developed much more in Cluster 3 so there is no need to go into any detail here—especially, do NOT discuss atomic structure or formulas.

2. Some of the substance must be added to or taken away from the system—like throwing quarters out of your pocket or putting some quarters into your pocket.

3. The paint adds weight to the car.

4. a. No. The number of molecules stayed the same whether the steel wool was stretched or compacted. Nothing left the system when compacting the steel wool. Picture should depict molecules spread out and far apart, possibly lined up in strands. The compacted picture should show the molecules much closer together possibly still in strands. Be sure students show the same number of molecules for each in their pictures.

4. b. No. The number of molecules did not change as the ice melted and changed to water. They simply went into a new arrangement. The water and ice cube picture should show water molecules as random and disordered while the ice cube molecules are neat and orderly floating in the water. When melted, all the molecules should show the same randomness and disorder. Be sure that the number of molecules stays the same in the ice cube

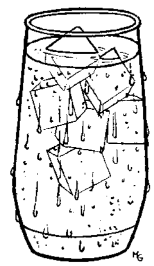
before and after melting. An important point to emphasize is that the ice and water molecules are identical. Be sure that students don't represent water molecules differently than ice molecules such as squares and circles. They should either be all square or all circles. Do not get into atomic structure here.

4. c. No. The number of molecules stays the same. When the sugar dissolves, the molecules separate and spread throughout the water molecules. The sugar should show a pile of ordered molecules as crystals of sugar (possibly square to show that they are different from water) and the water molecules (possibly round) should be random, disordered molecules in the glass. After dissolving, the sugar molecules (possibly square) should be equally dispersed into the water (round) molecules in the glass. None are lost in the process. Be sure that student drawings show no change in the number of molecules.

4. d. Yes. Bubbles filled with water molecules rise to the surface and burst, releasing some water molecules to the air. In the boiling water, as the water boils some of the molecules are leaving the beaker, spreading out and going into the air as water vapor. Since there are fewer molecules in the beaker, the water now weighs less.

5. a. All four reactions are physical changes.

5. b. Observing the changes reveals no new properties. Steel wool is still steel wool. Melted ice cubes and dissolved sugar taste the same. If you condense steam from boiling water on a spoon or lid of a pot, it is still water. Therefore, these are probably physical changes. Help students understand that observation alone is frequently not enough to tell if a change is physical or chemical.



5. a. Are these changes physical or chemical changes?

   b. How do your observations help you figure this out? Can you be sure?

   c. How do molecules help you figure this out? Why is this a problem?

6. Try these problems:

   a. Predict what would happen to the weight of a cold glass of water on a humid summer day? Explain your prediction.

   b. Predict what would happen to the weight of a car that gets very rusty over several years. Explain your prediction.

7. Can you think of any other examples of a change where weight would stay the same?

8. Can you think of any other examples of change where weight would increase or decrease?

We will use these ideas about weight change to understand more about that other kind of reaction, chemical reactions. The next lesson will give you more insight into chemical reactions as you make predictions about weight changes in some chemical reactions.

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5. c. At the molecular level, the molecules are still the same kind of molecule. But since you can't see individual molecules, this is not a practical way to detect physical changes. You need sophisticated instrumentation to figure out whether the molecules have changed or not.

6. a. It becomes very moist on the outside of the glass as it picks up water vapor from the air. It has added more matter so it will weigh more. Students have difficulty with this question. Some think that the water seeps through the glass. That doesn't make much sense to them, but they do not have a better explanation.

6. b. There are several plausible answers for this—the car gets lighter because metal rusts and falls off; the car gets heavier because the iron combines with oxygen from the air and forms a heavier molecule; there is no change in weight since rust is just the same iron discolored. Accept any reasonable explanation. Do not give answers here as this reaction is explored in lessons that follow.

7. Examples are chocolate melting, water freezing, bending metal, etc.

8. Answers will vary.

THINK AND WRITE

1. a. Does the experiment support your prediction for the open system reaction?

   b. Does the experiment support your prediction for the closed system reaction?

2. a. Try to explain what happened to cause the weight change in the open system.

   b. Try to explain what happened which prevented a change in weight in the closed system.

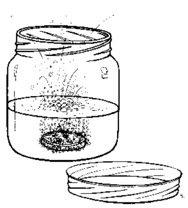
   c. Try to explain what happened when the bottle cap was opened.

3. What did you learn? Do gases have weight or not? What evidence do you have?

4. a. The reactants are ALL the substances you started with including any invisible gases, and the products are ALL the substance that were formed, including any invisible gases. Are they different in an open system than they are in a closed system?

   b. And now the big question, the one you've been trying to answer all along: How does the weight of the products compare to the weight of the reactants?

(E) Share your ideas with the class. Compare your thoughts with the thinking of the rest of the class.



Here's how scientists think about this reaction. When Alka-Seltzer reacted with water, it produced a gas which formed under the water. When trapped under water, the gas gets inside little, empty spaces or small pockets that we see as bubbles. The bubbles rise to the top of the water and break. The gas inside the bubbles flies off into the jar. If the jar does not have a cap on it (open system), then the gas leaves the jar and goes off into the air.

Would this result in a loss of weight? Is the reaction "throwing off" any quarters? You don't see anything leave the container, do you? But the evidence from your experiment is a weight loss. So something must be leaving, and whatever it is must have weight. It's the gas

1. a & b. Answers vary.

2. a. The cap was not on the bottle so the gases, which do have weight, escaped, and the system weighed less at the end than at the beginning.

   b. The cap was on the bottle so the gases, which do have weight, were trapped inside the bottle, and the system weighed the same at the end as it did at the beginning.

   c. When the cap was opened, the gases, which do have weight, escaped into the air, and the system weighed less than it did at the beginning.

3. Gases do have weight. The weight did not change when the gases were trapped inside the bottle, but when the gases were let out, the system got lighter.

4. a. No, since all substances are included whether they escaped or not, the reactants and the products always weigh the same.

   b. The weight of the products is equal to the weight of the reactants.

E. The class discussion should focus on the differences in weight when the gases are included and when they are not. Students should come to realize that often the products of a reaction are gases which are invisible. This leads many people to believe that matter is lost. The weight of the system after the reaction without the gases is actually less than the weight of the reactants, but the actual weight of the products is the same as the weight of the reactants.