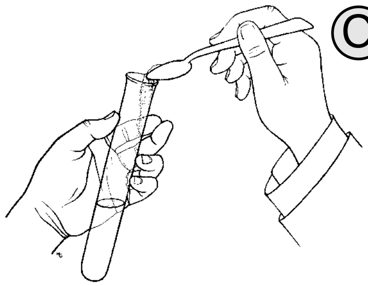
Category III Physical science examples

Providing variety of phenomena

Chemistry That Applies
A sufficient number and variety of phenomena are used to support each of the key ideas. For the idea that mass is conserved in a closed system, several phenomena are provided and are linked explicitly to the idea (the Alka-Seltzer in water reaction, the reaction between baking soda and vinegar, iron rusting, and butane burning). For example, students observe that when Alka-Seltzer is mixed with water or when baking soda reacts with vinegar in an open container, the mass decreases (lesson 7, activities 1 and 2, p. **29s**); but when Alka-Seltzer is mixed with water or when baking soda reacts with vinegar in a closed container, the mass does not change (lesson 7, pp. **29–30s**). In each case, the link is made to the Law of Conservation of Matter (Alka-Seltzer and water and baking soda and vinegar are linked on p. **34s**, question 5; rusting iron is linked on pp. **40–41s**, questions 5–7; burning butane is linked explicitly in the text, p. **43s**). In a practice task, students are asked what happens to the mass of a house when it burns to the ground, leaving behind only a pile of burned wood and ashes (p. **86s**), and the text then provides a chart that accounts for all the matter involved (p. **87s**). These same reactions and others (e.g., water decomposition, pp. 10–11s; precipitate formation, pp. 26–27s; copper chloride and aluminum reaction, pp. 78–79s) are used to support the idea that substances may combine with other substances to form new substances with different characteristic properties. The four main phenomena (water decomposing, iron rusting, butane burning, and baking soda and vinegar reacting) are repeated again in Cluster 3; and, this time, they are linked to the idea that in chemical reactions, atoms combine and recombine in various combinations but are not created or destroyed and to the idea that atoms can be used to explain the conservation of matter (in other words, if the number of atoms stays the same no matter how the atoms are rearranged, then their total mass stays the same).

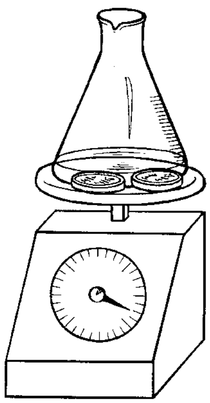


C

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.

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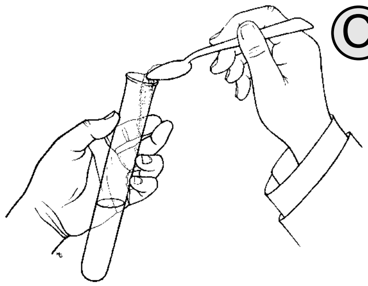

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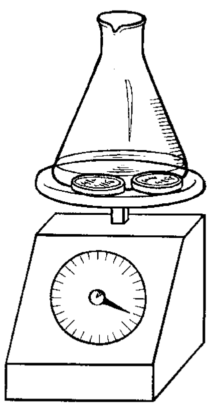

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ACTIVITY 4

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.

E 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?

F 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.

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.

from the bubbles. They leave the container and take weight away with them. So gases must have weight!

Having trouble believing that gases have weight? So do lots of other people. Many people believe that nothing is inside bubbles, and that gases have no weight because they can't be seen or touched. They think that part of the substance just disappeared during the reaction.

Here's another way to think about this: Are the gases produced in this reaction matter or energy? If they are matter, then they are made of molecules. If they are composed of molecules, then they have weight. In fact, they are molecules of carbon dioxide gas. When gases leave a container, it is really molecules leaving the container, taking their weight away with them.

So what happened when the top was left on the bottles (closed system)? Could the gas inside the bubbles float off into the air? No. This time, the gases escaped from the bubbles and got into the air inside the bottle. But with the cap on the bottle, the gases could not get out of the bottle, so no weight left the container. Nothing could leave the closed system. The weight did not change. But when the cap was released (open system), the gases flew out into the air.

And what happened to the weight? It decreased because gases, which are matter and have weight, left the bottle. It's like throwing quarters out of your pocket.

Now go back to the four reactions you did in the previous lesson and review your predictions. Discuss each prediction and reason in your group. Remember that a correct prediction depends on whether you think any matter is leaving the container.

5. For each of the four reactions, use the new information you just learned to decide whether the weight would increase, decrease, or remain the same. Give a reason for your answer.

So where does all of this bring us now? These experiments all demonstrate one of the most fundamental laws of nature—the Law of the Conservation of Matter. It states that: Matter can neither be lost nor gained. It can only be changed from one form to another.

5. Students should have no difficulty now predicting what should happen in the four reactions from the last lesson. In the first two, when bubbles formed and gases escaped, the weight of the system would be less because something (gas molecules) was let out of the system. But in the last two reactions, where you used a stopper or a balloon, the weight would be the same because now the gas molecules are trapped inside the system.

B. FOR GROUP DISCUSSION:

The steel wool reacted with something to gain weight and that something was probably oxygen from the air. The product weights more than the steel wool but it weighs the same as the steel wool and the oxygen together. It is like putting quarters into your pocket. Your new weight is the weight of you and the quarters together. In this case, the oxygen is comparable to the quarters. So the gases do not disappear—they change into a different substance which is no longer a gas. The product is black and powdery. It is iron oxide and is very similar to rust which is also iron oxide. Do not discuss formulas at this time.

1. The steel wool is very black. This looks different from normal rust.

2. The weight increased. This is surprising to most students, since they usually believe that things get lighter when they burn (e.g., wood ashes weigh less than the original wood).

3. Since its weight increased, something must have been added to it, like when you add stones to your pocket and your weight increases.

4. Either the “flame” or the gas from the Bunsen burner was involved in the reaction, or something from the air.

5. The best guess would be that oxygen from the air is used in this reaction. In fact, this is the case. Oxygen is “added” in some way to the steel wool, making it heavier. A complete explanation of this reaction is constructed in Lesson 3.

the steel wool about 10 to 15 cm from the ends of the meter stick. The steel wool should be suspended at least 8 to 10 inches below the meter stick. This will help prevent the stick from burning because of the heat from the Bunsen burner. Tape the hangers to the meter stick so they do not move during the experiment. Balance the set-up by moving the meter stick slightly to the left or right on the balance until all is level.

C. Make a prediction about how the weight might change if the steel wool is heated with a very hot Bunsen burner.

(B) D. When all is balanced, heat the steel wool very intensely for five or six minutes with the Bunsen burner. Be sure to use the hottest part of the flame—the tip of the inner cone. When the steel wool begins to glow, remove the Bunsen burner. Observe what happens. Allow the product to cool and examine it. Has it changed?

THINK AND WRITE

1. Write a description of the product in your journal.
2. What happened to the weight after the steel wool was burned? Did this surprise you? Did you expect something else?

In your group, discuss the answers to the following questions. Be prepared to share your answers with the entire class.

3. Using the analogy of throwing stones out of your pocket to lose weight or picking up stones and adding them to your pocket to gain weight, write about whether the steel wool had something added to it or something taken away from it during the chemical reaction.
4. What, besides the steel wool, do you think might be involved in the reaction?
5. Remember, this reaction is similar to that of the rusting of steel wool. The same reactants are needed, and very similar products are formed. Can you now explain what happened with the steel wool rusting under the balloon?

How would scientists explain the steel wool rusting and burning reactions? You may remember that steel wool is a form of iron. When steel wool burns, a chemical reaction occurs that is very similar to the chemical reaction of rusting. Just like a candle or a match or a piece of paper needs oxygen from the air to burn, steel wool needs oxygen from the air to rust or to burn. Candles, matches and paper wouldn't burn on the moon, and neither would steel wool rust or burn on the moon. In both cases, steel wool combines with oxygen from the air to form new substances, both of which are called iron oxide. The reddish, flaky rust is actually a new substance and the jet black, powdery substance left after burning the steel wool is also a new substance. These two new substances are very similar to each other.

6. What do you think happened to the weight of steel wool when it rusted? Explain your answer using the data you collected in the experiment with the balloon: the observation that the balloon was sucked in to the beaker (what does this mean about the air around the steel wool?).
7. Why might your little brother think that matter was created in this experiment?

Ⓒ TRY THIS

Here is the final activity of this cluster. You'll use all the new information you learned in this cluster as you predict and write your explanations of what is happening.

YOU WILL NEED

- butane lighter
- aluminum pie tin
- clay or florist's adhesive
- rubber band
- 400 ml beaker

A. Remember the butane lighter? Observe it as you light it and allow it to burn for a minute or two.

6. The weight of the steel wool in the beaker probably increased, since air seems to disappear from the beaker. The air must have attached itself in some way to the steel, making it heavier.

7. If the steel wool gets heavier, without adding anything *that is visible* to it, it might seem that new matter was created.

C. In this activity, students will try to use all the information about invisible reactants and products and their effect on weight. Usually students are somewhat puzzled about the butane reaction because invisible gases are involved both as reactants and as products. Many times, even though students see the fog collect on the inside of the beaker, they have no idea what this is or where it came from because they do not know what fog is. They may just think it is smoke but butane really burns with a clean flame if it gets enough oxygen. They may know that carbon dioxide is produced when substances burn.

Allow students to observe the reaction and try to fit the pieces of the puzzle together without help from the teacher. They should answer the questions and then compare their explanations with the scientific explanation given later.

with the oxygen in the air, and forms two new substances, water and carbon dioxide. The lighter gets lighter. Carbon dioxide is a gas. It floats off into the air. The water formed is hot so it is a gas (water vapor) and it, too, floats off into the air. If the gas hits the cool beaker, it forms a mist of tiny liquid droplets on the side of the beaker. Frequently, you can't see any products in this reaction because both products are gases and they go off into the air.

But in the closed system—when the gases are trapped inside a closed jar—the weight would not change, since the butane and oxygen gas were used to make two new substances, carbon dioxide and water vapor.

9. Review your answers to the last question and use any new information to revise or add to these answers.
10. Do you think this reaction is a physical change or a chemical change? What evidence do you have?
11. Why might your little sister think that the butane just burned up and disappeared in this reaction?
12. Write a paragraph in your journal that explains how the Law of Conservation of Matter applies to this reaction.

In the next cluster, you will see how atoms and molecules can help you understand even more about the Law of Conservation of Matter.

9. Answers vary.

10. It is probably a chemical change since new substances were produced. The properties of the products (invisible gas and water vapor) are totally different from the properties of the reactants (a clear liquid and an invisible gas from the air).

11. Because both products are gases that often are invisible to the naked eye.

12. Points to include are:
    - even through the system appears to weigh less, that is only true if you don't account for ALL of the reactants
    - when the invisible gases of the reactants are accounted for, the products weigh the same as the reactants
    - matter is conserved in all chemical reactions

about every other substance around you. It is used in the harvesting of food as well as in preparing and preserving it and transporting it to consumers.

3. Answers vary but most reactions on student lists will probably be fuels.

4. Most uses of energy on student lists will require fuels.

5. Good fuels are substances which, when burned, release a lot of heat energy.

6. Answers will vary. Most students will have questions about what energy is and where the heat energy comes from, how it formed, etc. Do not answer these questions at this time. They will be answered in the next lesson.

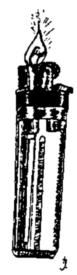
7. Some students will answer that the heat and light comes from the wood that is no longer there. Others will know that the wood (combining with oxygen) has turned into carbon dioxide and water vapor.

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

b. 8 carbon atoms, 26 oxygen atoms and 20 hydrogen atoms

c. The same number, 8 carbon atoms, 26 oxygen atoms and 20 hydrogen atoms.

5. Look at these two columns and try to decide what make a good fuel. List as many of these characteristics as you can.
6. If, as you brainstormed about and answered these questions, other questions came up about energy, write them in your journal.



A question you may have asked was, “Where does the heat and light come from when paper or butane or wood burns?” Does it come from the paper or the butane or the wood? Well, yes. But does the butane or paper turn into energy?

Here’s another way to ask the same question: When a house burns to the ground and only a pile of burned wood and ashes is left, has the weight that’s disappeared turned into heat and light?

7. Record in your journal what you think about this question at this point in the lesson.

* * * *

How can we find an answer to that question?

First, you already know that when something burns—whether it’s butane, paper, or wood—carbon dioxide and water vapor are produced, that float off into the air. Also, when wood or paper burn, sometimes smoke is produced that floats off into the air. Smoke is tiny particles of dust.

But to many people, it doesn’t seem possible that all of the weight that was in a house could float off into the air as gases or as smoke. They believe that the heat and light come from the weight of the wood or butane or paper. They believe that the weight of the wood or butane was changed into heat or light energy.

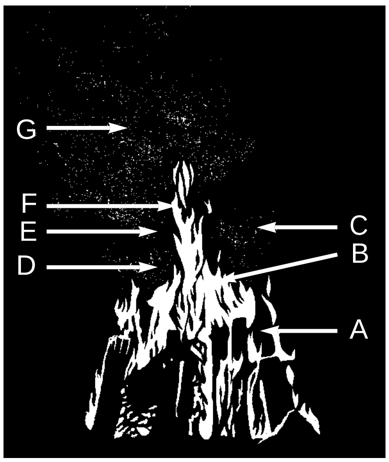
To think more deeply about this, think about the chemical equation for burning butane:

8. a. Write and balance the equation for burning butane. Refer to Cluster 3 if you need to.
   b. How many oxygen, hydrogen, and carbon atoms are present in the starting substances before the reaction takes place?
   c. How many oxygen, hydrogen, and carbon atoms are present in the ending substance after the reaction takes place?

9. Based on your answers to the above questions, what do you think:

   a. Were any atoms that make up butane or oxygen not accounted for in the molecules of the products?

   b. Was all of the weight of the original starting substances (the butane and the oxygen) accounted for by the products (carbon dioxide and water)?



   c. Could heat or light energy be composed of other atoms from the reaction that didn't make up the carbon dioxide or water?

   d. So would you say that heat or light energy has weight, or carries weight away from a fire? Explain.

   e. Using a table similar to the one below, label each "substance" with its corresponding letter from the drawing to the left. Then answer whether each is made of atoms and has weight.

   f. Does butane turn into heat or light?

	"SUBSTANCE"	LETTER FROM DRAWING	MADE OF ATOMS? (YES OR NO)	HAS WEIGHT? (YES OR NO)
REACTANTS	wood	C	Yes	Yes
	oxygen	B, E, or D	Yes	Yes
PRODUCTS	carbon dioxide	B, E, or D	Yes	Yes
	water	B, E, or D	Yes	Yes
	smoke	G	Yes	Yes
ENERGY	heat	*	No	No
	light	F	No	No

*Can't see heat, but could be anywhere around the flames

Explain your reasoning.

If butane does not turn into heat and light, then where does this energy come from? The next lesson will help you answer these questions.

9. a. No

   b. Yes

   c. No, because all the atoms were accounted for; no new matter was created, none was lost.

   d. No, since all the weight comes from the atoms, and all the atoms of the reactants are accounted for in the products.

   e. See chart for answers; oxygen, carbon dioxide and water vapor are all gases in the air and can therefore be either b, c, or d.

   f. No, the atoms of the butane molecule come apart and rearrange with atoms from the oxygen molecules to form new substances, but none of the butane turns into heat and light. The heat and light must come from somewhere else.