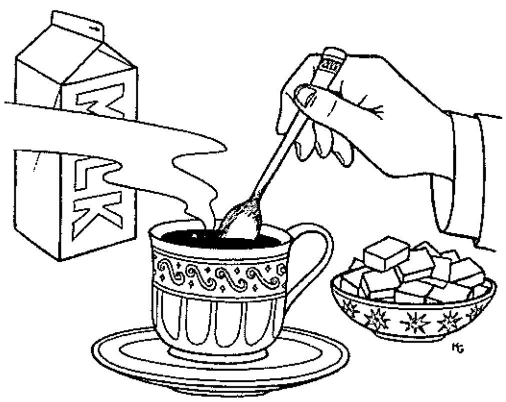
Describing Chemical Reactions

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.

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?

KEY QUESTION

What happens when some ordinary household substances are mixed?

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.

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.

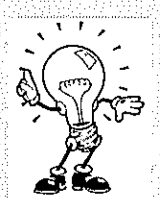
STARTING SUBSTANCES			DESCRIPTION OF WHAT HAPPENED	DESCRIPTION OF ENDING SUBSTANCES
	COMMON NAME	DESCRIPTION		
SUBSTANCE #1				
SUBSTANCE #2				
SUBSTANCE #3				

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.

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. After each demonstration you should:

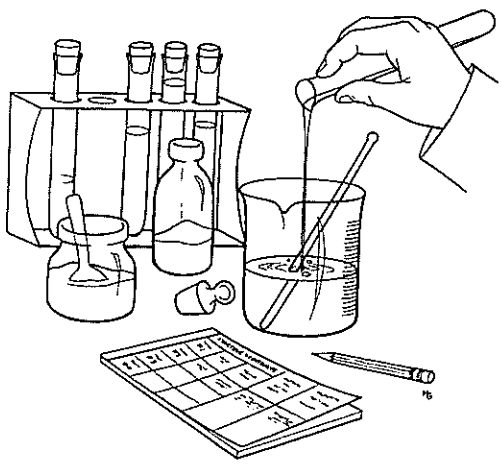
- Add the new reaction to your data chart. Use the same one you used earlier. Be sure to number each new reaction. Write a description of the starting and ending substances and what you observed happening when the substances were combined.
- Share your descriptions with the class and compare your observations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

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?

If you found it difficult to answer these questions, you are not alone. Scientists often have difficulty with these questions because sometimes, when two substances are mixed, they just move in and around each other, like mixing tea and lemon juice, or sugar and salt. At other times, when two substances are combined, a chemical reaction takes place where new substances are made that didn't exist before the mixing took place. So how can you tell which of these two things is happening? The first step in figuring this out is making good observations and writing good descriptions of what you see. In the next lesson you will get more practice at this.



Lesson 2: IS IT A NEW SUBSTANCE?

Now that you have observed and described a variety of common household substances that were mixed, you are ready to try describing some other reactions that occur around you everyday and see if new substances are formed.

KEY QUESTION

What happens when baking soda and vinegar are mixed, when water decomposes and when things burn or rust? What kind of observations and evidence indicate whether or not new substances are or are not being formed?

In this activity you will perform four reactions that involve solids, liquids, and gases. You will observe and describe each reaction and try to decide if new substances are formed. To know this, you must be able to describe accurately and completely both the beginning and the ending substances.

In order to help you write good descriptions, the class should brainstorm to make a list of terms that can be used to describe substances. Be sure to include words that describe solids, liquids and gases. Your teacher may appoint a student to write the list on the blackboard or on an overhead projector so that you can refer to the lists often as you make your observations and write your descriptions. For each description you write, you should use at least three descriptive terms. Of course, you may use more than three. You may use terms you think up yourself or you may refer to the list for help.

TRY THIS

Prepare a data chart similar to the one you prepared in Lesson 1. 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. You should save your charts so you can refer to them again in Cluster 3.

REACTION 1

RUSTING IRON

YOU WILL NEED

- A small wad of steel wool
- 100 ml beaker
- 25-30 ml of vinegar
- paper towel

DO, OBSERVE, AND RECORD:

A. Write the common name for each starting substance in the appropriate space on your data chart.

B. Observe the small wad of steel wool and write as complete a description as you can in the appropriate space on your data chart. Remember, you should use a minimum of three descriptive words to describe the steel wool. Refer to the list on the board if necessary.

C. Place the steel wool in a beaker. Pour enough vinegar over the steel wool to cover it. Swirl the steel wool and vinegar making sure that the vinegar has come in contact with all the steel wool. The vinegar will remove an oily protective coating from the steel wool and leave the thin strands of steel wool.

D. Remove the steel wool from the beaker and blot it very dry with paper towels.

E. Loosen the strands by pulling them apart. Observe the steel wool for a few minutes. Then, put it aside and continue with the next reaction, but observe the steel wool every 5 to 10 minutes while you continue with the following activities.

F. Record your final observations of what happened on your data sheet.

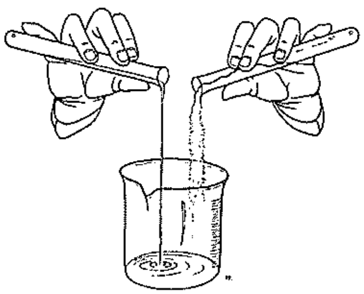
G. In the appropriate space, write the common name of the ending substance if you recognize it. Then describe the substance as completely as you can. Remember to use at least three descriptive words.

H. Was anything needed for this reaction besides steel wool? If you think it was, you may want to add it to your data chart under beginning substances and write a description of it.

I. Share your observations and descriptions with the other members of your group and change or add to your descriptions if you wish.

REACTION 2

BAKING SODA & VINEGAR



YOU WILL NEED

- small vials or test tube containing about 1 tsp. of baking soda
- test tube full of vinegar (about 25 ml)
- 100 ml beaker

DO, OBSERVE, AND RECORD:

A. Fill in the common name of each starting substance.

B. Observe each of these substances very carefully and write descriptions of each in the proper place on your data chart. Use at lease three descriptive words for each substance. Refer to the lists on the board if necessary.

C. Combine the baking soda and vinegar in a beaker and observe the reaction.

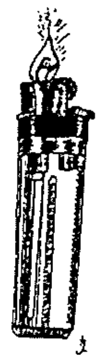
D. Record your observations of what happened in the appropriate space on your data chart. Be as complete as possible. Use at least three good, descriptive words.

E. If you think you can identify any ending substances, write good descriptions of them on your data chart. Use at least three descriptive words.

F. Discuss and compare your observations with those of other members of your group and make any changes or additions you want on your data sheet.

REACTION 3

BUTANE LIGHTER



YOU WILL NEED

- a clear plastic butane lighter
- balance

DO, OBSERVE, AND RECORD:

A. Record the common name of the starting substance that is inside the butane lighter in the appropriate space. Does the kind of lighter help you figure out what the starting substance is?

B. Are there any other starting substances? (Hint: Can a fire burn without air? What is in air that a fire needs? Is this a starting substance?)

C. Observe the fuel in the lighter and write a complete description (prior to lighting it) in the proper place on your data chart.

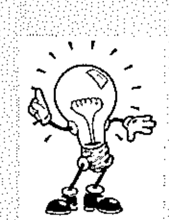
D. Write a description of the other starting substance.

E. Ignite the lighter and observe the flame.

F. Weigh the lighter. Then light it and let it burn for a few minutes. While it is burning, write a description of what you observe to be happening while the butane burns. Weigh it again and write a note about whether the lighter lost or gained weight or stayed the same.

G. If you can identify any ending substances, write complete descriptions of them in the appropriate spaces on your data sheet.

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

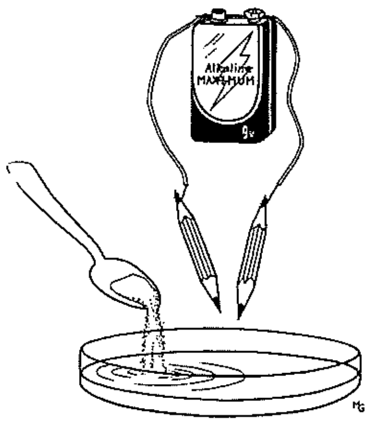


SAFETY!

If you have long hair, you should tie it back to avoid flames.

REACTION 4

DECOMPOSITION OF WATER



YOU WILL NEED

- 9 volt battery
- 2–12" pieces of telephone wire or wire with alligator clips on each end
- 1 petri dish
- 2–pencils sharpened at each end with 1/4" to 1/2" of pencil lead exposed at each end
- water
- 2 or 3 pinches of table salt

DO, OBSERVE, AND RECORD:

A. Write the name of the starting substance in the appropriate space on your data sheet.

B. Observe this substance and write as complete a description of it as you can. Be sure to use at least three descriptive words.

C. Attach one end of the wire to the pencil lead (not the wood) at one end of a pencil.

D. Similarly, attach one end of the other wire to the pencil lead at one end of the other pencil.

E. Fill the petri dish about half full with water. Be sure there is enough water to cover the bottom of the dish. Add about three pinches of salt to the water and stir it with your finger. (The salt just dissolves in the water but does not react. The salt is necessary for the reaction to occur. All the salt is still left after this reaction and it didn't change in any way. It just helps the water conduct electricity better.)

F. Connect the other ends of each of the two wires to one of the two terminals of the 9-volt battery.

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.

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!

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?

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.

Lesson 3: RESEARCHING A COMMON SUBSTANCE

Every day we come into contact with substances that affect our personal lives. Most of us take them for granted, or know little about them other than their common name. One example is cholesterol; another is plastic. Other examples include aspirin, glass, nylon, gasoline, Tylenol, whiskey, beer, baking soda, fertilizer, baking powder, marijuana, sugar, cigarettes, and cornstarch. The list is a long one, but most people have limited knowledge about the items on it. If we examined these common substances, we would discover that a better understanding of them would improve our health, assist in cleaning up our environment, and upgrade our standard of living.

In this lesson, you will begin research of a common everyday substance that is of interest to you. You will begin by identifying its common and chemical names and by describing its appearance and any other physical properties. Later on in the unit, you'll continue your investigation and find out much more new information about your substance.

RESEARCH QUESTION

What substance are you going to research? What other names does it have? What are its physical properties?

TRY THIS

1. Your teacher will provide you with a list of substances. Select a substance of interest to you.
2. Using the sources of information provided by your teacher (or any at your own disposal), research your substance to determine the following:
   a. the chemical name, and any other name it goes by.
   b. a complete description of the substance.

That's all you need to find right now. In future lessons, you will continue your research with the following questions which are related to future clusters:

- What it is used for, present and past.
- Any special importance to various cultures or ethnic groups.
- The history of its discovery and development.
- How it is produced and disposed of.
- How energy and "boosters" are involved in its production and disposal.

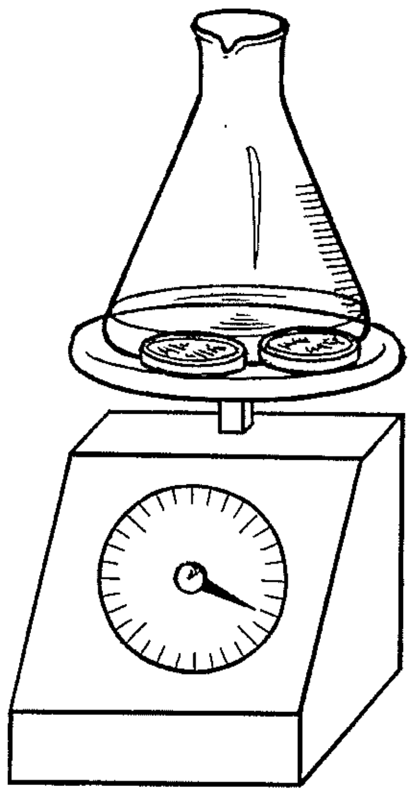
For each reference book or other source of information you use, include this information about your sources:

- Title of source
- Author
- Copyright date
- Publishing company
- Pages on which the information is found

Record these findings in your notebook or science journal. You may prefer to keep your research notes on 5 x 8 cards with references at the top. Scientists often do this in order to help organize their information. Then, when they are preparing their report, they can shuffle the cards and put them in the order they want to use them when they write their report.

Scientists attempt to keep clear and concise records of their work and findings because they realize the importance of checking, verifying, and understanding what has happened over a period of time. It is important that you keep clear and concise records of the subject you are investigating. You will continue to investigate this same substance throughout the entire unit. In fact, by the end of the unit, you will be an expert on your substance, and you will prepare a presentation about your substance to share with others in your class or your school. More about this later in this unit!

Weight Changes in Chemical Reactions



Lesson 4: DOES THE WEIGHT CHANGE?

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

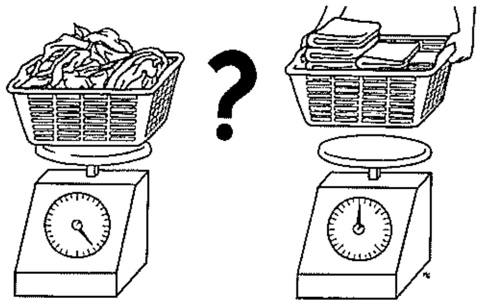
In Cluster 1, you observed many changes and wrote detailed descriptions of the starting and the ending substances. In some of these changes, only the size, shape, the space it occupied or temperature of the material changed while the material itself stayed the same. But in other changes you observed,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

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

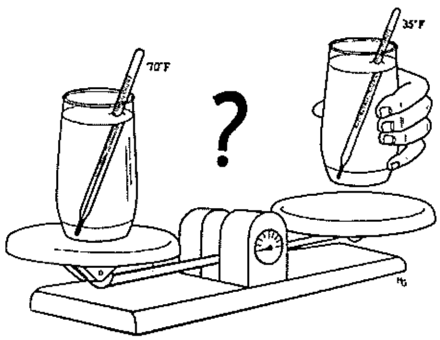
Which of the changes above are ones where the material itself actually changes into a new substance? Can you name other changes like this?

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

What do you think?

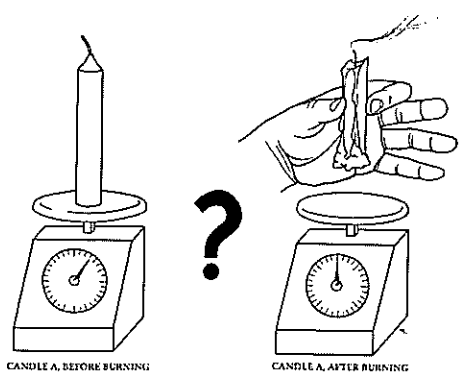


- Would a basket of mixed-up, rumpled clothes weigh more, less, or the same after they are folded? Why?



- Would a glass of water at 70°F weigh more, less or the same after it is cooled to 35°F? Why?

- Would a car weigh more, less, or the same if painted a new color? Why?



- Would a candle weigh more, less, or the same after burning for awhile? Why?

KEY QUESTION

Are there types of changes where you wouldn't expect the weight to change, and other types of changes where the weight may change?

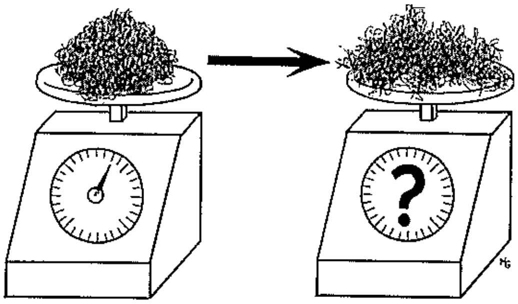
In this lesson, we will look at changes that scientists call physical changes—where only the size, shape, volume or temperature change, but not the material itself—and make predictions about how weight may change. For example, if you were standing on a bridge and took a quarter out of your pocket and threw it off the bridge, would your weight change? If you were standing outside in the rain, and your clothes changed from dry to soaking wet, would your weight (with the clothes on) change?

Making predictions and then writing the reasons behind your predictions is a very important aspect of doing science. Without reasons, predictions are really only wild guesses, but when reasons are given, scientists can share their thinking with others and devise experiments to test their predictions. If their predictions turn out to be correct, then scientists have faith in their reasons and believe them to be true. In the following activities, you will be practicing science as you explore how weight changes.

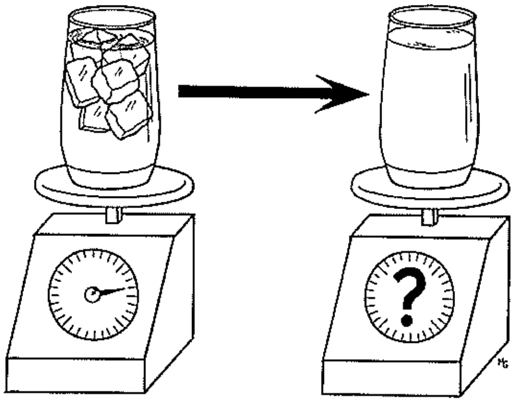
TRY THIS

Your teacher will perform four demonstrations. Pay close attention to what is happening and then predict whether you believe the weight increased, decreased or stayed the same. Then give reasons for your predictions. Use a chart similar to the one below.

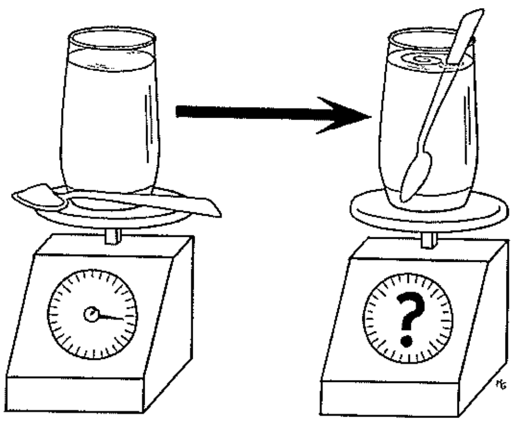
DEMO #	PREDICTION	EXPLANATION
1		
2		
3		
4		



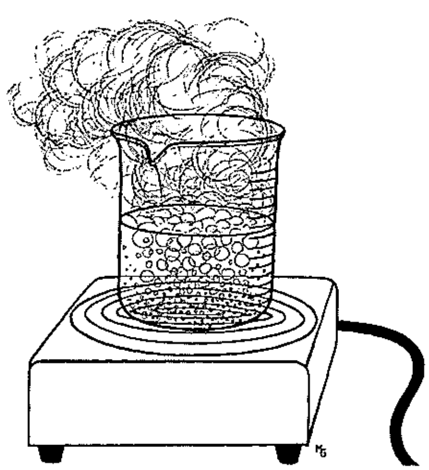
DEMONSTRATION 1: Which weights more, a tightly wadded ball of steel wool or the same steel wool stretched and pulled apart?



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?

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.
- 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.
- 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.

Lesson 5: GATHERING EVIDENCE ABOUT WEIGHT FROM EXPERIMENTS

How can we test the predictions you made in the last lesson?

Did someone say "By actually weighing the materials?" Sure. In this lesson, you will perform the same activities that your teacher demonstrated. You will use a balance or scale to actually weigh the substances and then compare these results to your predictions.

KEY QUESTION

How do your predictions compare to the actual changes in weights of the substances?

TRY THIS

You should work in groups. Here's how you might go about conducting these experiments:

- Begin by planning, as a group, how to conduct each 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 these possible inaccuracies.
- Conduct the experiment, making measurements that are as accurate as possible. Record your measurements in the spaces you provided on your data sheet.

Here are the experiments again:

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

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:

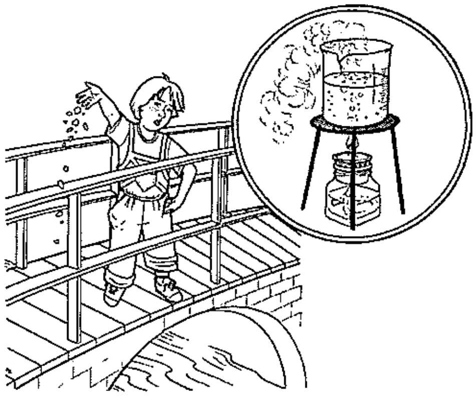
- Whether your results helped to prove or disprove your predictions.
- If your group still believes in the reasons you gave for your prediction.

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

- 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:

- In which of the experiments did the weight decrease significantly?
- What was different about that experiment from the others where there was no weight change?



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

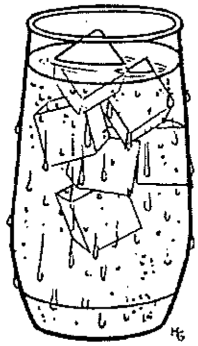
Now try to answer the following questions in your journal:

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.



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.

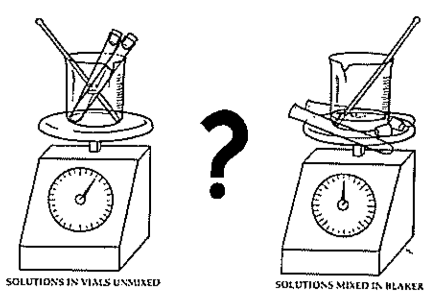
Lesson 6: DOES THE WEIGHT CHANGE IN CHEMICAL REACTIONS?

Chemical reactions are a little more mysterious than physical changes (some would say a lot more mysterious). When you mixed baking soda and vinegar together, what kind of change was that? Was it a change in shape, size or temperature? Not really. It was a change that produced bubbles, among other things. Where did the bubbles come from? They contained a new substance that was formed during the reaction which was different from the baking soda and vinegar that you started with. In this lesson you will look at an interesting chemical reaction and ask the same questions about weight as in the last lesson.

KEY QUESTION

How can you predict if the weight of a substance will change during a chemical reaction?

Unlike physical changes where the substances and the molecules that make them up do not change, chemical changes actually produce new substances with new molecules. The important question for this unit is when is a change a chemical reaction that produces new substances, and when is it a physical change?



In this lesson, you will examine two liquids before and after they are mixed together, to determine if new substances are formed. You will also check the weight of the liquids before and after to find out what happens to the weight.

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.

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.

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.

- Check your plan with your teacher before starting.

F. Conduct the experiment, making measurements that are as accurate as possible. Record your measurements in your journal.

G. Discuss as a group whether your results help prove or disprove your predictions. Also discuss whether there were any substances that left the reaction or that were added to the reaction.

THINK AND WRITE

After the experiment, answer the following questions:

1. a. How were the ending substances different from the starting substances?

   b. Does this indicate that the change was a physical change or a chemical change? Explain your reasoning.

2. a. Did the weight change during this experiment? If so, how?

   b. How can you explain these results? Think about whether any substances entered or left the beaker during the reaction.

You'll continue your investigation of whether the weight changes during chemical changes in the next lesson.

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

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

KEY QUESTION

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

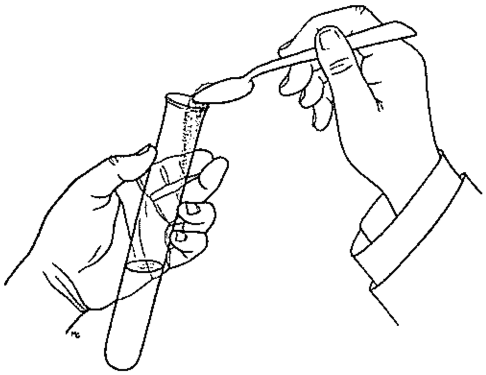
You have observed both of the following reactions (vinegar with baking soda and Alka-Seltzer with water) many times before, but have you ever taken the time to observe what is really happening? Have you ever thought about or wondered what's in the bubbles? And what happens to the weight after the reaction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

TRY THIS

YOU WILL NEED

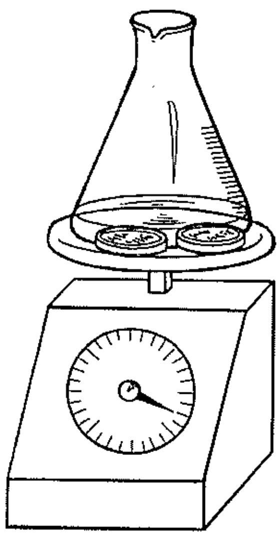
- test tube about 1/3 filled with vinegar fitted with a stopper
- about 1/2 teaspoon of baking soda
- 250 ml Erlenmeyer flask and balloon that fits over the neck of the flask
- Alka-Seltzer tablets

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.

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.

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.

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

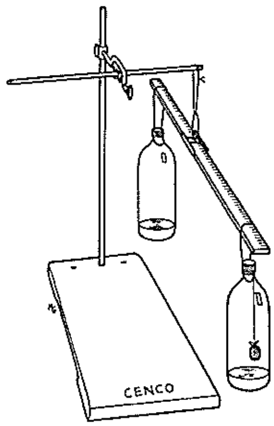
Do gases have weight? How can you find out? How does the weight of the starting substances compare to the weight of the ending substances when gases are formed and given off in a reaction?

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. This demonstration is done first as an "open system"—that is, the cap is left off the bottles. The Alka-Seltzer is fizzing in a open bottle. Write your prediction about weight change—increase, decrease, or remain the same—for this reaction. Also, be sure to write a reason for your prediction.

B. Your teacher will prepare the apparatus for a class demonstration. When all is ready, balance the set-up by moving the meter stick slightly to the left or right on the balance until all is level. When all is balanced and the reaction is to begin, tip the bottle slightly so that the Alka-Seltzer is dropped into the water. You may need a student assistant to support the other bottle as you tip it. Observe and notice any change in the position of the bottles as the reaction proceeds. Any change in weight will show up as the meter stick tipping to one end, just like a see-saw tips to the heavier end.

C. Does the experiment support your prediction? Any new thoughts about what happened to weight? Share your ideas with your group.

Now you teacher will repeat the demonstration as a "closed system." When there's a top on a jar, so that nothing can get in or out, it is called a "closed system." The Alka-Seltzer will be fizzing in a closed jar.

D. Write your prediction about weight change—increase, decrease, or remain the same—for this demonstration and the reason for your prediction.

Are you ready for this one?

E. Prepare the apparatus as described above, but this time screw the caps on the bottles very securely. When all is balanced, tip the bottle with the Alka-Seltzer to start the reaction. Observe the reaction and watch the meter sticks as the reaction proceeds.

F. What do you think will happen to the weight when the caps are released? Write your prediction and the reason for your prediction.

G. Now, open, but do not remove, the cap of the bottle with the Alka-Seltzer. Watch what happens?

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.

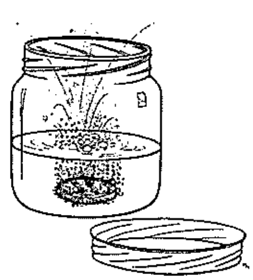
   c. Try to explain what happened when the bottle cap was opened.

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?

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 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.

6. Write a paragraph in your journal telling how this law can explain the result of the demonstration you observed today.
7. For all reactions involving physical or chemical changes, how does the weight of the products formed compare to the weight of the reactants you started with? Remember that the reactants are ALL the substances you started with including any invisible gases and the products are ALL the substances that were formed, including any invisible gases. Write the answer in your journal.
8. A newspaper headline recently read: "Young chemist discovers substance that continually loses weight." Use your scientific knowledge to write a letter to the newspaper editor refuting the article.

In the next lesson you will explore another variation on this law.

Lesson 9: RUSTING METAL AND THE DEFLATING BALLOON

You learned in the last two lessons that chemical reactions sometimes produce invisible gases. The gases often make bubbles if they are produced inside a liquid. When the bubbles pop, the gases fly off into the atmosphere.

KEY QUESTION

Can invisible substances like oxygen and other gases be involved in chemical reactions in any other way (not just as products)?

TRY THIS

Here is an activity to start you thinking about these questions.

YOU WILL NEED

- steel wool
- beaker with vinegar for cleaning the steel wool
- paper towel
- 250 ml Erlenmeyer flask and balloon to attach securely to the top

A. Obtain a piece of steel wool that will form a ball about the size of a ping-pong ball. Dip it in vinegar very briefly just to clean off the protective coating. Dry it very thoroughly by pressing it between several layers of paper towel.

B. Pull the strands apart to loosen them and then drop the steel wool into a clean, 250 ml Erlenmeyer flask.

C. Squeeze all the air out of a balloon and then stretch this deflated balloon over the top of the Erlenmeyer flask.

D. Observe for a few minutes and then set it aside while you discuss the following question.

- What are some very important properties of gases in addition to the fact that they are usually invisible? Refer back to the last lesson if you need help on this answer.

E. Now observe the reaction again.

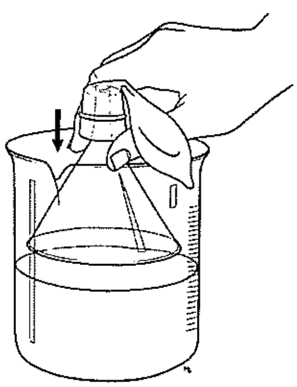
- What happened to the balloon in this experiment?
- What is this evidence for?

TRY THIS

If you are having trouble with this last question, the next activity will help you.

YOU WILL NEED

- funnel
- a balloon that will attach securely to the small end of the funnel—if necessary, fit a rubber stopper over the stem of the funnel to attach the balloon
- beaker



A. Obtain a funnel and a beaker half filled with water, such that the large end of the funnel will fit into it. Lower the funnel gradually into the beaker all the way to the bottom. Does water enter the funnel? Why or why not?

B. Now repeat the process, but this time hold your finger over the small end of the funnel and immerse it into the beaker of water. Lower it gradually all the way to the bottom. Does water enter the funnel? Why or why not? Now, with the funnel at the bottom of the beaker, remove your finger and observe what happens. Try this several more times by placing your finger over the end of the funnel when it is only partly immersed and see what happens.

C. Place a balloon tightly over the small end of the funnel by first squeezing all the air out of the balloon and then pulling it over the end of the funnel. Be careful not to rip the balloon. You may need to insert the funnel through a rubber stopper so that the balloon can fit securely. Your teacher will do this for you or tell you how to do it. Place the large end of the funnel in the water. Lower it gradually. What happens?

D. Squeeze the balloon slowly but firmly and see what happens. What is causing this to happen?

THINK AND WRITE

1. What invisible substance was in the funnel when you first placed it in the water?
2. a. When you placed your finger over the end of the funnel and pushed it into the water, no water entered the funnel. How would you explain this?

   b. How would you explain what happened when you removed your finger from the funnel and water rushed in?
3. a. Why did the balloon inflate?

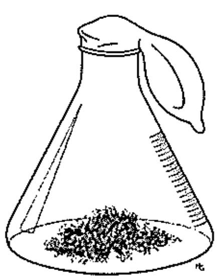
   b. How can you explain your observations when you squeezed on the balloon?

This is a demonstration about air. It can push on water. Water can push on it. If you get some pop in a straw and blow on the straw, the pop flies across the room. The air in your mouth pushed on the air in the straw, which pushed on the pop.

Air is a substance. You can't see it, but is pushes on things.

4. If you put a straw into a plastic bag filled with air, and started to suck the air out, what would happen to the plastic bag? Why?

Now look at your steel wool experiment.



5. How can you explain why the balloon was sucked into the flask when the steel wool rusted.

Did the air in the flask just disappear? Did it leak out? What happened to it?

Could it have been used in some way when the steel wool rusted?

This is the big question for the next lesson.

SAVE YOUR FLASK WITH THE STEEL WOOL REACTION FOR THE NEXT LESSON.

Lesson 10: DOES RUSTING NEED AIR?

What happened to make the balloon get sucked into the beaker?

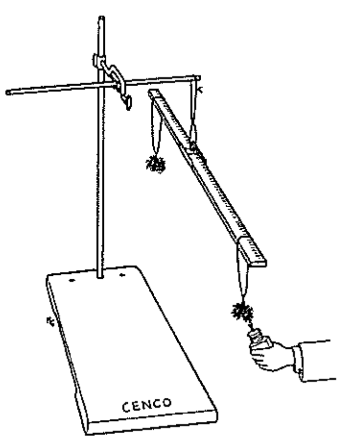
Here is an activity that will help you figure out what happens with air and rusting. You will start by making a prediction.

TRY THIS

A. Observe the flask with the steel wool reaction you saved from the last lesson. Make a prediction about what happened to the weight of the steel wool—increase, decrease or remain the same. Write your prediction and the reasons why you think this in your journal.

Once again, verifying your prediction is very tricky because—if there were any gases involved in the reaction—the weight of gases is very small. A very sensitive balance made with a big meter stick, similar to the one used earlier, will work again to test your prediction, but the procedure for reacting the steel wool must be changed slightly to make the steel wool react more, and therefore have a bigger change in weight that can be measured.

This time the steel wool will be burned intensely with a Bunsen burner to cause a reaction that is very similar to rusting, only faster and more intense. More about that after you observe the reaction.



B. Your teacher will once again prepare a demonstration using a meter stick balance similar to the one used in Lesson 8. Set up the balance as before and wrap the ends of the meter stick with aluminum foil to prevent them from burning. Obtain 2 large pieces of steel wool, enough so that when compacted and rolled into a ball, they are about the size of a ping-pong ball. Attach each of them to a piece of wire. Once again, a piece of a coat hanger works well with a loop at one end to hold the steel wool and a hook at the other end to hang over the meter stick. Suspend 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.

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?

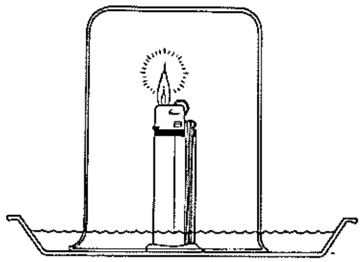
TRY THIS

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.



B. Place a rubber band around the butane lighter in such a way that it can hold the fluid release open, but don't open the release yet.

C. Secure the butane lighter to the bottom of an aluminum pie tin using a piece of clay or florist's adhesive.

D. Fill the pan at least half full with water.

E. Secure the rubber band in such a way that the fluid release is open and then quickly light the lighter.

F. Place a beaker over the lighter and immerse it in the water, making sure that the lip of the beaker stays entirely under water.

G. Observe what happens to the water and to the flame. You may need to repeat this several times to really see what is happening.

H. IMPORTANT: Release the rubber band from the lighter immediately.

8. a. Was any invisible gas involved in this reaction? What evidence do you have?

   b. What do you think the products were in this reaction? (Hint: What collected on the inside of the beaker? What else forms when fuel burns?)

   c. Suppose you placed a lighter on a balance and let it burn for five minutes. Predict what would happen to the weight of the lighter. Explain why you think this.

   d. Suppose you could collect just the products that form in this reaction. How would the weight of these products compare to the weight of the butane that burned? Explain why you think this.

   e. Predict what would happen to the weight of the system if you placed a lighter inside a closed jar and then placed the jar and burning lighter on a balance? Explain why you think this.

Here is how scientists would explain this reaction. Read the explanation and compare it to your explanations. Does the butane just "burn up"? No! It can't just disappear. Nothing disappears. It changes, though, into new substances. When butane burns, it combines 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.

Lesson 11: RESEARCH CONTINUED!

You may recall from cluster one that you selected a substance to research. You determined its common name and chemical make-up and started making notes in your journal or on separate cards in preparation for a scientific presentation at the end of the unit. Since that time, you have learned a great deal more about chemical substances and reactions, so you are now in a position to continue the investigation of your chemical substance.

WHAT YOU'VE ALREADY LEARNED ABOUT YOUR SUBSTANCE:

- the chemical name and any other name it goes by;
- a description of the substance.

HERE'S WHAT YOU SHOULD INVESTIGATE NOW:

A. What is this substance used for. Describe all the uses you can find from anywhere in the world.

B. Is this substance of any particular importance to any special culture or ethnic group. If yes, describe how and why.

C. Did the substance have any different uses in the past? If yes, describe them.

D. Give a history of its discovery and development. What person(s) was (were) involved?

HERE'S WHAT YOU'LL LEARN ABOUT IN LATER CLUSTERS:

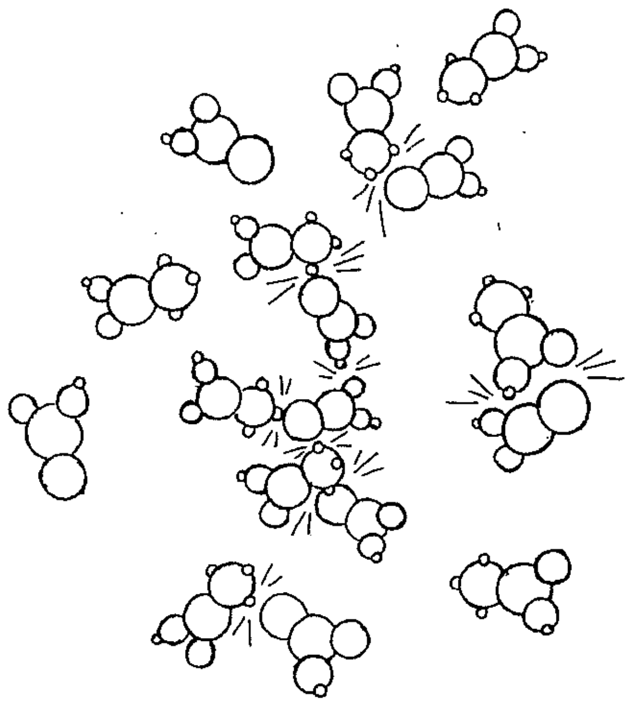
- how it is produced and disposed of;
- how energy is involved in its production and disposal.

As in Cluster 1, you should include this information for each reference book or other source of information you use,

- Title of source
- Author
- Copyright date
- Publishing company
- Pages on which the information is found

Record these findings in your notebook or science journal or on 5 x 8 cards as you did earlier. You may be able to use some of your former references again for this new information. In such cases, you may use a new card or you can add new information to the card you used earlier.

Molecules and Atoms



Lesson 12: WHAT MAKES ONE SUBSTANCE DIFFERENT FROM ANOTHER?

In Cluster 1, you observed reactions of some common, everyday substances. You made careful observations and wrote descriptions of the starting substances. That part was fairly easy. But when you described the ending substances and examined them to see if these substances were different from the original ones, it wasn't always easy to tell.

One reason for this is that many substances look alike. For example, vinegar and water look alike. They are both clear liquids. If you pour them, they both run out of the container about the same, that is, neither of them runs out of the container like syrup or oil would. Another reason it's hard to identify substances is that most people are familiar with only a few common substances out of millions of possibilities.

KEY QUESTION

What makes substances different even though sometimes they may look alike?

Think about this last question for a minute. What are some differences between vinegar and water? What are some differences between baking soda and sugar? Between hydrogen gas and oxygen gas?

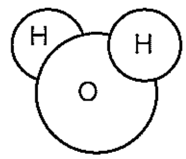
??????

The basic difference between substances, one that chemists have figured out over the last several centuries, is that *different substances are made up of different kinds of molecules.*

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.

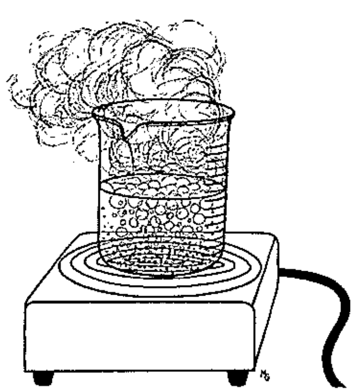
Oxygen is made up of still another kind of molecule.

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 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?

? ? ? ? ? ?

Every pure substance has its own special kind of molecule, different from the molecules of all other substances.

How might a vinegar molecule be *different* from a water molecule? How might a salt molecule be *different* from a sugar molecule? Brainstorm answers to these questions, and write them on the board. Then work through the following questions. They help explain how there can be so many different kinds of molecules in the world.

6. a. Think of all the letters of the alphabet. How many letters are there?

   b. What can you *build* out of letters?

   c. How many words can you build from the 26 letters of the alphabet?

   d. Where could you find a complete list of all these words?

   e. Are new words ever added to these lists?

LETTERS MAKE WORDS

ESNESNON EKAM OSLA SRETTEL

7. a. Do all combinations of letters make words?

   b. Does it make a difference what order the letters are in?

   c. Does it make a difference if you add or take letters away?

   d. Think of an example that will illustrate each of these last 3 questions.

So how do letters and words help us understand molecules? Well, it's like nature has a construction set too, only nature's set is made up of 92 different kinds of pieces called **atoms.**

ATOMS

Nature uses atoms as pieces to build hundreds of thousands of different substances—much like the 26 letters of the alphabet are used to build hundreds of thousands of different words. Many of these atoms are familiar to you. Others have very strange names. The chart lists the most common atoms.

The most common chemical "building blocks"	Its chemical symbol and normal state	
Oxygen	O	gas
Hydrogen	H	gas
Nitrogen	N	gas
Chlorine	Cl	gas
Fluorine	F	gas
Carbon	C	solid
Silicon	Si	solid
Sulfer	S	solid
Iron	Fe	metal
Aluminum	Al	metal
Zinc	Zn	metal
Mercury	Hg	metal
Silver	Ag	metal
Gold	Au	metal
Tin	Sn	metal
Sodium	Na	metal
Lead	Pb	metal
Nickel	Ni	metal
Platinum	Pt	metal
Calcium	Ca	metal
Chromium	Cr	metal
Copper	Cu	metal
Iodine	I	solid
Arsenic	As	solid

Think about how letters make words and use this information to answer the following questions.

8. How can all the different materials of the earth be made from only about 20 building blocks?
9. Where do you think you could find a complete list of all the different kinds of molecules?
10. Do all combinations of atoms make real molecules?
11. Does it make a difference what order the atoms are in when they form molecules?
12. Would it make a difference if you add atoms to a molecule or take them away?

Like with words, where not all combinations of letters make a real word, not all combinations of atoms make real molecules. When atoms join together to form molecules, they must fit together, much like particular legs fit on certain chairs. Not all legs fit on all chairs; you must get the right leg to fit a given chair. In the same way, you must have the right atoms to fit together to make a certain molecule.

You may have noticed that we are using a lot of models to talk about atoms and molecules. Why? Because atoms and molecules are so small that we cannot see them even under the most powerful microscope. So scientists use things we can see to help them understand how the things that we cannot see work. No model is ever perfect, so when using models it is important to think about how the model is similar to and how it is different from what it represents. Now it's your turn to be a scientist and think of a good model for atoms and molecules.

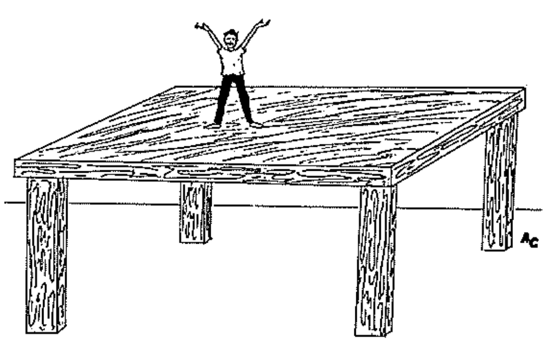
TRY THIS

A. Consider bricks as a model for how atoms make molecules. List three things that can be built from bricks.

B. Use the chart below to think about ways that objects made from bricks are like molecules, and ways that they are different.

Bricks	**Molecules**
A house is made out of smaller pieces called bricks.	Molecules are made out of smaller pieces called __________.
Bricks can be used to make many different objects, including__________.	Atoms can be used to make many different molecules, including __________.
A house is made of only one kind of building block (the brick.)	Most molecules are made of: a) only one kind of atom, or b) different kinds of atoms.
If someone adds bricks to the house (to build an addition) it is not the same house as it was before.	If somehow one or more atoms is added to a molecule, it is: a) just a larger molecule of the same substance, or b) a totally new and different molecule making a new substance.

13. Write a list of at least ten things in your classroom that are made of molecules.
14. Write a list of at least ten things in your classroom that are made of atoms.
15. What's the difference in these two lists? What's the similarity? Explain.



16. a. Pretend you are standing on your desk and somehow you are shrunk so small that you were the size of molecules. Draw a picture of what you think you would see as you looked around your desk top.

    b. Present your drawing to your group and explain it. Allow each other group member to ask questions to clarify what you say, and let them comment on your drawing.

Did your drawing include molecules? What kind of molecules were they? Were they all the same kind?

Did your drawing indicate that the molecules were built up of atoms? If yes, how many atoms did you have for each molecule—the same number for each, or different?

17. Is there anything between the molecules in your drawing? What?
18. Is sand made of molecules? Is each sand grain a molecules? Why do you think what you said?
19. Is clay made of molecules? Why do you say that?
20. a. Is soup made of molecules?

    b. How could you explain how soup is made of molecules? Fill in the blanks below, putting the following parts in their right order:

    a. broth, vegetables, rice, maybe meat

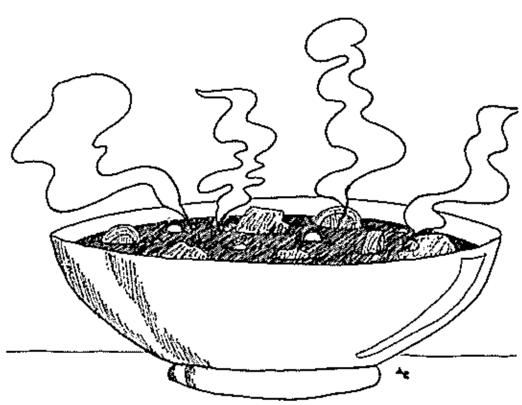
    b. proteins, and proteins are molecules

    c. cell parts, like a nucleus, mitochondria, cytoplasm

    d. animal and plant cells

Soup is made of

1. __________ … which are made of:
2. __________ … which are made of:
3. __________ … which are made of:
4. __________ … and molecules are made of:
5. __________



In the next several lessons, you will build models of the substances involved in some of the reactions you have done.

Lesson 13: ATOMS IN EQUALS ATOMS OUT: Decomposing Water

In Cluster 1, you observed some chemical reactions of common substances and wrote descriptions of what you observed. Then in Cluster 2, you learned one of the most basic laws of nature, the Law of Conservation of Matter. Take a few moments to think about what this law means and share your ideas with the class.

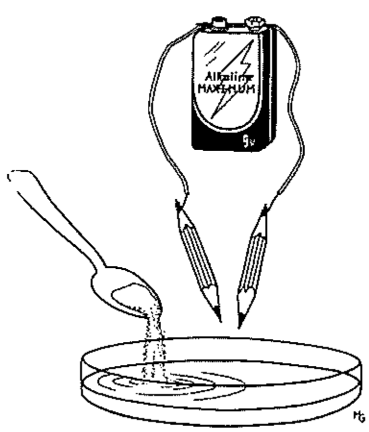
In the first lesson of this cluster, you learned how atoms combine to form molecules. Now you will see how atoms and molecules can explain both the formation of new substances and the Law of Conservation of Matter.

KEY QUESTION

How can atoms and molecules be used to explain the formation of new substances? How can they be used to explain the Law of Conservation of Matter?

In an earlier lesson, you used a battery to make bubbles appear under water. The water level went down as the bubbles were formed.

How can atoms and molecules be used to explain the formation of bubbles from water?



TRY THIS

SAFETY!

If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

Use a data chart like the one below:

A. Write the common name of the reactant (the starting substance) on your data chart in the appropriate space.

B. You probably know the chemical formula for water. Write it on your chart.

The formula for any substance is the shorthand way that chemists use to show the kind and number of atoms that are needed to make a molecule of that substance. Can you figure out what the formula for water means? The H stands for hydrogen, and there are 2 atoms of hydrogen in a molecule of water. The O stands for oxygen, and since there are no numbers beside it, there is only 1 atom of oxygen in the water molecule.

	REACTANTS	PRODUCTS
COMMON NAMES	WATER	
FORMULA		
PICTURE OF MODEL		
PICTURES OF MODELS FOR THE REACTION		
ACCOUNTING FOR ATOMS	Number of oxygen atoms: Number of hydrogen atoms:	Number of oxygen atoms: Number of hydrogen atoms:
BALANCED EQUATION		

Now think about the products that were formed. What could they be? They were bubbles, of course, but what was in the bubbles? Since the water level went down, we might assume that the water changed into the bubbles. We know, though, that the water wasn't boiling, because it never got hot. So the bubbles couldn't have been water vapor. What else could they be?

Here's a hint. Look at the types of atoms that make up a water molecule. Since water molecules are made up of only hydrogen and oxygen atoms, the substances formed inside the bubbles can only contain hydrogen and oxygen. Would it be possible to have carbon dioxide (CO_2) as a product of this reaction? Why?

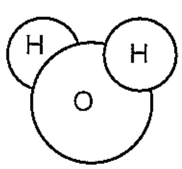
So what substances are inside the bubbles? Did someone say "Maybe there's oxygen gas inside some of the bubbles, and hydrogen gas in the other bubbles?" Yes! **The water molecule is coming apart and making hydrogen and oxygen molecules. Hydrogen gas is in the bubbles coming off one of the pencil leads, and oxygen gas is in the bubbles coming off the other lead.**

You can prove this by collecting the gases and conducting tests on them. The tests are easy. Hydrogen explodes with a loud pop when a burning piece of wood is placed in it. Oxygen makes a slightly burning (glowing) piece of wood burn very brightly. You need to collect these gases separately before you can test them.

C. Write the common name of the ending substances (the products.) In this case, they are oxygen gas and hydrogen gas.

D. Obtain a model-building kit and find the necessary pieces to build a water molecule. Your teacher will tell you which colors represent which kinds of atoms. Try making a model of a water molecule. You need two hydrogen atoms (the same color) and one oxygen atom (a different color).

Do all the models in the class look exactly alike? Why not?



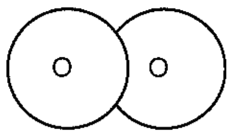
H_2O—a water molecule

Chemists have found that both hydrogens attach on opposite sides of the oxygen, not to each other, like in the picture on the left. If your model has the two hydrogens attached to each other, change it.

Make two water molecules.

Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are.

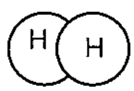
E. Now build models of the ending substances. Start with oxygen. Are you wondering what the formula is? Chemists found—a long time ago—that two oxygen atoms join together to make an oxygen molecule, so what would the formula be?



O_2—an oxygen molecule

Write the formula in the proper space. Then make the model. Remember to use the same color that you used above for oxygen. Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are. Remember to use the same color that you used above for oxygen.

F. Now try making a model of a hydrogen molecule. Like oxygen, two atoms of hydrogen join together to make a hydrogen molecule.



H_2—a hydrogen molecule

Write the formula in the proper space.

Draw a picture of your model of the water molecule on your data chart. Label each atom or color it to show what kind they are. Remember to use the same color that you used above for hydrogen.

Now that you know the formula and can make a model of each reactant and each product, you are ready to figure out how new substances form.

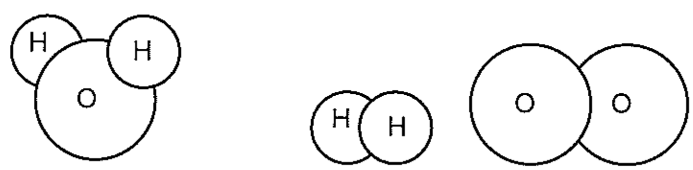
Recall from the last lesson what makes one substance different from another: Each substance is made up of its own kind of molecule, made of different kinds of atoms. Water is a collection of water molecules, each molecule made from 2 hydrogen and 1 oxygen atoms. Vinegar is a collection of vinegar molecules, each molecule made from 2 carbon atoms, 4 hydrogen atoms, and 2 oxygen atoms. Sugar is made of sugar molecules, each molecule made from 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.

What happens when an electric current runs through water, and the water decomposes into hydrogen gas and oxygen gas? The atoms of the water molecules come apart and then form into new molecules. **No new atoms of any kind are added.** Its like taking a Lego building apart and using all the pieces to make two smaller objects, like a plane and a tree.

Let's try doing this with your models.

G. Take a molecule of water apart and USE THESE SAME ATOMS to make the products, in this case, oxygen and hydrogen molecules.

starting substance "reactant"	ending substances "products"	
H_2O	H_2	O_2



What happens? You can make the hydrogen molecule (H_2), but you cannot make the oxygen molecule (O_2), because you have only one oxygen atom. Where can the other oxygen atom come from to make an oxygen molecule?

In the real chemical reaction you watched, with many bubbles being formed, there were billions and billions of molecules. Billions of water molecules were coming apart at the same time. And all the other water molecules coming apart also have an oxygen atom. So two oxygen atoms from different water molecules find each other and join together to form an oxygen molecule.

H. Try doing that with your models now. Take a second molecule of water apart and make another hydrogen molecule. Use this single oxygen atoms to join the oxygen atom from the first water molecule. Together they form an oxygen molecule.

I. How many water molecules did you use in all? Draw exactly that many water molecules in the space on your data sheet labeled PICTURES OF MODELS FOR THE REACTION. Color your models using the same color code as above.

How many hydrogen molecules were formed? Draw exactly that many hydrogen molecules in the appropriate space on your data sheet. Color your models using the same color code as above.

How many oxygen molecules were formed? Draw exactly that many oxygen molecules in the appropriate space on your data sheet. Color your models using the same color code as above.

Are you beginning to see how atoms rearrange themselves to make new substances?

CONSERVATION OF MATTER

Now let's see how atoms and molecules can be used to explain conservation of matter. Remember that conservation of matter in chemical reactions means that the beginning weight of all of the reactants is exactly the same as the ending weight of all of the products. Can you speculate about why this might be?

? ? ? ? ?

J. How many atoms of oxygen are there in the molecules of the reactant—the starting substance? How many atoms of hydrogen are there in the molecules of the reactant? Record this information on your data sheet under ACCOUNTING FOR ATOMS.

How many oxygen atoms are there in the product molecules—the ending substances? How many hydrogen atoms are there in the product molecules ? Record this information on your data sheet in the appropriate space.

WHAT DO YOU NOTICE ABOUT THE NUMBERS OF **ATOMS** IN THE STARTING SUBSTANCES AND THE ENDING SUBSTANCES? They are the same! The atoms don't disappear or appear out of nowhere... they just rearrange themselves into new molecules.

And if each atom has a certain weight (which it does), then how does the weight of the reactant compare with the weight of the products?

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.

4. After doing the same experiment with water that you just completed, and doing it until all the water was gone, the teacher asked what happened to the water. Jamie responded quickly with "Oh, that's easy. It just decomposed into nothing." You are now an expert on this. How would you help Jamie understand what happened?

Lesson 14: ATOMS IN EQUALS ATOMS OUT: Rusting

Let's repeat the whole process now with a different chemical reaction: rusting. Take a minute or two to remember what a fresh piece of steel wool and a piece that has reacted (perhaps the one with the balloon on top) look like.

TRY THIS

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

SAFETY!

If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

A. Draw a new data chart in your journal.

THE REACTANTS

B. **Write the common names of the reactants** in the proper place on your data sheet. One is steel wool, which is just threads of steel. What's the other reactant? (Can you remember how you knew that it was used in this reaction?)

C. The steel in steel wool (or in cars, bikes, etc.) is made by adding small amounts of carbon or other metals to iron. Probably "iron wool" would be a better name since it is mostly iron and it's the iron in steel wool that reacts. The chemical formula for iron is Fe (from the Latin word for iron: ferrum). The molecule is made from just one atom. **Write the formula** in the appropriate space on your data chart.

Write the formula for an oxygen molecule in the reactants column also. If you don't remember it, look in the last lesson.

D. **Make a model of the iron molecule.** You need only one atom. **Draw a picture of it** and label or color it to show that it is different from the other atoms you have worked with.

Make several molecules of iron, in case you need them later.

Make a model of the oxygen molecule and draw a picture of it on your chart.

Make several molecules of oxygen, to take apart and use to make rust molecules. Return ALL unused pieces to the model kit.

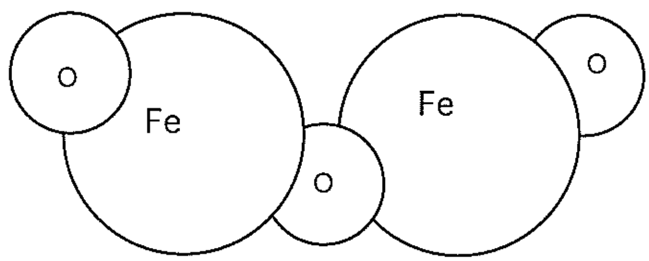
THE PRODUCTS

What is the formula for rust? Steel wool needs oxygen from the air in order to rust. So what kind of atoms can be present in rust?

? ? ? ?

If you said that rust can be made only from iron and oxygen atoms because only those two kinds of atoms are present in the reactants, you are correct. Chemists have found that the formula for rust is Fe_2O_3. **Write the formula** in the products column.

E. Make a model of rust. It looks like this:



Draw a picture of it on your chart. Use the same labels or color codes you used above.

MODELING THE CHEMICAL REACTION

F. Use your models to show how the rust forms from the steel wool and the oxygen: Take an oxygen molecule apart, grab an iron molecule (yes, it's just one atom) and start building a molecule of rust. Is one molecule of oxygen and one molecule of iron enough? No. So take a second molecule of oxygen apart. How many iron molecules do you need?

Is anything left over? Once again, an oxygen atom is left over. Remember, in chemical reactions, reactant molecules never break into atoms that are left over in the reaction. This is a very, very important characteristic of chemical reactions. So what happens? Yes: Two molecules of rust are formed. Make another molecule of rust, using the left over oxygen atom, and any more oxygen molecules and iron molecules you need. (Remember, the steel wool contains billions of molecules and so does the oxygen in the air. There are plenty of iron and oxygen molecules available to react. Now can you see why you started with several models of each reactant molecule?)

Put all the unused reactant molecules back in the kit. They did not react in your model.

G. Count how many iron molecules and oxygen molecules you used and how many rust molecules you formed and draw them on your data chart, in the row marked "Pictures of models for the reaction." Color or label your models using the same color codes or labels you used above.

CONSERVATION OF MATTER and THE CHEMICAL EQUATION

Would the weight of the iron and oxygen used equal the weight of the rust formed? Remember the experiment with the balance? If you put the flask with the rusting iron and balloon on a scale and watched the weight as the steel wool rusted, would it stay the same?

What do you think, and why?

? ? ? ?

You can use what you know about atoms and molecules to prove that the weight (or mass) stays the same. Here's how:

H. On the next line of your chart, labeled ACCOUNTING FOR ATOMS IN REACTANTS AND PRODUCTS, **decide what kinds of atoms are present in the reactants and the number of each kind. Do the same for the product.** Record this information on your chart.

Are there the same number of oxygen atoms in the starting substances as in the ending substances?

Are there the same number of iron atoms in the starting substances as in the ending substances?

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?

5. Design an experiment that shows that weight is conserved when a car rusts. Use a car that stays in the same place for 10 years, getting rustier and rustier.
6. Give some examples of how we protect things made of iron and keep them from rusting. Then explain how the protection works.

You are now ready to explore what happens when vinegar and baking soda are combined and that great bubbling reaction begins!

Lesson 15: ATOMS IN EQUALS ATOMS OUT: Baking Soda & Vinegar

Now, what about the baking soda and vinegar reaction? These molecules get a little more complicated, but you are getting to be an expert at this, so you should not have difficulty.

Your teacher will perform this reaction. Observe it carefully. It is easy to tell that a reaction is occurring (because of the bubbles) but it is not so easy to tell what the products are. What do you think is in the bubbles? Can you see anything else that might have been formed? You'll be able to figure out what all the products are as you proceed with model-building.

TRY THIS

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

A. Use a chart to help study this reaction, as you did with the decomposition of water and with rusting of iron.

THE REACTANTS

B. **Write the common names of the reactants** in the proper place on your data sheet.

C. Chemists have discovered that the chemical formula for baking soda is $NaHCO_3$. Each of the oxygens are joined to the single carbon atom. The hydrogen and sodium (Na is from the Latin name for sodium, natrium) are each connected to different oxygens. **Write the formula** for baking soda on your chart, and **draw a picture** of the molecule. Label or color each atom appropriately using the same color code you used earlier.

SAFETY!

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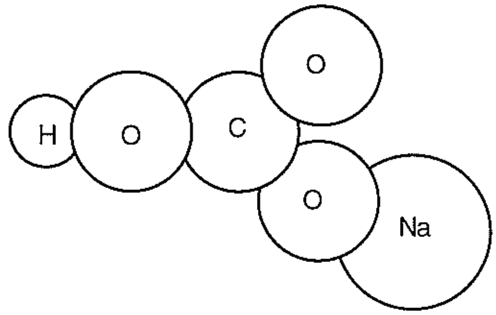
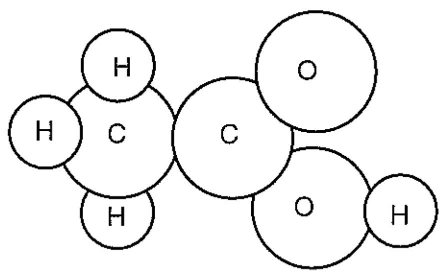


baking soda

D. Vinegar is made up of 2 carbon atoms, 2 oxygen atoms, and 4 hydrogens: CH_3COOH. It is written that way because that is pretty much how the atoms are arranged in the molecule. The two carbon atoms join to each other. Three hydrogen atoms join to one of the carbon atoms and are spaced equally around it. Two oxygens join to the other carbon atom. The other hydrogen atom joins to one of the oxygens. **Write the formula** for baking soda on your chart, **and draw a picture** of the molecule. Label or color each atom appropriately using the same color code you used earlier.



vinegar

E. Make models of the reactant molecules. Make **two** models of each, then replace all the unused atoms in your kit.

THE PRODUCTS

What are the products from this reaction? What is in the bubbles?

Look at the atoms that make up vinegar and baking soda: carbon, oxygen, hydrogen, and sodium. What substances can these atoms make that you are familiar with?

Carbon dioxide, CO_2?

Oxygen, O_2?

Water?

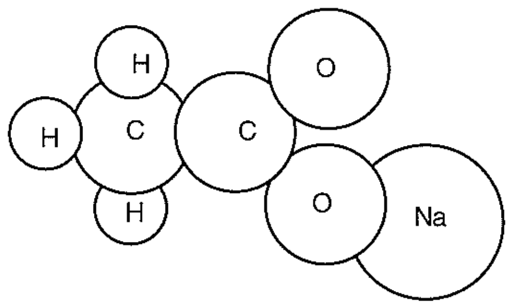
Hydrogen gas?

Butane?

Salt—sodium chloride, NaCl?

Something had to be in the bubbles. It could be any of the gases listed above. (Which substances are gases?)

Actually, three substances are formed in this reaction. Chemists have analyzed what's left over after the reaction, by doing tests on the products. They have found carbon dioxide in the bubbles, water in the liquid, and another substance called sodium acetate. Its formula is CH_3COONa.



sodium acetate

F. **Record the appropriate information about the products** in your chart.

G. **Draw pictures of each molecule** in your chart.

MODELING THE CHEMICAL REACTION

H. **Use your models to show how the products form from the vinegar and baking soda:**

First, look carefully at the pictures you have of the baking soda and sodium acetate molecules. Notice the cluster of atoms on the right side, the COONa? That cluster stays together during the reaction, as part of the baking soda molecule becomes part of the sodium acetate molecule.

Second, look carefully at the pictures of the vinegar and sodium acetate molecules. Notice the cluster of atoms on the left side, the CH_3? That cluster stays together, as part of the vinegar molecule becomes the other part of the sodium acetate molecule.

Now take a baking soda molecule apart, leaving the COONa cluster of atoms together. Take a vinegar molecule apart, leaving the CH_3 cluster together. Then make one sodium acetate molecule out of the two clusters.

Look at what you have left, and try to build a carbon dioxide molecule and a water molecule.

CONSERVATION OF MATTER and THE CHEMICAL EQUATION

I. Check the kinds of atoms and number of each kind in both reactants and products and fill in the ACCOUNTING FOR ATOMS IN THE REACTANTS AND PRODUCTS portion of your data sheet.

Are there as many atoms of carbon in the reactants as in the products?

Are there as many atoms of oxygen in the reactants as in the products?

Are there as many atoms of hydrogen in the reactants as in the products?

Are there as many atoms of sodium in the reactants as in the products?

Explain how this proves that if you trapped all the gas given off in this reaction, the weight of the original baking soda and vinegar would be the same as the weight of all the products after the reaction.

J. 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, 1 $NaHCO_3$).

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

__ $NaHCO_3$	+	__ CH_3COOH	→	__ CH_3COONa	+	__ CO_2	+	__ H_2O
BAKING SODA	+	VINEGAR	PRODUCES	SODIUM ACETATE	+	CAR. DIOX.	+	WATER

THINK AND WRITE

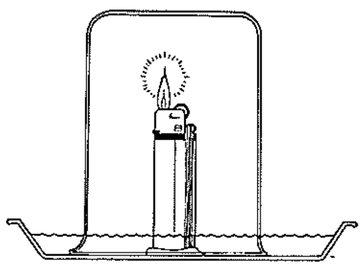
Discuss each question below in your group. Then write the answers on the back of your data sheet.

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.

Lesson 16: ATOMS IN EQUALS ATOMS OUT Burning Butane



Recall the burning of butane from Cluster 2. Your teacher will demonstrate the reaction for you, to refresh your memory and to try to identify the products.

What did you learn about starting substances when the beaker was put over the lighter?

What product formed as little droplets on the inside of the beaker?

Turn the beaker upright and add a little dilute Bromthymol blue to the dish and swirl it around. What does this chemical test show you about one product formed when butane is burned?

	REACTANTS		PRODUCTS	
DESCRIPTION	Clear liquid	Invisible gas	Liquid droplets	Turns BTB yellow
COMMON NAME	Butane	???	??? (don't write here!)	???
FORMULA	C_4H_{10}	???	??? (don't write here!)	???
PICTURE OF MODEL	(write on chart in journal)			

TRY THIS

YOU WILL NEED

Marshmallows or gumdrops and toothpicks for model building.

SAFETY!

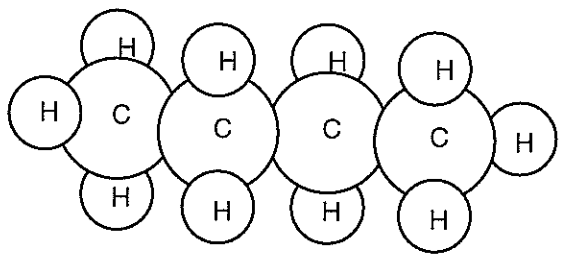
If your model kits contain gumdrops, marshmallows, and toothpicks, do not place any of them in your mouths. Upon completion of this project discard these materials as instructed by your teacher.

A. Use a chart to help study this reaction, as you did with the decomposition of water and with rusting of iron.

B. Fill in whatever you can about the starting and ending substances.

C. Build models of the reactant molecules.

Chemists have analyzed butane as it burns, and found that its formula is C_4H_{10}—four carbon atoms and 10 hydrogens.



D. Draw pictures of the product molecules in your chart. Use the pictures as you do the next step.

E. Take apart the starting molecules and rearrange them to form the ending molecules. You'll need to start with two butane molecules and many molecules of oxygen.

F. As a special project, make a video, or draw a cartoon strip to show what happens when butane burns—how butane molecules come apart and recombine with oxygen atoms to make the ending substances. In the video or cartoon explain why a butane lighter gets lighter when it burns, but why the lighter under the beaker **doesn't** change its weight.

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 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!

Lesson 17: WHERE DOES IT GO?

If new substances are really made from the atoms of old substances...

if atoms are never destroyed in chemical reactions, but only rearranged to make new materials...

could it be true that the atoms that make up my body may have once been part of a dinosaur?

Could it be possible that some atoms that are part of me could someday be part of a spaceship that travels to distant galaxies?

And would it be true that the materials we throw in landfills don't just rot into nothingness?

KEY QUESTION

Where do the materials and substances we use go when we are finished with them and throw them away?

TRY THIS

YOU WILL NEED

- a small beaker about 3/4 full of a solution of copper chloride
- a piece of aluminum cut from an aluminum pie pan
- model kit

A. Draw a data chart in your journal.

B. Observe the solution of copper chloride. It was made by dissolving a crystal of copper chloride ($CuCl_2$) in water.

Observe the piece of aluminum. It is a thinly rolled piece of metal. Its molecule has only one atom: Al.

Write the names, descriptions and formulas on your data chart for the reactants.

Copper chloride is a mineral found in the earth. You'll see in a few minutes where it gets its name (at least part of its name!)

C. Place the piece of aluminum into the copper chloride solution. Observe for several minutes. How many changes can you find? **Discuss these changes in your group.**

D. **Write a description of any product you notice.** One of them is coating the aluminum pie pan. Can you identify it? (Hint: What kinds of atoms could be present in this product?)

E. Your class will figure out, with your teacher's help, what the products are. **Make models of the reactants and products,** and draw pictures on your chart.

F. **Write a balanced equation** for this reaction.

THINK AND WRITE

Discuss these questions in your group before writing answers.

1. Would every blue solution work like this to form copper? Why do you think this?
2. What do you think you would get if you tried this experiment again but started with a solution of iron chloride instead of copper chloride?
3. There are many chemical reactions that can be used to obtain various metals from the rocks (ores) of these metals. You have used only one of them. What is the essential chemical property of a rock or ore in order to obtain a certain metal from it?
4. Where do you think the copper in the electrical wiring in your home came from? Explain your thinking.
5. Have you ever seen an outdoor copper statue or monument, or perhaps nuggets of copper near a mine in the Upper Peninsula? Can you relate what it looked like to this activity? Explain.

6. What happens to copper wires, pots, jewelry, etc. when you throw them away?
7. Almost everyday you hear that you should recycle such things as aluminum, copper, paper, etc. Do you think this is important? Use what you have learned in this unit to explain why you think this.

   As you thought about the Law of the Conservation of Matter, you wondered if it could possibly apply to this situation. What do you think?
8. Now what do you think about the KEY QUESTIONS for this lesson? Here they are again:

   Could it be true that the atoms that make up my body may have once been part of a dinosaur?

   Could it be possible that some atoms that are part of me could someday be part of a spaceship that travels to distant galaxies?

   And would it be true that the materials we throw in landfills don't just rot into nothingness?

   Explain your thinking about each question.

In this cluster, you have learned where new substances come from and how they form. As you continue your research in the next lesson, think about atoms and molecules, and how new substances are formed.

Lesson 18: MORE RESEARCH!

To end this cluster, you will use your new knowledge of chemistry to continue your research. Consult your resources and try to find answers to the following questions. Each of these are big questions and could require a lot of research and information. Do the best you can with the time allowed!

Here are the questions you have already researched.

- the chemical name, and any other name it goes by.
- a complete description of the substance.
- what it's used for, present and past.
- any special importance to various cultures or ethnic groups.
- the history of its discovery and development.

Here are the questions for this cluster:

1. What is the chemical composition of this substance? Find the chemical formula if you can.
2. How do we get more of this substance? Try to trace its origin all the way back to its source. This may require several steps. If you find any chemical processes involved in its production, be sure to include these in your report.
3. How is this substance disposed of at the end of its useful life? There may be more than one process or more than one step in the process. You may find some chemical reactions that occur. You should include all of these facts in your report.

At the end of cluster four, there will be one more question to answer for your research: How is energy involved in the production and disposal of your substance.

Energy and "Boosters"

Lesson 19: WHERE DO THE HEAT AND LIGHT COME FROM?

In the first three clusters of this unit you studied chemical reactions. You learned

- how weight changes during the reactions,
- where any invisible reactants and products come from,
- what the chemical formulas for the substances are, and
- what a balanced equation tells you.

In this cluster you will study the **energy** involved in some of these reactions.

Some reactions—such as burning butane, paper, or wood—give off heat and light. But many other reactions—such as reacting vinegar with baking soda or decomposing water—release no heat or light at all. Where does that heat and light come from?

KEY QUESTION

Where does the heat and light come from when things burn?

Let's begin by doing a little brainstorming.

THINK AND WRITE

Make a chart like the one below. Then, in your group, discuss and answer the following questions:

REACTIONS OR PROCESSES THAT GIVE OFF ENERGY	WAYS WE USE THE ENERGY

1. a. Think of all the reactions you performed in this unit that gave off heat and list them on your chart.

   b. Many reactions or processes that you see around you every day also give off energy. Add as many as you can think of to your list. You may not realize it, but you depend daily on these forms of energy for many activities.

2. a. Think now of all the ways you use this energy and add them to your chart.

   b. Often, common things use energy in hidden ways. For example, the aluminum can that your soda comes in required energy to dig ore from the earth, transport it to a refinery, and melt it to form the can. Think of hidden energy uses for the items on your chart and write them down.

Probably one of the first things you associate with energy-releasing reactions are fuels. See how many of the reactions or uses of energy that you've listed involve fuels.

3. Circle each reaction in the first column that involves a fuel.

4. Circle each use in the second column that requires a fuel.

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.

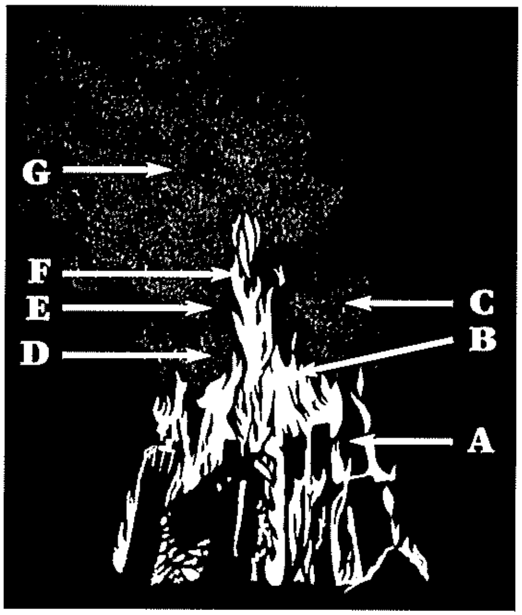
   b. How many oxygen, hydrogen, and carbon atoms are present in the starting substances before the reaction takes place?

   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			
	oxygen			
PRODUCTS	carbon dioxide			
	water			
	smoke			
ENERGY	heat			
	light			

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.

Lesson 20: WHERE DOES FUEL GET ITS ENERGY?

Since energy is not matter, it is not given off during reactions in the same way that gases are produced and float away. Energy is not made up of molecules that leave the system. So the big question still remains:

Where does energy come from? (The same key question that we started this cluster with.)

The following familiar activity will start you thinking about this question.

TRY THIS

YOU WILL NEED

- rubber bands
- strong magnets
- matches
- paper
- forceps
- pan of water
- wooden splints
- butane lighter

A. Stretch and relax a rubber band without letting it go. What differences, if any, do you feel between its stretched and relaxed states?

B. Hold the rubber band without stretching it, then let it go. What happens?

C. Stretch the rubber band and release it towards a wall **(NOT TOWARDS ANY PERSON—YOU WOULDN'T WANT TO BE RESPONSIBLE FOR POKING SOMEONE'S EYE OUT!)** What happens now? What differences in reactions are there, if any, between releasing it after stretching it a lot and just a little? Record your observations of what happened.

THINK AND WRITE

Discuss the answers to the following questions in your group. Then write the answers in your journal.

1. What difference did you feel in the rubber band when it was stretched compared to when it was relaxed?
2. What difference did you see between releasing the rubber band without stretching it compared to stretching it?
3. What difference did you see when releasing the rubber band stretched only a little compared to stretched a lot?
4. What did you do to the rubber band when you stretched it that accounts for its motion across the room?

If you find any of these questions hard to answer, you are not alone. Here's how scientists think about rubber bands flying across the room:

When you stretch a rubber band, you are giving it energy. When you let the rubber band go, that energy is responsible for it flying across the room and perhaps hurting someone or possibly moving something small if it hits it. You can't see the energy and—if the rubber band is held stretched apart by someone else or by some machine—you can't feel it **while it is stored in the rubber band.**

The idea of storing energy is very important in explaining where heat and light in fires come from. Stored energy is being set free when the rubber band flies across the room and hits something.

D. Take a few minutes to think of situations in which energy is set free. Since you know it was stored before it could get free, think about where it was stored. Make a chart and, in the first column, tell what form you see the energy take when it gets free.

Then, in the second column, tell what substance stored the energy. You may use the rubber band for your first entry. A sample chart with the first entry is shown below:

WHAT FORM DOES THE ENERGY TAKE?	**WHAT SUBSTANCE STORED THE ENERGY?**
Motion of rubber band	In the stretched rubber band

Here are some familiar examples to see energy being freed. Try them to see if you can figure out where their energy was stored. Add each of them to your chart if they are not already there.

E. (In your head) hit a rock hard with a large sledge hammer. What energy did you observe? Where was it stored when the hammer was raised and ready to hit the rock?

F. Plug a light into a socket and turn it on. What energy do you observe? Where was it stored before the light was turned on?

G. Light a match and observe it. What form of energy do you observe? Where was it stored?

H. Use forceps to hold a piece of paper with a pan of water under it. Then light the paper. **CAUTION: Tie back long hair to avoid flames.** Repeat once more with a wooden splint and with a butane lighter. In each case, decide what form of energy you see. Then try to decide where it was stored before it burned. Be sure to include each of these in your chart.

Since each of these substances gives off heat and light, you know that the energy was stored in them. But what does it mean to say that energy is stored in butane or in wood? That is the hard question.

The energy was not stored as heat or light inside the substance, since the match, paper, wooden splint, and butane were neither hot nor glowing before they burned. So how was this energy stored? To help you answer this question, try the next part of this activity.

I. You probably know that magnets attract each other if you hold their opposite ends together. Also, if you turn one magnet over, end over end, they repel each other. Try doing this now. Be sure that everyone in your group can feel both the attraction and the repulsion of the magnets.

J. Place the magnets on the table or desk and hold them together so they repel each other while they are touching. Now let go. What happens? Everyone in your group should try this to feel the energy it takes to push them together. Record your results.

K. Repeat this process. This time move the magnets close but not touching—say 1 inch apart—and release. Record what happens.

L. Repeat this process several more times, with the magnets a little farther apart each time. Record what happens.

5. What difference did you observe as you placed the magnets farther and farther apart?

6. What can you conclude about the amount of energy stored in the magnets when they are pushed close together compared to when they are held not so close?

M. If more magnets are available, try holding four or six magnets together and then release them. What differs from when you held just two magnets together? Record your results.

N. Repeat the process several more times, again moving the magnets a little farther apart each time. Record the difference.

7. What difference didyou observe when you held four or six instead of just two magnets?

8. Did the magnets store energy? What evidence do you have of this?

9. Did the magnets lose any weight when they flew apart? What does this tell you about energy?

How are magnets like butane molecules?

Substances store energy very much like magnets do. Some molecules need less force to hold them together, and therefore store a small amount of energy. Other molecules need more force to hold them together, and therefore store a considerable amount of energy.

Butane molecules, paper molecules, and other fuels store a great deal of energy, which is released when they react with oxygen—when they burn.

Not all of the energy stored in butane molecules is released as heat and light, though. Some of it is needed to form the carbon dioxide and water molecules. In fact, when this chemical reaction takes place, some of the energy stored in the butane and oxygen molecules is used to form the carbon dioxide and water molecules, and what's left over is released as heat and light.

If we wrote this idea as an equation, it would look like this:

Energy in reactants	***equals*** energy in products	***plus*** energy given off
The energy stored in butane and oxygen	= the energy stored in carbon dioxide and water	+ the energy released as heat and light

How is this "equation" like the equations used to represent chemical reactions? In chemical equations, all of the atoms in the reactants (on the left side of the arrow) show up again in the products (on the right side of the arrow.) In this equation, all of the *energy* before the reaction begins shows up again after the reaction takes place. Some of it is in the new chemical substances, and some of it is given off.

10. Write an energy equation for burning paper.
11. Remember how chemical equations help explain conservation of mass? Since the atoms of the reactants is what has weight (or mass), and the atoms of the products are exactly the same, no weight (or mass) has been lost or gained. How does this "energy equation" show another kind of conservation?

The next lesson is about the match that starts a fire. It gives a boost to get the burning reaction started, and the paper wouldn't burn without it.

But before we get to the next lesson, think about the house that burned down:

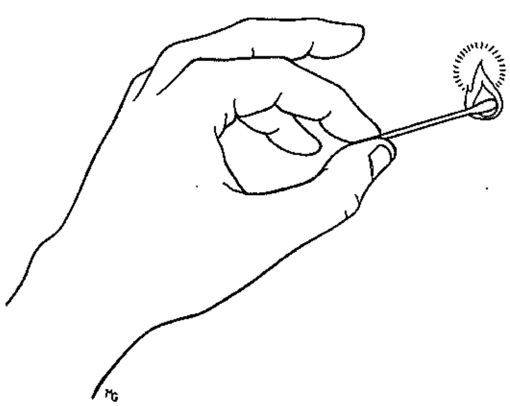
12. Write a short paragraph that explains what happens to the weight of all the wood in a house when it burns down. In your paragraph, talk about the heat and light energy given off, and whether the heat and light have any weight.

Lesson 21: HOW DO CHEMICAL REACTIONS GET STARTED?

Some people believe that the energy given off when wood or candles burn comes from the match that was used to start them. What do you think about this?

????

Picture a burning match and a burning fire. Is there as much energy given off by a burning match as there is given off by a burning fire in a fire place? How can you explain your thinking?



If you think back to the last lesson and the idea that energy can be stored in substances, would you think it was possible that all of the energy released from the fire was stored in the match?

If it was all stored in the match, then what is the wood for?

Does it seem reasonable to say that almost all of the heat and light of the fire come from the energy stored in the ***wood,*** not from the match?

Then why do you need a match? What does a match do? Of course it starts the fire. But it does this by giving the burning reaction a **boost to get started.**

Most chemical reactions don't start by themselves. Most need boosters.

Think about the idea of boosters for a minute. Picture a large boulder perched on top of a hill, about ready to roll down the side (maybe aimed at the Road Runner down in the valley). It's just sitting there, until... one little push, and it can do tremendous damage when it hits the ground way below.

What gave it the boost to get started? Did all of the energy given off when it hit the ground come from your little push?

Can you think of other examples of things that need boosts to get started? Brainstorm on this for a few minutes.

? ? ? ?

How about the student who's having a hard time with his or her homework. Sometimes if someone comes along and gives them a little help, then they get started and do O.K. with the rest of the homework. They get a boost. Did all of the effort involved in doing the homework come from the person who helped a little at the beginning?

KEY QUESTION

What does a booster do in a chemical reaction?

Try to answer this question for the example of a student who needs a little help to get started:

1. What does the "boost" do for the student who is having a hard time getting started on her or his homework?

Let's look closely at a boosted reaction that you've done already, to think about why boosters are needed in chemical reactions.

THE RUSTING REACTION THAT NEEDED A TORCH

Remember when you watched as steel wool turned *black* as it was heated vigorously by a torch (or Bunsen burner)? Think for a minute about this chemical reaction:

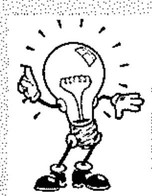
2. How was this different from the normal rusting reaction?
3. How was it similar?
4. Did the steel wool weigh more after the reaction? Why?
5. Was the torch (or Bunsen burner) needed throughout the entire reaction?

To check on the last question, try the experiment again.

TRY THIS

TEACHER DEMONSTRATION

- steel wool
- Bunsen burner or propane torch
- ring stand and clamp, or something to hang the steel wool from



CAUTION!

DO NOT TOUCH THE STEEL WOOL! The reaction is probably not finished even when it looks like it is, and the steel wool will still be hot.

A. Darken your room, if you can, so you can observe the energy involved in this reaction.

B. Watch closely as your teacher begins to heat the steel wool. After a moment of intense heating, the flame can be removed. Record what you observe.

C. After the reaction seems to be completed, turns the lights back on in the room and observe the steel wool carefully. Record your observations.

D. Go back to number 5 above, and change your answer if you need to.

6. Was there a booster in this reaction? If you think there was, what was it?
7. Did this reaction give off energy? What evidence do you have of this?
8. How is this reaction like burning?
9. Think of this reaction as happening to small pieces of iron throughout the steel wool: iron reacts with oxygen to form iron oxide, a black powdery substance. Why does the reaction eventually stop?
10. Why does it take heat to start this reaction? That is, why is the boost needed? *What's your guess?* Think about the molecules of iron and oxygen coming together to form iron oxide molecules.

The last question is really difficult. Here's how scientists think about why boosters are needed:

Remember when you took apart molecules of reactants and put them together again to form molecules of products? In the actual chemical reaction, no one's hands take apart molecules and rearrange the atoms, of course.

For the atoms of one molecule to rearrange themselves with the atoms of another molecule, the two molecules have to get very close together. Take baking soda and vinegar, for example. Put the two in the same bottle, mix them together, and a reaction just starts. No booster needed. At the molecular level, baking soda molecules and vinegar molecules get close together, close enough so their atoms can rearrange and make new molecules. The key here is that the molecules of baking soda and vinegar *have to be very close together.*

The same is true with iron and oxygen. Put the two in close contact, and rusting starts. Not the intense-heat rusting that produces the black product, but normal rusting. It happens to bikes, to tools, to cars. We have to protect iron and steel with paint and other coatings so they don't rust.

But not all reactions start immediately, without any help, without any boosters, like baking soda and vinegar or iron and oxygen. Butane doesn't just spontaneously ignite and burn. Good thing!

Why doesn't it start spontaneously? Could it be because butane and oxygen molecules can't get close enough together? If that was so, then what would a booster do?

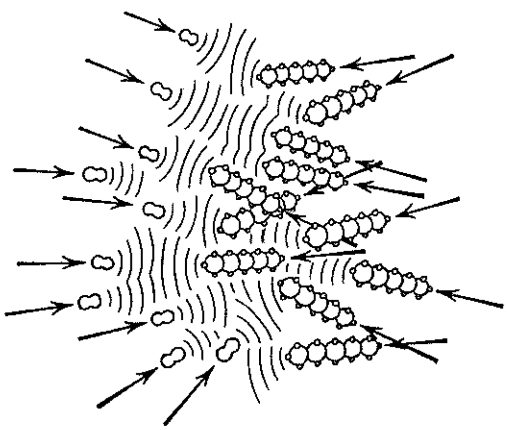
11. Go back to question 10 and add to it, if you want.

But wait. Maybe you're thinking that it seems like butane molecules and oxygen molecules do mix together—when you open the butane lighter and some of the butane evaporates out of the container and goes into the air. Then butane molecules should be close to oxygen molecules. So why doesn't the reaction start by itself?

Or what about paper. It needs a booster. But it seems like oxygen molecules are floating all around paper.

Think of the paper sitting on your desk. Oxygen molecules must be getting fairly close to it. But it doesn't just start on fire.

Although air breezes move across pieces of paper and sticks of wood all the time, it's not at this level that we need to look. We need to look at the level of individual molecules.

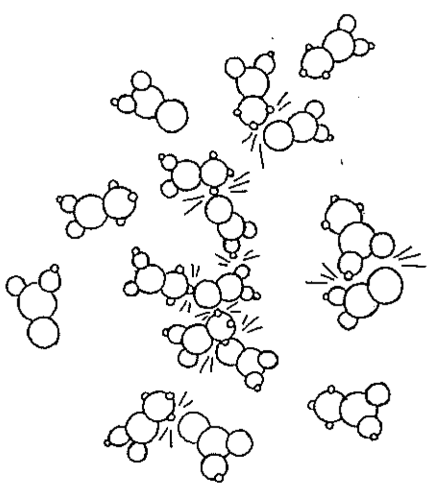


Butane and Oxygen molecules need a push to get them close enough to react.

Individual molecules of butane and oxygen apparently can't get close enough to each other, or hit hard enough, to let their atoms rearrange. A booster "pushes" them together.

What keeps them from getting as close as they need to? Good question. Some molecules tend to push away from each other, like magnets that repel, and keep each other far enough apart so they can't react.

When heat is the booster, it makes the molecules move faster, and push harder against the force that repels them, so they can get close enough to react.



Vinegar and Baking Soda molecules move close to each other.

And when they react, wow! Paper and oxygen, after they get started, give off lots of energy. Dynamite, whatever that chemical reaction is, releases a tremendous amount of energy!!

12. Use the ideas written above—about why boosters are needed in chemical reactions—to explain why a booster is needed to start the iron and oxygen reaction that you observed above.

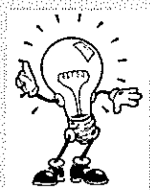
ANOTHER BOOSTED REACTION: STRIKING A MATCH

We've talked about how a match is needed to start a fire. But what about starting a match? This may sound silly, but have you ever thought about why you strike a match? What are you doing to the match when you strike it?

TRY THIS

YOU WILL NEED

- wooden matches and a rough surface
- safety matches
- pan of water



SAFETY!

Tie back long hair to avoid flames.

A. Look carefully at a match before burning it and draw a picture of it.

B. Strike the match and observe what happens. Record your observations. You may need to repeat this several times in order to make good observations. If possible, use both a wooden kitchen match and a safety match. What differences do you observe in the two types of matches?

C. In your groups, discuss what happened: List all the factors involved in starting the reaction, that is, in lighting the match.

THINK AND WRITE

13. Describe the substances that react when a match burns. Use your observations of the match to think about what the substances are.
14. Why did you have to rub the match on a rough surface? (Hint: Rub your hands together very briskly and observe what happens.)
15. What was the booster for this reaction?
16. Is is possible that all the heat produced when burning the match may have come from striking it? How can you tell?

When you strike a match, you rub its tip on a very rough surface. This generates some heat, just as when you rub your hands together on a cold day in order to warm them. The small amount of heat, generated by the friction of rubbing, is enough to cause the chemicals in the match tip to react. These chemicals release enough heat to start burning the match wood.

THE BUTANE LIGHTER: WHAT'S THE BOOSTER?

Here is a check to see how well you understand boosters.

D. The booster in the butane lighter resembles the one used when striking a match. Examine the lighter and figure out what it is and how it works.

17. Tell what the booster is when lighting the butane lighter. Then explain how it is provided.

So far, all the boosters we have talked about provide heat to start the reaction. In the next lesson, you will look at other kinds of boosters that help start chemical reactions.

Lesson 22: OTHER KINDS OF BOOSTERS?

In the last lesson, you learned that many chemical reactions require boosters in order to start. So far, all the boosters you have observed were heat energy. Are there any other kinds of boosters?

KEY QUESTION

What kinds of boosters, other than heat, can help start chemical reactions?

Here's the problem for the first part of this lesson: What's the booster in the decomposition of water reaction?

Remember this reaction?

1. Try to write the chemical equation for this reaction. Think about the reactant and the products. Look back to Cluster 3 if you need to.
2. Do you have any thoughts about what the boosters might be? Write your guesses in your journal.

TRY THIS

To figure out what the boosters are, you might try setting up your own experiment. The **question** you need to answer is:

Will this reaction work if any of the components are not used? If it works only with a certain component, that must be the booster.

A. First, think about how you did the experiment earlier, and draw a picture of the set-up in your journal. List the equipment you will need.

B. Think about what might be a booster, and set up the experiment without using that component. If you think there is more than one booster, you will need to set up the experiment a couple of times to try different boosters.

C. Conduct the experiments. Record your observations in your journal.

If you want help setting up these experiments, here are some possible approaches.

Experiment 1

Question: Is electricity a booster?

Procedure: Set up the experiment as in Lesson 3, but don't attach the wires to the battery. Place the lead in the water and look for bubbles.

Results:

Experiment 2

Question: Is sodium sulfate a booster?

Procedure: Set up the experiment as in Lesson 3, including attaching the wires to the battery. But don't add any sodium sulfate to the water.

Results:

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3. Let's think about whether electricity was a booster.
   a. Would the reaction work if the battery was disconnected?
   b. So is electricity an energy booster, like heat? Or is the electricity something that flows into the water to make the hydrogen and oxygen gas?

You can answer this now because you know where the hydrogen and oxygen come from—from the water molecules! They don't come from the electricity.

So the electricity must be a booster like heat from a match. The reaction doesn't work unless electrical energy makes it work.

Was the pencil lead a booster? No. It's just a way to conduct the electricity into the water. If you place the bare wires into the water without the pencil lead, you'd still get bubbles of some kind.

What about the sodium sulfate? Does the reaction work without it? Not very well. But is the sodium sulfate a part of the reaction? Look at the equation:

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

4. Is the sodium sulfate a reactant? Is it a product?
5. Would you say that the sodium sulfate is still in the water at the end of the reaction? Explain why you think this.
6. Is the sodium sulfate an energy booster? Why not?
7. Fill in the following chart.

COMPONENT	REACTANT, PRODUCT OR BOOSTER?	WHAT EVIDENCE DO YOU HAVE?
water		
electricity		
sodium sulfate		
pencil lead		
hydrogen gas		
oxygen gas		

Sodium sulfate is not an energy booster, but it is a booster—a different kind. It's a matter booster. That is, sodium sulfate is matter (made of molecules), not energy. Many reactions need matter boosters to work.

Here's another example of a matter booster:

TRY THIS

YOU WILL NEED

- 1 tbsp iron power
- 1 tsp. sand
- Ziploc bag or other plastic bag with tie
- 1 ml salt water solution

A. Place the iron power, salt water, and sand in the plastic bag. Do not close the bag.

B. Use one hand to hold open the bag and the other to gently knead its contents for several minutes to thoroughly mix them.

C. Feel the bag. What happened?

D. Press all the air out of the bag and seal it very tightly. Knead the contents for several more minutes.

E. Feel what happens. Write your observations in your notebook.

F. Open the bag again and knead the contents for several more minutes.

G. Feel what happens. Write your observations in your notebook.

THINK AND WRITE

Discuss and then write your answers to the following questions.

8. What happened when you pressed all the air out of the bag and sealed it?
9. What happened when you let air back in the bag?
10. What substance in the air does this reaction need?
11. What in the bag reacts with the oxygen? (Hint: You observed this reaction in various ways in every cluster of this unit.)
12. What product is forming?

◆◆◆◆

Yes, this is the rusting reaction! It produces heat. But there are two other substances in the bag. How can you figure out whether one of them is a booster?

Write an experimental plan in your group to find out which is the booster, and check it with your teacher. The plan will be similar to the experiments you did with decomposing water and adding salt.

I. Use your plan to conduct your experiment.

13. a. Which substance do you believe is the booster? Explain how you used your experimental evidence to determine which substances (if any) are boosters.

    b. Is it a matter booster or an energy booster?

14. Which substances are not boosters? Explain your thinking. Fill in the following chart.

COMPONENT	REACTANT, PRODUCT OR BOOSTER?	WHAT EVIDENCE DO YOU HAVE?
iron		
oxygen		
rust (iron oxide)		
sand		
salt water		

15. If one substance is not a reactant, product, or booster, then what could be its role? Hint: It functions the same as bricks in a pizza oven or the rocks used to keep the heat in a sauna.

16. Does this reaction give off energy? Where does it come from?

Can you think of a practical use for this reaction?

Here's one: To warm cold hands or toes in winter, you may have bought commercial hand or toe warmers. Many of these warmers use the reaction of iron rusting to make heat. The warmers come in small, sealed packages. To use one, you open the package and shake it a little before putting it into your shoes or mittens. Since salt water dries very quickly, most commercial products use charcoal as the booster, premixed with iron powder before packaging. Your teacher may have a sample for you to examine.

17. Why doesn't the reaction in the commercial warmers start until you open the package?

18. Usually the commercial product states that it can supply heat for about six hours. Suppose you went skiing for two hours and wanted to use the toe warmers again later. Suggest what you might do to stop the reaction for awhile.

You were probably surprised to find such a common reaction used in many commercial hand and foot warmers. There are many other everyday situations where iron rusts: cars, lawn mowers, snow blowers, tools, and pipes all rust when exposed to air.

19. Why does iron rust much more readily near oceans or lakes than in deserts?

20. You usually don't notice heat being emitted in these every-day rusting situations. Can you think of some reason why you don't?

There are many, many reactions that require matter boosters to make them happen. Many occur in your body all the time. The matter boosters are called enzymes in your cells. Matter boosters outside of living things are called catalysts.

Millions of enzymes in the human body act as boosters to start the chemical reactions necessary for your body to function properly. The absence or improper functioning of these enzymes cause many serious diseases.

Energy and other boosters in chemical reactions are very complex topics that you have barely scratched the surface of in this study. But you do see by now that there is much more to chemical reactions than just the substances written in chemical equations.

You are now ready to investigate how the production and disposal of your research substance uses boosters.

Lesson 23: RESEARCH SUBSTANCE— ANY BOOSTERS?

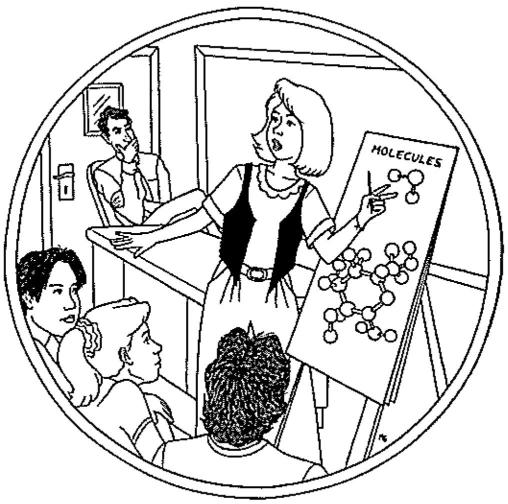
You are now ready to finish your research! You have learned many things about your substance:

- the chemical name and any other name it goes by;
- a complete description of it;
- its use, present and past;
- its importance to various cultures and ethnic groups;
- the history of its discovery and development;
- how we get more of this substance; and
- how we dispose of this substance at the end of its useful life.

Now you are ready to discover how making and discarding your substance uses energy. Use the knowledge gained in this cluster to help you answer these final questions about your substance. Then get ready for the grand finale!

1. How does producing your substance use energy? What form of energy does it use and how is it supplied?
2. Which boosters does the production of your substance require? Remember that boosters can be energy or matter. Include any information you can find as part of your report.
3. How does eliminating your substance involve energy? What form of energy does it use and how is it supplied?
4. Even disposal can require boosters. Investigate what these boosters are and include them as part of your report.

Lesson 24: THE GRAND FINALE OF YOUR RESEARCH



One of the major activities of science is to share your research with others so they, too, can learn about, benefit from, and question your findings. Scientists do this in many ways, some of which include writing articles, talking at meetings, giving slide presentations or poster sessions, preparing videos, etc. Choose one method for your presentation, either one mentioned above or that you think of yourself.

Having decided how you want to present your material, you must now decide to whom you would like to present it—your class, another class in your school, or perhaps the entire student body.

Perhaps it is possible for you to set up a poster session in the hallway or cafeteria in order to share it with other students. You may be able to visit another science class with your slide presentation or video. Of course, you must get permission from the teacher or supervisor if you plan to visit another class or use a hall or cafeteria display.

Think about the possibilities and each of the following:

- how you will present your research findings—whether the necessary equipment is accessible and needed supplies available;
- whom you will share it with and whether you have the necessary permission; and
- when you will make your presentation.

Write a plan and get approval from your teacher before you start preparing. Then get ready for your grand finale!