Category V Physical Science Examples

Guiding student interpretation and reasoning

Chemistry That Applies
Chemistry That Applies contains numerous questions to guide students' interpretation of and reasoning about investigations and readings. For example, after observing whether or not the weight changes during four physical changes (pulling apart steel wool, melting an ice cube, dissolving sugar in water, and boiling water), the text assists students in thinking about their results and relating them to the idea of open and closed systems, an understanding which is needed in order to appreciate when mass will be conserved (p. **22s**).

Later in the unit, lesson 13 is used to help students see how the idea of atoms explains the mass conservation that they have observed previously. Teacher notes make clear that teachers should guide their students through the process of using physical models to represent the conservation of matter and then move their students from physical models to pictures of models, to formulas that account for atoms, and to the balanced equation (p. **56t**).

Questions and answers are used to help students interpret the decomposition of water at the molecular level. First, the questions focus students on the problem they are trying to answer (p. **56s**). Next, students carry out the experiment and write the common name of the reactant and its chemical formula, H_2O (p. **57s**). Then the text guides them to relate their observations to the idea that atoms can combine and recombine but do not disappear (p. **58s**). After this, students are led through an exercise in which they make two water molecules, drawing and labeling them; then they disassemble and reassemble them to make two hydrogen molecules and one oxygen molecule (pp. **58–60s**). Next, they are asked to think about how many water molecules they used in all, how many hydrogen molecules were formed, and how many oxygen molecules were formed. The text asks: "Are you beginning to see how atoms rearrange themselves to make new substances?" (p. **61s**). Finally, students are helped to relate atoms and molecules to the conservation of matter (p. **61-62s**).

In the above and other examples, the questions are arranged in an increasingly complex sequence in order to help students move from phenomena and their own ideas to the scientific ideas (e.g., pp. 27s, 33–35s, 40–43s, 50–55s).

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

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

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

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

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

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

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

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

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

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

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

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

D. • The weight of the boiled water decreased.

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

Cluster 3—Lesson 13

A. KEY QUESTION: We've been preparing for this "big idea" for a long time now. Allow students to speculate about answers. This will help you understand their current thinking so you can guide better them through these difficult concepts.

The four reactions that form the backbone of this entire unit are used again in this cluster as a basis for understanding how new substances are formed. Since each reaction has already been done by the students, it will be done here as a teacher demonstration. The purpose of observing the reaction again is to help students make the connection between the actual reactants and products observed in the reaction and the words and symbols they will be using. This is an extremely difficult conceptualization for most students. You need to use every possible visual aid in your presentation. By now, students should be aware that gases can be part of the system of the reactants and/or the products and they should be looking for signs that gases are involved.

In this cluster, the teacher should work with the students, step-by-step through the entire first (and possibly second) reaction. For each successive reaction, the teacher role should diminish gradually and students should begin to work in groups independent of the teacher as much as possible. By the end of the cluster, students should be able to work through the process on their own. Do not expect students to balance dozens of equations. That is not the purpose. Rather, a conceptual understanding of the principles and laws involved, along with the association of the real world context, is much more important.

Lesson 13: ATOMS IN EQUALS ATOMS OUT: Decomposing Water

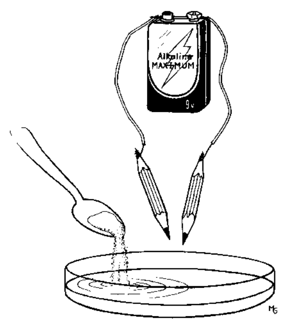
In Cluster 1, you observed some chemical reactions of common substances and wrote descriptions of what you observed. Then in Cluster 2, you learned one of the most basic laws of nature, the Law of Conservation of Matter. Take a few moments to think about what this law means and share your ideas with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

LESSON STATEMENT: Students will make models of the molecules involved in the decomposition of water; they will take the water molecule apart and use the atoms to build hydrogen and oxygen molecules. They will draw pictures of the reactant and product molecules, write formulas showing how the atoms have recombined, and consider why mass is conserved in chemical reactions based on the idea that no atoms are created or destroyed, only rearranged to form new molecules.
PURPOSE: To begin to construct a picture of how new substances are formed by observing the decomposition of water reaction and building models to demonstrate how reactants form products; to write balanced equations based on these models; and to consider why mass is conserved in chemical reactions.
APPROX. TIME: 1 class period.

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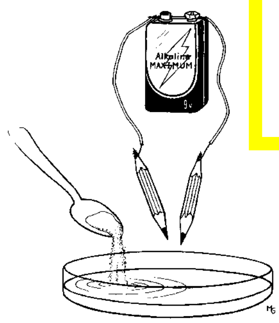

In an earlier lesson, you used a battery to make bubbles appear under water. The water level went down as the bubbles were formed.

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

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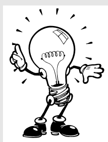
TRY THIS

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.

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		

The gases produced as water decomposes look exactly the same and students need to be convinced that there are two different substances being formed. If you have a Hoffman apparatus with platinum, stainless steel or nichrome electrodes, you will be able to set up this experiment in advance and generate enough oxygen and hydrogen gas to test them with a burning splint. Other electrodes do not work well, since although it is easy to make and collect the hydrogen gas, the reaction at the anode tends to be with other ions rather than with water to produce oxygen gas. If you do collect the gases, you can test them with a burning splint to show that they are different gases. The evidence that oxygen gas has been produced is that a glowing or burning splint bursts into flame or burns very brightly when brought to the mouth of the upright test tube. The evidence that hydrogen gas has been produced is a "bark" or a pop when a burning splint is brought to the mouth of the test tube. You will need to explain these two tests to the students. If you do not have the materials to generate the gases, you can use a few drops of bromthymol blue indicator in the water, which will produce different colors at each of the electrodes. This ought, at least, to convince the students that the gases being produced are different. You can use the same set-up used in Cluster 1, a petri dish and pencil lead (graphite) as the electrodes, salt and water with bromthymol blue indicator. Bromthymol blue will turn yellow where the oxygen is being produced and blue where the hydrogen is being produced. An overhead projector or microcam can be used and will project the color quite well.

	REACTANTS	PRODUCTS	
COMMON NAMES	WATER	HYDROGEN	OXYGEN
FORMULA	H_2O	H_2	O_2
PICTURE OF MODEL			
PICTURES OF MODELS FOR REACTION			
ACCOUNTING OF ATOMS	H 4, O 2, Atoms Total 6	H 4, O 2, Atoms Total 6	
BALANCED EQUATION	$2\ H_2O \rightarrow$	$2\ H_2 + O_2$	

B. Since bonding is not taught in this unit, space-filling models such as the marshmallows or gumdrops, rather than ball and stick models which represent double, single or triple bonds, work best. You need to decide what colors represent each kind of atom depending on what model kits you have. It is best to be consistent in the color representations so that students begin to think about different kinds of atoms as being different. The toothpicks should be broken into halves or thirds and the model built so that the marshmallows or gumdrops are touching and the toothpicks are pushed all the way in. This eliminates any need to discuss bonding of any type which is beyond the scope of the unit. Students should always check their models with the teacher to be sure they are correct.

C. Students should realize very quickly that it is not enough to know the formula which tells what pieces are required and how many of each piece, but they also need to know how these pieces are connected. In water, for example, the 2 hydrogens are both connected to the oxygen, not to each other. Some students may have connected the two hydrogens to each other and the oxygen to the outside of the two hydrogens.

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.

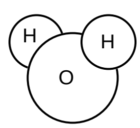
C. Write the common name of the ending substances (the products.) In this case, they are oxygen gas and hydrogen gas.

B

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).

C

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.

Model-building is an extremely important tool that enables students to develop their understanding of the structure of matter. The transformation of students' thinking about matter from continuous to the particle model is usually very gradual. As students make models of various molecules, the way they talk about matter as being made up of molecules and of molecules as being made up of atoms will indicate changes in their thinking that often do not occur without model-building. Changing students' view of the world around them is not a concept that is taught in a day or a week. Only very slowly over time will you see the correct scientific picture evolve and take shape. Don't omit any of the model-building lessons if you expect this transformation in your students.

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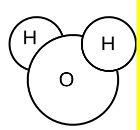

H_2O—a water molecule

Chemistry That Applies—Michigan Dept. of Education **58**

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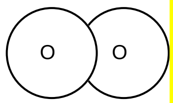
D

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.

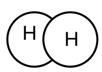
E



O_2—an oxygen molecule

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?

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.



H_2—a hydrogen molecule

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

D. Students will need two water molecules later (in step G) from which to make hydrogen and oxygen molecules.

E. Most model-building is done by making models of the reactants and models of the products. This method often does not get the point across of where these product molecules come from, so in step G we have students take apart the water molecules and use those atoms to build the oxygen and hydrogen molecules.

F. Be sure to collect all unused "atoms" so they cannot pick up these pieces to make the products. If they balance the equation by using multiples of the expected equation (doubling or tripling the quantities), don't have them change it since the equation is balanced and the concept is equally well demonstrated.

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.

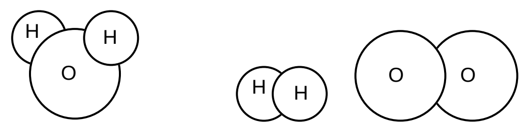
Let's try doing this with your models.

F

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.

G 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.

H 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?

G. When the models are completed, students will draw pictures of the 3-D models that represent the balanced equation. Since the drawings are two-dimensional and the models, like real molecules, are 3-dimensional, the models will look somewhat different from the pictures. It is a good idea to bring this to the students' attention since students often have great difficulty seeing this connection. Be sure they use the same color coding for different kinds of atoms throughout their entire data sheet.

H. Students will begin to construct new knowledge as they see that not only must the kinds of atoms in the reactants and products be the same, but the number of each kind of atom must also be the same. They should also begin to see that the Law of the Conservation of Matter is true because atoms are conserved.

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

QUESTIONS:

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

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

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

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

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

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

CHEMICAL EQUATIONS

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

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

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

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

THINK AND WRITE

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

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