HOW CAN I MAKE NEW STUFF FROM OLD STUFF?

Chemical Reactions and Conservation of Matter

IQWST LEADERSHIP AND DEVELOPMENT TEAM

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Investigating and Questioning
Our World through Science
and Technology
(IQWST)

HOW CAN I MAKE NEW STUFF FROM OLD STUFF?

Chemical Reactions and Conservation of Matter

Student Edition
Introduction to
Chemistry 2 (IC2)
IC2 Stuff SE 2.0.2
ISBN-13: 978-1-937846-94-7

Introduction to Chemistry 2 (IC2)
How Can I Make New Stuff from Old Stuff?
Chemical Reactions and Conservation of Matter

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IQWST (Investigating and Questioning Our World through Science and Technology) was developed with funding from the National Science Foundation grants 0101780 and 0439352 awarded to the University of Michigan, and 0439493 awarded to Northwestern University. The ideas expressed herein are those of members of the development team and not necessarily those of NSF.

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SCIENTIFIC PRINCIPLES

A scientific principle states a scientific idea that is believed to be true based on evidence. As your class decides on new principles in this unit, add them to the list.

SCIENTIFIC PRINCIPLES

DRIVING QUESTION NOTES

Use these sheets to organize and record ideas that will help you answer the Driving Question or your own original questions.

DRIVING QUESTION NOTES

DRIVING QUESTION NOTES

DRIVING QUESTION NOTES

DRIVING QUESTION NOTES

DRIVING QUESTION NOTES

LESSON 1

How Is This Stuff the Same and Different?

ACTIVITY 1.1 – CAN I MAKE NEW STUFF FROM OLD STUFF?

What Will We Do?

We will observe two materials before and after we put them together. Our observations will help us think of questions that we would like to answer in this unit.

Safety

- Copper chloride solution can irritate your skin and eyes.
- Wear safety goggles, gloves, and aprons (if your teacher has them) at all times. Copper chloride solution can irritate your skin and eyes.
- If you get copper chloride solution on your skin or in your eyes, rinse the area with cold water, and tell your teacher immediately.
- Do not handle the beaker after you have mixed the solution and the foil ball. You may touch the sides of the container carefully, but do not pick up the beaker.

Procedure

1. Collect your 150mL beaker with 50mL of copper chloride solution in it.
2. Use a scale to measure 0.5g of aluminum foil, or collect the piece your teacher has premeasured.
3. Look carefully at each material. Record your observations in the table before you move on.
4. Record the temperature of the copper chloride solution.
5. Gently crumple the aluminum foil into a loose ball; do not pack the foil tightly.
6. Gently place the foil ball into the copper chloride solution in the beaker.

7. Use the glass stirring rod to push the foil into the solution. You may stir gently during this activity.

8. Record your observations in the data table.

9. Measure and record the temperature again.

Data

Material	Observations Before	Observations After	Questions
Aluminum Foil			
Copper Chloride Solution			

Conclusion

1. Compare the materials before and after you put them together.

2. If you think about the old stuff as the aluminum foil and copper chloride, do you think new stuff was made when you put them together? Explain your ideas.

3. What questions do you have based on your observations?

ACTIVITY 1.2 – HOW IS THIS STUFF THE SAME AND DIFFERENT?

ACTIVITY 1.3 – DEMONSTRATION AND REVIEW OF SUBSTANCE, MIXTURE, AND PROPERTY

Reading 1.1 – What Is Important about the Stuff I Use?

Getting Ready

Look around you. What do you see? You may see clothes, books, papers, empty soda cans, or leftover pizza. Some people use the word *stuff* to describe all these things. Maybe you have heard someone say, "Look at this mess—there is stuff everywhere." When people use the word *stuff*, they mean anything that takes up space. This unit is about stuff and how it can change into new, different stuff. As you read, think about why someone might want to change the stuff they start with into something new.

Why Would Someone Want to Make New Stuff?

There are many reasons to make new stuff. Scientists develop new materials to make people's lives easier, healthier, safer, or more fun. Medicines are one example. Companies start with substances that are not medicines, and change the substances into medicines that help people.

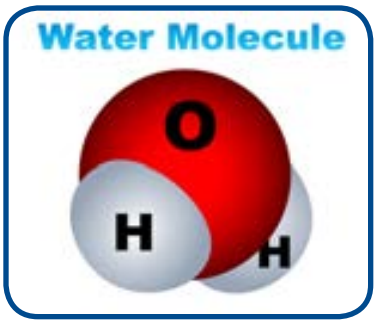
Here is a different type of example: In the early 1900s, animal hair was used to make wigs, toothbrush bristles, and ladies' stockings. Can you imagine brushing your teeth with animal hair? Can you imagine wearing a wig made of animal hair? Later, scientists developed a new material called nylon that could replace animal hair. Nylon is like animal hair in some ways. Nylon and animal hair can both be very flexible, for example. Animal hair and nylon are also different. Animal hair is made by animals, but nylon is created in a laboratory. Nylon bristles last longer in toothbrushes than animal hair does.

Sometimes scientists create new stuff that will solve a problem. Sometimes they make old stuff better. Other times, scientists create new stuff, study and learn about it, and then determine how the new stuff can be used. For example, you might have a polar fleece blanket or sweatshirt. Polar fleece is a material scientists created. They found that polar fleece is similar to wool, but it is not as heavy as wool. Now many people wear polar fleece to keep warm.

New stuff is created for many different reasons. Soda and milk used to come only in glass bottles. Then someone invented plastic. Now you can buy soda and milk in glass or plastic containers. Why do you suppose that someone invented plastic?

A lot of the stuff you use every day was created from other stuff. As scientists experiment, they compare the new stuff they make with the stuff they started with. In this unit, you will explore ways 1) to make new stuff, 2) to study the new stuff, and 3) to compare new stuff to old stuff.

Why might scientists want to compare the new stuff they create to the old stuff they started with?



Scientists have a word for stuff that has mass and volume. That word is *matter*. Sometimes *stuff* is a good word. If someone tells you to move your stuff off the table, you probably know what he or she means; but sometimes it is important to be more specific. You may have already learned that matter is made of particles. For a while, *particles* was the best word for you to use. Then you learned more about particles. You learned that atoms and molecules are specific types of particles. Water is made of water molecules. Water molecules are made of hydrogen and oxygen atoms. The difference between atoms and molecules is important in science, so learning the specific words and what they mean are also important.

In class you studied two unknowns. You made careful observations and descriptions as you compared them. Making observations and keeping notes about them are important processes for scientists to keep track of their progress as they develop new materials or try to solve a problem.

You described the unknowns in many different ways such as color, shape, smell, texture, and hardness. You could tell by feeling and smelling the two materials that they were different. However, saying they are different does not tell what makes them different. One unknown was soap, and the other was fat. Saying they are different cannot help you determine why people use the soap and fat in different ways. For example, what happens when you put soap in water? What happens when you put fat in water? What happens to soap and to fat if you put them in a pan on the stove? Answering questions like these can help you determine why people use soap to wash, and why they use fat to cook.

When you think like a scientist, you ask good questions, and you can figure out how to get answers. The Driving Question for this unit is How Can I Make New Stuff from Old Stuff? To figure out the answer, you will start by thinking about the old stuff that you start with. Today you looked at soap and fat. They might not seem like very exciting materials, but you are going to do some exciting things with them over the next few weeks.

If you think about fat as old stuff, what new stuff do you think it could be made into?

Reading 1.2 – What Makes a Substance a Special Kind of Stuff?

Getting Ready

People describe objects and people all the time in order to tell them apart. You tell two people apart by saying, "The short one, not the tall one." When you have to decide between two pieces of cake, you might choose to eat the large piece instead of the small piece. When scientists need to tell substances apart, they describe the properties of the substances.

You may remember words like substances and properties from previous science classes. In the following space, list the types of properties you have studied in science.

How Can I Use Properties in Science Class and at Home?

Properties are important because they can help you determine how new stuff can be used and how new stuff is better than the stuff people used in the past. Previously you read about scientists creating materials like nylon. By testing and comparing properties of new and old materials like nylon and animal hair, scientists could keep trying to make the perfect toothbrush. The bristles bend just right and do not break.

If scientists did not study properties of materials, then they would not know that nylon could be used for toothbrush bristles. If scientists did not compare the nylon with hair, no one would know that nylon is better than hair for brushing teeth.

In class you will focus on properties because identifying properties of substances helps you answer questions such as how do nylon and animal hair compare? Properties can also be important outside of science class. For example, imagine that someone wanted to sell you a very expensive ring with a shiny stone in it that looked like a diamond. How would you know whether the stone was a real diamond or a fake diamond?

Some stones that look like diamond are not real diamond. Cubic zirconia is one kind of artificial (fake) diamond. Cubic zirconia is a fake because it looks like a diamond, but it is made of different atoms than diamond. Diamond is a substance. It is made only of carbon atoms. Those atoms are arranged in a specific way that makes diamond. Cubic zirconia is also a substance. It is made of zirconium atoms and oxygen atoms (ZrO_2). They are arranged in a specific way that makes cubic zirconia. Cubic zirconia and diamonds are different substances because they are made of different atoms.

Both diamond and cubic zirconia are clear and sparkling. To most people, they look the same. However, diamonds from mines in Africa or India are more valuable and more expensive than cubic zirconia, which can be made in a laboratory. If you knew the properties of diamond and cubic zirconia, and the properties of the stone in a ring, you would be able to tell whether it was diamond or cubic zirconia. You would be sure to pay the right amount of money for your ring.

Are There Ways to Describe a Substance that Are Not Properties?

When scientists talk about substances and their properties, they are talking about what an object is made of, not what it is used for. A block of gold, a gold necklace, and a gold ring could all be made of the same substance—pure gold—even though all three objects are used differently. A property of a substance stays the same no matter how the substance is used. If you use pure gold to make a ring, a necklace, a bracelet, or earrings, the gold that these objects are made of is still the same substance. It will always have the same properties.

How gold is used is not a property of gold as a substance. There are other ways of describing objects that are not properties of the substance they are made of. What are some other ways you could describe a gold ring that are not properties of gold?

Is Gold Always a Substance?

Most people know the substance gold because it is made into jewelry. Do you know someone who wears a gold ring, a necklace, or earrings? Maybe you own gold jewelry. Jewelry that people call gold jewelry sometimes has other substances mixed in it, too. Gold is a substance made only of gold atoms. It is one type of matter all the way through. Gold is also called 24-karat gold, which can be written this way: 24k.

Most jewelry that looks gold to your eye, however, is not made of 24k gold. Gold is a soft metal, which means that it can bend easily. Jewelers have to mix gold with other metals like silver and copper to make jewelry harder so it does not bend. They can mix in different amounts of silver or copper. Depending on how much other metal is mixed in, jewelry could be labeled 18-karat (18k), 14-karat (14k), or 10-karat (10k) gold. The original gold was a substance. It was made of gold particles and nothing else. If silver or

copper is added to it, the material becomes a mixture instead of a substance. Neither 18k nor 14k is just one type of matter all the way through. Both 18k and 14k gold are gold plus other metals. Most of the stuff in the world is 18k or 14k gold jewelry. Most of the stuff in the world is a mixture of materials and not a substance.

Sometimes the way people talk about things gets everybody confused. People say gold jewelry whether they are talking about 24k, 18k, 14k, or 10k gold. All of them look the same color, which is also called gold. Now you know that only 24k gold is gold atoms all the way through. Only 24k gold is a substance. Everything else that people call gold is really a mixture. Everything else is made of gold atoms plus other atoms, like silver or copper.

Scientists can classify all materials as either a substance or a mixture. Chalk has three different types of atoms, but chalk is also pure substance. How can something with different atoms be a pure substance and not a mixture?

What Does It Mean to Be Made of One Type of Matter All the Way Through?

A pure substance is made of only one type of matter all the way through. The matter can be billions of atoms of one type, like gold. Even a very tiny piece of gold is made of billions of gold atoms all the way through, or the matter can be billions of groups of different atoms connected in a specific way. Chalk is made of groups of calcium, carbon, and oxygen atoms connected in a specific way. Chalk is made of billions of those groups, but each group is arranged the same way.

When something is made of one type of matter all the way through, you can take any piece of the substance and it will be exactly the same as any other piece of the same substance. In class, you illustrated this with chalk. Whether your teacher broke off a small piece or a large one, the pieces were made of chalk all the way through. If you were in Mexico or in Japan, chalk would be the same because it is a substance.

What Makes Something a Mixture?

It may help you to think about the difference between pure substances and mixtures if you think about what you already know about mixing. You can mix milk with chocolate powder (or chocolate syrup) to make chocolate milk or to make hot cocoa. Chocolate milk is a mixture.

You mix different materials together to get chocolate milk. Sand is also a mixture. Sand can be made of different kinds of rock, in different size pieces, and in different amounts mixed together. Sand and chocolate milk have something in common that makes them both mixtures. A mixture is made of more than one type of substance, and the combination of the substances can be different.

How Are Substances and Mixtures Different?

A substance always has the same composition. That means it is always composed of, or made of, the same thing. A mixture does not always have the same composition. A mixture can be made of different amounts of each substance. Think about making chocolate milk or cocoa. Chocolate milk may be made of milk and powder, milk and syrup, or milk plus cocoa and sugar. The ingredients in two different packages of chocolate powder or two kinds of syrup might be different, so the chocolate milk you make will be different. In fact, chocolate milk is always made of more than one substance. Chocolate milk is a mixture.

If you like your milk really chocolaty, you can add a lot of powder or syrup, but someone else might choose to add only a little. The composition of chocolate milk can change with different amounts of chocolate and different amounts of milk. Chocolate milk is made of different materials that can be in different amounts every time you make it. Sand and chocolate milk are mixtures because each one is made of different types of materials that can be in different amounts. Sometimes something looks like a pure substance, but it is a mixture. Looking at a sample of a material might help you to know that something is a mixture, but you cannot always tell by looking whether something is a substance. You can tell that sand is a mixture, but you cannot tell whether a gold ring is made of a substance (24k gold) or a mixture (18k, 14k, or 10k gold).

Look at the label on a product that your family buys. You can use either a food label or a product made for cleaning. Find the place where the package describes the ingredient (or ingredients). Write four details: (1) name of the product, (2) what the product is used for, (3) whether the product is a substance or a mixture, and (4) the reason for your answer. Your reason should describe how the product fits the definition of substance or mixture.

LESSON 2

Do Fat and Soap Dissolve in the Same Liquid?

ACTIVITY 2.1 – TEACHER DEMONSTRATION: INVESTIGATING SOLUBILITY

What Will We Do?

We will make observations as our teacher shows us how to measure solubility of substances in oil and water.

ACTIVITY 2.2 – INVESTIGATING SOLUBILITY OF SOAP AND FAT

What Will We Do?

We will measure solubility to give us more information about soap and fat.

Prediction

Do you think fat and soap will have the same solubility? Why?

Safety

Wear safety goggles.

Procedure

Based on the procedure that your teacher demonstrated, write your group's procedure in the following box.

Data

Substance	Observation in Oil	Observation in Water
Fat		
Soap		

Conclusion

What do your data tell you about another way that fat and soap are different? Write a conclusion about whether soap and fat are different substances. Your conclusion should provide evidence from your data table.

Reading 2.1 – Why Can I Easily Wash Soap off My Hands with Water?

Getting Ready

Have you ever tried to wash your hands with butter? You probably have not because butter does not help to make your hands clean. Try it. Rub a small amount of butter, vegetable shortening, or lard on your hands, and try to rinse your hands with water. The fats make your hands slippery, but they do not rinse off easily. This reading will help you understand why you can rinse soap off your hands with water, but you cannot rinse fats off with water. You will have an opportunity to explain this later in the reading.

Solubility: What Does It Mean for a Substance to Be Soluble?

If you sprinkle a little salt into a glass of water and stir, the salt seems to disappear. Instead of seeing pieces of salt in the water, you see cloudy salt water. You do not see the grains of salt, because salt dissolves in water. Scientists say the salt is soluble in water. However, salt does not dissolve in all liquids. When you determine if a substance is soluble in a liquid, you are identifying another property of the substance. The property is called solubility.

Solubility is the capacity of one substance to dissolve in a liquid substance. The substance salt is soluble in water. Solubility in water is a property of salt. Remember that substances have properties that are always the same for that substance. If solubility in water is a property of salt, then it must always be true of salt. You will read more about this in the following sections.

When describing solubility, it is important to name the two substances—the substance being tested (salt) and the liquid substance it is being tested in (water). No one would say that salt is always soluble. Is salt soluble in milk? in cooking oil? in orange juice? Whether or not a substance is soluble depends on the substance and the liquid substance it is being tested in. You always have to name both of them to describe a substance's solubility. A correct way to describe the solubility of salt is to say, salt is soluble in water. Salt is not soluble in oil. If you sprinkle salt in a glass of oil, it will not dissolve.

What do you think would happen if you had a very small amount of water in a glass and you filled the glass with salt? Would the salt dissolve? Give reasons for your answer.

In fact, only some of the salt would actually dissolve, and then the water would not be able to dissolve any more salt. The substance salt is always soluble in water; but you cannot dissolve a lot of salt in a small amount of water. (If possible try this at home to check it out for yourself.) The fact that some of the salt would dissolve in water is evidence that salt is soluble in water. Water can dissolve many substances, but not all substances are soluble in water. For example, aluminum does not dissolve in water. That is why you might see empty soda cans at the bottom of a lake or a river. The substance aluminum is not soluble in water.

Where Does a Substance Go When It Dissolves?

If you stir sugar into a glass of iced tea, the sugar will look like it has disappeared. You know the sugar is still there because the tea tastes sweet. This is an interesting fact about solubility. When a substance is soluble, it might look like it disappears in the liquid, but the substance is still there. The substance breaks up into very small pieces that are too small for you to see. Sugar is soluble in water, and a glass of iced tea is mostly made of water. The particles that make up the solid sugar move away from each other and mix with the particles of the water. Iced tea is another example of a mixture. It is a mixture of water and tea. Sweetened iced tea is a mixture of water, tea, and sugar.

In Lesson 1, you read that toothbrush bristles are made of nylon. Would you use a toothbrush with nylon bristles if nylon were soluble in water? Explain your ideas.

Not All Substances Are Soluble in Water

You have learned that solubility is another property of substances. Some substances are soluble in water, but others are not. Some substances are soluble in oil, or other liquids, and other substances are not. Solubility can help you better describe what substances are and how they can be used. Have you ever had something greasy on your hands that was difficult to wash off? One example is grease from working on machines or engines. Another example is cooking oil or butter.

Now that you have learned about solubility, how can you explain why greasy substances are difficult to wash off?

You have also learned that some ways of describing substances are not properties—like mass, volume, shape, and texture. You have now learned about solubility. Soon you will learn about other properties. Remember, properties help scientists describe substances, identify substances, and to tell samples of different substances apart. These are two lists of what you have learned so far, with the property solubility now added.

Properties	Not Properties
Color	Mass
Solubility	Shape (round, tall)
	Volume
	Texture

How do you know if something is a property or not?

LESSON 3

Do Fat and Soap Melt at Different Temperatures?

ACTIVITY 3.1 – TEACHER DEMONSTRATION OF MELTING POINT

What Will We Do?

We will use different amounts of fat and soap to determine whether the amount affects melting point.

Predictions

Do you think fat and soap will have the same melting point? Explain your ideas.

Do you think the amount of fat will affect its melting point? Explain your ideas.

Do you think the amount of soap will affect its melting point? Explain your ideas.

Safety

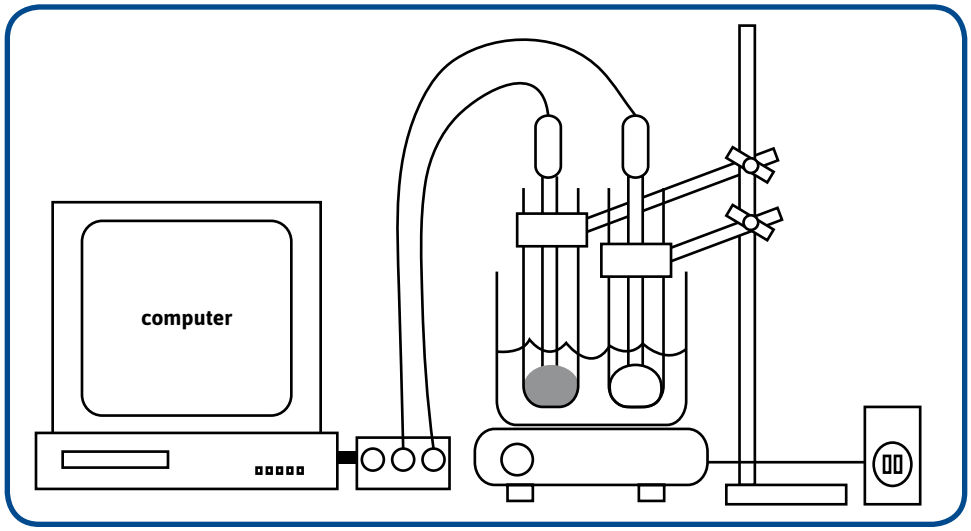
- Wear safety goggles during this investigation.
- Do not touch the top of the hot plates or the beakers. Touching the surface of the plates or beakers could result in a serious burn.
- Be cautious when heating water. Hot water and steam can seriously burn skin.

Procedure

1. Place one or two inches of soap shavings into one test tube.

2. Place one or two inches of fat into the second test tube using a spatula or craft stick. Try not to get fat on the sides of the test tube.

3. Set up your equipment as shown in the following diagram.



Strategy: Make sure the water level in the beaker is above that of the fat and soap.

4. Start the computer program to make a graph of temperature by time.

5. Record the starting temperatures of the fat and soap in the table.

6. Turn the hot plate to medium-high.

7. Observe the fat and soap. When one substance starts to melt, record the temperature in the table.

8. Record the temperature of the melting point of the other substance.

9. When the water starts to boil, end the investigation. Record the temperatures of the fat and soap. Remove the temperature probes. Turn off the hot plate.

Data

Material and Amount	Starting Temperature	Melting Point	Final Temperature (After Water Boiled)
1" of Fat			
2" of Fat			
1" of Soap			
2" of Soap			

Conclusion

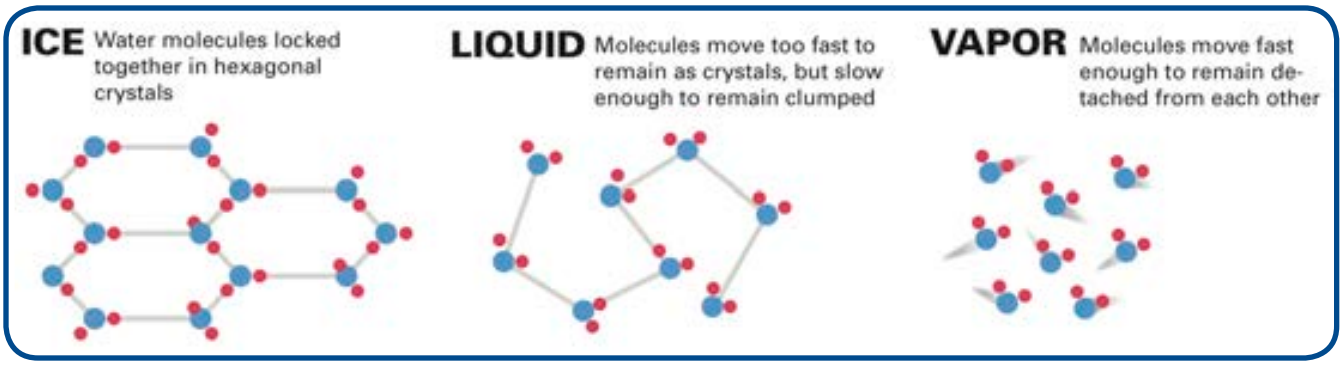
1. Imagine someone who thinks the two white materials are the same because they both look the same. How could you argue that they are different substances?

2. How does the amount of a substance affect its melting point? Write an explanation below. Use your data as evidence.

Reading 3.1 – Melting Points

Getting Ready

Have you ever melted butter in a frying pan or spread butter on hot corn on the cob or rolls? You have already learned that melting is a phase change. Melting is the process through which a substance changes from a solid to a liquid. Look at the diagram of water in three phases—solid, liquid, and gas. The diagram shows what the billions of water molecules do in each phase. Look at each part of the diagram. As you do, think about what the billions of molecules are doing when the butter melts on your food.



As you read, think about when melting point is important outside of science class.

What Is the Difference between Melting and Melting Point?

Butter starts to melt when it reaches a temperature of 32.3°C or 90.1°F. This temperature is called the melting point of butter. *Melting point* is the temperature at which a solid substance starts to become a liquid. A solid substance gets hot, but it does not start to melt until it reaches its melting point.

It is difficult to measure melting point in class. Scientists have tools and techniques they have learned that are difficult to do in a classroom. When you investigated melting butter, fat, and soap in class, you may have had some difficulty.

You learned that a whole stick of butter would take longer to melt than a small piece of butter because there is more of it. The time it takes for a piece of butter to melt depends on the size of the piece. However, the temperature at which each of them starts to melt is the same. Remember that a property of a substance is characteristic of that substance. If you had a huge chunk of butter or a small piece of the same butter, the melting point would be the same. It also does not matter what the shape of the substance is. A stick of butter and a round piece of the same butter have the same melting point. The time it takes to melt may change, but the temperature at which it starts to melt is the same.

Why Is Melting Point Difficult to Measure?

In class, you observed melting point when the substance just started to melt. Depending on where your thermometer was, it could have been still touching some of the solid substance or the thermometer could have been resting completely in the melted butter, while the solid

butter was on the other side of the test tube. Where your thermometer rested, compared to where the solid and the liquid (melted) butter were, made a difference in what you saw. In fact, the solid butter stays at 32.3°C or 90.14°F until it melts. If the solid and liquid are stirred together, the temperature will stay the same until all of the solid melts. Only when the entire solid has melted will the temperature start to rise again. In class, you may have seen something different. You may have observed the temperature increase before the entire solid had melted. If you saw that, it was because the energy was increasing the temperature of the liquid instead of melting the rest of the solid. How evenly the particles of solid and liquid are distributed makes a difference when measuring temperature.

In class you did an experiment to determine the melting points of soap and fat. You can now use your observations as a way to describe how soap and fat are different. The difference in one of their properties was evidence that they are different substances. You can now add melting point to the list of properties you can use to learn about substances.

Properties	Not Properties
Color	Mass
Hardness	Volume
Solubility	Shape (round, tall)
Melting Point	Texture

Do All Substances Have Melting Points?

Look again at the definition of melting point. Do you think that all substances have melting points? For example, do you think aluminum has a melting point? Does oxygen have a melting point? Tell whether you think all substances have a melting point. Give reasons for your answer.

If the definition of melting point is the temperature at which a solid starts to become a liquid, then a substance can only melt if it is in a solid form. A gas does not melt. A liquid does not melt. Think about water as an example. Liquid water does not melt. Water vapor does not melt. When water gets cold enough to become a solid, it can melt when heat is added to it. The substance that ice, liquid water, and water vapor are made of has a melting point. That substance is water.

In fact, all substances have melting points. Think about oxygen for a minute. You probably think of oxygen as a gas. You breathe it in, and you know that people need to breathe oxygen to live. If you could make the temperature really cold, you could turn oxygen gas into solid oxygen. Once oxygen became solid, it could be melted into a liquid.

In everyday experience, however, the temperature is not cold enough to see oxygen as a solid. It is not even safe or possible for your teacher to demonstrate this in the classroom. People must rely on scientists who have done these things to provide other people with information.

The following table shows some of the properties of water and oxygen. Notice that oxygen and water both have melting points.

Substance	Properties		
	Melting Point	Color in the Gas Phase	Color in the Solid Phase
Water	0 °C	Colorless	Colorless
Oxygen	−218.79 °C	Colorless	Light Blue

Some Properties of Water and Oxygen

Look back at the diagram in the Getting Ready section of this reading. Use the diagram to describe the change that would occur if you observed oxygen (O_2) change from a solid into a liquid by melting.

Now think about this: How could knowing the melting point of a substance be helpful to scientists?

ACTIVITY 3.2 – DOES THE SIZE OF SOMETHING AFFECT ITS PROPERTIES?

What Will We Do?

We will measure the hardness of two different lengths of zinc to determine whether size affects the property of hardness.

Prediction

Do you think a short and a long strip of zinc will have the same relative hardness? Why?

Procedure

1. Try to scratch the short strip of zinc using the edge of one of the iron strips:
    - If the edge of the metal strip creates a scratch, the element is harder than the strip being scratched.
    - If the edge of the metal strip does not create a scratch, the element being scratched is harder.
2. Repeat the test with the long strip of zinc.
3. Record the results in the table.
4. Try to scratch the short strip of zinc using the edge of one of the copper strips.
5. Repeat the test with the long strip of zinc.
6. Record the results in the table.
7. Try to scratch the long strip of zinc using the edge of one of the magnesium strips.
8. Repeat the test with the long strip of zinc.
9. Record the results in the table.

Data

Length	Scratched by	Not Scratched by

Conclusion

1. Does the length of the piece of zinc affect the hardness of zinc?

2. Is hardness a property of substances? Write a conclusion based on your data.

Reading 3.2 – Which Properties Can I Use When?

Getting Ready

Imagine that you wanted to test whether the stone in your ring is a diamond or cubic zirconia. What properties could you use to test it? Are there any properties you would not use? To help you answer these two questions, look back at the list of properties you have studied so far.

This reading will help you think about which properties make sense to use to learn about different substances.

When Does It Make Sense to Use Hardness to Learn about a Substance?

Hardness is one property that can help you compare and describe substances. You might remember using hardness to show how elements were different from each other. The Mohs Scale of Hardness is a measurement used to compare substances. Every substance in the world has a hardness between 0 and 10. The higher the number on the scale, the more difficult the substance is to scratch. Diamond is the hardest natural substance that scientists know about. On the Mohs Scale of Hardness, diamond has the highest hardness of 10.0. Diamond always has a hardness of 10.0 whether it is used to make a ring, earrings, or a necklace. Cubic zirconia has a hardness of 8.5. That means cubic zirconia is not as hard as diamond. In fact, diamond can scratch cubic zirconia, but cubic zirconia cannot scratch diamond. Cubic zirconia will always have a hardness of 8.5.

Which property is useful for describing a substance might depend on the state of matter the substance is in. You cannot use the Mohs Scale of Hardness to describe gases. The scale is only useful for solids. You have learned about solubility of solids in liquids, but solubility would not be a useful property for comparing substances in the gaseous state either. As you think about properties, you need to think not only about the substance, but also about the state of matter it is in when you test it.

How does the state of matter affect your answer to the question at the beginning of this reading?

Another Time that Properties May Not Be Helpful for Telling Substances Apart

If you hold a block of pure gold in your hand, you would say the gold looks yellow. You might call the color gold. Because this can be a little confusing, think about the substance as gold and the color as yellow as you read this section. If you wear jewelry that is pure gold, then your ring, necklace, or earrings look yellow. Yellow is the color of each of those gold samples. Gold is yellow because the billions and billions of gold atoms in one piece of jewelry, together, reflect yellowish light.

In this unit, the samples you see and hold are of substances that are made of billions and billions of atoms or molecules. If you split a sample in half, you would still have samples with billions of atoms or molecules. The properties you test from one big sample would still be the same if that sample were split into small pieces. As long as you have billions of atoms or molecules in your sample, the properties would still be the same. The only size piece of a substance it is possible to measure in a classroom—the tiniest piece you can imagine—is still made of billions of atoms or molecules. However, something different happens to properties when the sample has only a few atoms. For example, although a chunk of gold big enough for you to see is yellow, atoms of gold are not yellow. Gold atoms have no color. Individual atoms of any substance have no color. Only when gold atoms are arranged with billions of other gold atoms do they reflect the light that humans see as yellowish.

Scientists have been studying materials made of only a small number of atoms. They are studying samples too small to see with your eyes. They can study samples made of only 30 atoms instead of 300 billion atoms. Scientists have found that when they test materials made of about 30 atoms or fewer, the materials have different properties than when the same substance is made of billions and billions of atoms. Scientists are still learning a lot about materials when they are so small and how the materials can be used in the world. The study of these small amounts of materials is called nanoscience. In this unit, you will not be studying these tiny materials. They are even too small to see with a light microscope. Even though properties of a substance may not be the same at the nanoscale, properties of substances are always the same when you are studying amounts that you can see and hold in your hand.

LESSON 4

What Other Properties Can Distinguish Soap from Fat?

ACTIVITY 4.1 – EXPLORING THE RELATIONSHIP BETWEEN MASS AND VOLUME

What Will We Do?

We will explore the relationship between mass and volume to determine whether that relationship provides scientists with evidence for comparing substances.

Prediction

Do you think knowing the mass and volume of a substance can help you identify the substance? Why?

Procedure

1. Measure the mass of each piece of chalk. Record the masses in Data Table 1. Include the unit grams.

2. Put 50mL of liquid water into a 100mL graduated cylinder. Record the volume of the liquid in Data Table 2.

3. Put the largest piece of chalk into the graduated cylinder containing liquid. Record the volume of the chalk and liquid in Data Table 2.

4. Calculate the volume of the chalk: (Volume of Liquid and Chalk) – (Volume of Liquid) = (Volume of Chalk). Record the volume of the chalk in Data Table 2.

5. Repeat Steps 2–4 for each piece of chalk. Use the same volume of liquid in Step 2.

6. Fill in the Data Table 1 volume column for each piece of chalk. Include the unit cm^3.

7. Calculate the mass divided by the volume for each piece of chalk. Record the measurement in the last column of the table. Include units for both mass and volume.

Data

Table 1			
	Mass	**Volume**	**Mass/Volume**
Chalk #1: large			
Chalk #2: medium			
Chalk #3: small			

Data

Table 2			
	Volume of Chalk and Liquid	**Volume of Liquid**	**Volume of Chalk = (Volume of Chalk and Liquid) Minus (Volume of Liquid)**
Chalk #1: large			
Chalk #2: medium			
Chalk #3: small			

Conclusion

1. Refer to Data Table 1. What general trend do you observe about the data you have collected?

2. Which row in your data table is the same for all pieces of chalk? You know that chalk is a substance, so if this row is the same for all pieces of chalk, do you think this is a property? Why?

Reading 4.1 – How Can Two Objects that Are the Same Size Have Different Masses?

Getting Ready

If you were sitting at a table and in front of you were a loaf of bread and a cement block that were the same size, which one would be heavier?

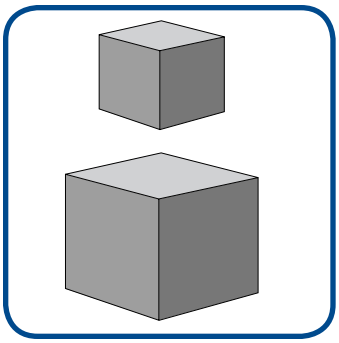
You probably do not need to do scientific tests to answer this question. You could easily pick up the loaf of bread, but the cement block would be harder to pick up. Even if a cement block and a loaf of bread have the same volume, they have different masses. They take up the same amount of space (volume), but the amount of stuff or matter in them is different (mass). Thinking about the bread and cement block may help you learn about another property of substances called density.

Properties	Not Properties
color	mass
hardness	volume
solubility	shape (round, tall)
melting point	texture
density	

Liquids and gases also have density. This reading will focus only on solids, however, like the chalk, soap, and fat you investigated in class.

How Can I Use Mass and Volume to Get a Property Called Density?

Imagine for a moment that one of these two cubes is cement. If you doubled the volume of the cement (if you had twice as much), what would you expect to happen to the mass of the cement? You might suppose that the mass would double because you have twice as much cement as you had before.



What if you broke off a piece of cement (or bread) so that it was only half the volume of the original piece? What would happen to the mass?

Even though cement and bread are not substances, they can help you to understand these concepts:

Whatever you do to volume affects mass the same way.

Whatever you do to mass affects volume the same way.

If you have half as much of a material, you would expect the volume of the material to also be half as much. If you have twice as much of the material, you would expect its volume to also be twice as much. Substances, which you know are always the same throughout, will follow this rule. This relationship between mass and volume will stay the same for any substance, no matter how much of that substance you can sample and measure in the classroom.

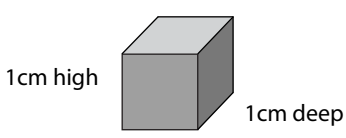
Why is this principle about the relationship between mass and volume always true of substances, but not always true of mixtures?

The relationship between mass and volume is what scientists call density. Density is the mass in a set volume of a substance. You may have heard the word *dense* before. When something is dense, it has a lot of mass for a little volume. You could say that cement is denser than bread. The amount of mass for a set volume of cement is more than the amount of mass for that same volume of bread. This mass-volume relationship is important because every substance has a specific mass-to-volume relationship. Every substance has a specific density.

How Can You Determine Density from the Mass-Volume Relationship?

In class, you saw that pieces of chalk had the same density, even though they were different sizes. First, you measured the mass and volume of each piece of chalk. Then, for each piece, you divided its mass by its volume. The numbers you calculated for each piece of chalk should have been very similar to each other, around 2.4 g/cm^3. The *g* stands for grams (the mass of the chalk). The cm^3 stands for cubic centimeters (the volume of the chalk). The number with the g/cm^3 is the density of the chalk. You read the measurement, grams per cubic centimeter. It tells you about the mass-to-volume relationship.

The measurement of volume that scientists use when talking about density is 1 cubic centimeter ($1cm^3$). The following cube is approximately $1cm^3$. One cubic centimeter is a measurement for the volume of substances. The cube takes up space that is 1cm high, 1cm wide, and 1cm deep. When you calculate the density of chalk, it is like you are saying for every 1 cubic centimeter of chalk, you would have 2.4 grams of chalk.



Two Ways to Measure Volume

In class, you learned that the unit 1cm^3 and 1mL are two ways of stating the same measurement. You can see this by measuring an amount of water in a graduated cylinder. If you drop a 1cm^3 block into the cylinder, the amount of water it displaces will equal 1mL. Look at the picture of the graduated cylinder. If the water level starts at 30mL and you drop the 1cm^3 block into the water, the water level will rise to 31mL. That means that the water has been displaced by 1mL (31mL minus 30mL equals 1mL). In other words, a 1cm^3 block displaces water by 1mL.

These two units—1cm^3 and 1mL—can both be used to represent the same measurement. If you have the opportunity, you can do this in class so that you can see they are the same. When you refer to density, you can use either measurement, just as scientists can.

31mL (water measurement after adding 1cm^3 cube)

– 30mL (water measurement to begin)

1mL (difference = amount of water displaced)

Therefore, 1cm^3 = 1mL.

Density Tells You about a Substance

If you know the volume of a substance, the density can help you predict how much of a substance you have without measuring its mass. If you know its mass and its density, you know how much space a substance will occupy.

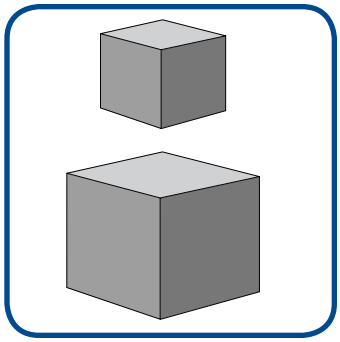
The density of aluminum is always 2.7g/mL no matter how big or small the piece is. Use aluminum's density to fill in the missing boxes in the following table.

To fill in the boxes, ask yourself: If I have 2.7g of aluminum for every 1cm^3, then how much aluminum would be in 2cm^3? Based on aluminum's density, how much volume (how many cm^3) would 0.85g of aluminum have? Remember that whatever you do to a set volume of a substance affects the mass in the same way.

Determining the Volume or Mass of Aluminum Based on Its Density

Substance	Volume	Mass	Density
Aluminum	1cm^3	2.7g	2.7g/cm^3
Aluminum	2cm^3		2.7g/cm^3
Aluminum		0.85g	2.7 g/cm^3

How Do Scientists Always Get 1cm^3 When Figuring a Substance's Density?



It is often difficult to determine the density of something because most objects and most samples of substances are not exactly one cubic centimeter in size. Scientists use math to determine density no matter what mass or volume of a substance they have.

As long as you know the mass and volume of something, you can determine the density by determining the mass to volume ratio. You can do this by dividing the mass by the volume:

mass ÷ volume = density.

Using the formula, a person can determine the density of the bread and cement block, for example, even though they have a whole loaf of bread and a whole cement block in front of them. The formula allows a person to calculate without having a 1cm^3 sample of each substance. The formula allows scientists (or you) to calculate density of any substance no matter what mass or volume of that substance they are measuring.

Density is a property of substances because every substance has a characteristic density, and that density does not change. A substance always has the same density. A small sample of the substance has less mass and takes up less space, but it has the same density as a different sample of the same substance. If the two cubes were both made of iron, their density would be the same. It does not matter if the larger sample has more mass and takes up more space. The mass and volume change, but the density of a substance is always the same.

If you tripled the volume of your sample of chalk, what would happen to the mass?

If you doubled the volume of your sample of chalk, what would happen to the density?

Try This at Home

Here is another way to observe the principle of density that may give you some surprises. Ask an adult if you can try this experiment at home. You will need a glass container that you can see through—a drinking glass, measuring cup, or empty jar will work. One at a time, you should slowly pour equal amounts of the following three liquids into the container:

- vegetable oil or baby oil
- corn syrup or pancake syrup
- water

Keep a chart of your observations. You may even want to draw what you see. What do you observe? What does this tell you about the density of the liquids and the objects you put into them?

Now, predict what will happen when you add some objects to your container. Try adding a paper clip or a safety pin, a toothpick or a cork, a grape or a raisin, a birthday candle, and a rubber pencil eraser. If an adult can show you how to separate an egg yolk from the egg white, predict what will happen when you drop an egg yolk into the container. Then do it. What does this investigation tell you about the densities of the materials you used? Maybe you can report what you learned back to your classmates.

ACTIVITY 4.2 – DO FAT AND SOAP HAVE THE SAME DENSITY?

What Will We Do?

We will collect data about one more property that can determine whether substances are the same or different.

Prediction

Do you think that fat and soap have the same density? Why?

Safety

Wear safety goggles.

Procedure

1. Measure the mass of a piece of fat using a balance. Record the mass.
2. Measure 25mL rubbing alcohol into a 100mL graduated cylinder. Record the volume.
3. Put the piece of fat into the graduated cylinder. Record the volume.
4. Subtract to calculate the volume of the solid. Record the volume.
5. Divide to calculate the density. Record the density.
6. Repeat Steps 1–5 with the piece of soap.

Data

	Fat	Soap
Mass of Solid		
Volume of Liquid + Solid		
Volume of Liquid		
Volume of Solid		
Density = (g/cm^3) Volume of Solid		

During class discussion, you may choose to create a table to record each group's density data. Even if data differ across groups, analyze the class data to determine what trend you see.

Conclusion

1. Which rows in your data table provide evidence that fat and soap are different substances? Which rows in your data table do not help you? Why?

2. If you measured an entire bar of soap and compared it to the piece of soap from this activity, would the bar and the piece have the same mass, volume, and density? Why?

3. Why do you think the fat sank in the liquid in the graduated cylinder, but soap floated?

LESSON 5

How Are Fat and Soap Different?

ACTIVITY 5.1 – ARE FAT AND SOAP THE SAME OR DIFFERENT SUBSTANCES?

What Will We Do?

We will construct an explanation about whether soap and fat are the same substance using our data from several lessons as evidence.

Procedure

1. Look at your activity sheets from Lessons 1–4 to complete the data table.

2. Fill in all of the properties for fat and soap in the following table.

Data

	Properties				
	Color	Hardness	Solubility	Melting Point	Density
Fat					
Soap					

Conclusion

Write a scientific explanation that answers the following question: How do you know scientifically that fat and soap are different substances?

Checklist

- [ ] Does the claim clearly state a conclusion about soap and fat?
- [ ] Does the explanation include appropriate evidence?

  (Think about what kind of evidence would not be appropriate.)
- [ ] Does the explanation include sufficient evidence?

  (Is all of the important data from the table included?)
- [ ] Is there reasoning that helps you understand how the evidence connects to the claim?

  (Think about what you have learned that makes certain data important for this claim.)
- [ ] Does the explanation include one or more appropriate scientific principles?

Reading 5.1 – What Evidence Would I Use to Tell if the Stones in a Ring Are the Same or Different?

Getting Ready

Scientists often investigate something and then share their findings with other people. Imagine a scientist telling you that "Shampoo X" is better for your hair than "Shampoo Y." What are some things you would want to know about that scientist's investigation before you make a decision about whether to buy Shampoo X or Shampoo Y?

Just saying one is better than another is not useful in helping you choose which shampoo to buy. You might ask questions like the following: "How did you figure out that Shampoo X is better?" "What evidence do you have?" "Did you test it on hair that is different colors and different textures?" "In what way is Shampoo X better?" "Does it matter how often you use it?" You might ask these questions because the answers would help you to decide if you agree or disagree with the scientist. The answers would also help you decide if Shampoo X is better than Shampoo Y. This section is about one reason scientists use scientific explanations. Scientific explanations communicate your ideas so that other people can decide whether they agree or disagree with you or whether they think your explanation of something in science makes sense. In class you wrote a scientific explanation about whether fat and soap were the same substance; to support your claim you provided evidence and reasoning.

What Are the Parts of This Scientific Explanation about Shampoo?

Remember a useful scientific explanation is not just a simple answer. A useful explanation includes a claim, evidence to support the claim, and reasoning that uses scientific principles to describe how the evidence supports the claim.

In the shampoo example, the question might have been "Which shampoo is better for protecting hair from the sun, Shampoo X or Shampoo Y?" The scientist's claim in this example is: Shampoo X is better for you than Shampoo Y. The claim would be better if it told how Shampoo X is better. This is a better claim: Shampoo X is better than Shampoo Y at protecting hair from damage by the sun.

The scientist in the shampoo example probably has evidence. However, if he or she does not use data as evidence in the explanation, there is no reason to believe that the claim is a good one. You need to know what tests the scientist did and what he or she learned from those tests. For example, if tests show that Shampoo X contains a particular ingredient that is

also found in sunscreen, but Shampoo Y does not contain that ingredient, that could be one piece of evidence for the scientist's claim. Data from an experiment become evidence when you use the data to support a claim you have made.

Reasoning illustrates why the data count as evidence to support the claim. Reasoning includes the important scientific principles. You might ask, "What do people know in science that can help to explain these findings?" In the shampoo example, the scientist should tell what he or she knows about the importance of sunscreen, for example.

Anyone can make a claim, but a good scientific explanation includes the evidence and reasoning that show the claim to be true. You do not know any of this kind of information if someone only says, "Shampoo X is better for your hair than Shampoo Y." There is no reason to believe this person's claim to be true without more information.

Constructing a Scientific Argument

In this section, you will practice constructing an argument by looking at data from two rings. Here are two rings that look very similar. The stones in the rings look the same. They are the same size. Both rings occupy the same volume.

The following table summarizes some properties of the stones in each ring. The table gives you data you need to compare the stones. Decide whether they are the same or different substances. Your argument needs a claim, evidence, and reasoning that shows how the data you choose connects with the claim you make. Your reasoning will need to include scientific principles about substances and properties.

	Properties				
	Density	Color	Hardness	Melting Point	Solubility in Water
Stones in Ring #1	5.92g/cm^3	No color	8.5	2759°C	No
Stones in Ring #2	3.52g/cm^3	No color	10.0	3547°C	No

Some Properties of the Unknown Substances in Two Rings

Are the stones in Ring 1 and in Ring 2 the same or different substances? Construct an argument in the following box.

LESSON 6

What Happens to Properties When I Combine Substances?

ACTIVITY 6.1 – TEACHER DEMONSTRATION OF INVESTIGATION PROCEDURE

What Will We Do?

We will investigate what happens when we bring together baking soda, road salt, and water.

Safety

- Wear safety goggles and an apron.
- Wash your hands after you finish the investigation.

Procedure

1. Make careful observations of the materials in the bag. Record your observations in the data table.
2. Record the solubility data about baking soda and road salt from Lesson 2.
3. Put 1tsp of baking soda and 2tsp of road salt into a plastic bag.
4. Use a graduated cylinder to measure 10mL of water. Pour the water into a small container.
5. Carefully set the container inside the bag without tipping.
6. Do not spill the container as you zip the bag closed.
7. Tip over the container inside the sealed bag.
8. Make careful observations. Record your observations.

Data

Observations Before Mixing Substances				
Substance	**Color**	**Solubility in Water**	**State of Matter**	**Other Observations**
Baking Soda				
Road Salt				
Observations After Mixing Substances				

Conclusions

Talk with your group about what you observed. Discuss how to answer this question: What happened when we mixed substances together? Write a scientific explanation including a claim, evidence, and reasoning.

Reading 6.1 – Could Someone Change Straw into Gold?

Getting Ready

When you were younger, did you ever read fairy tales? In this lesson, you will read a fairy tale that you might know. The story will help you think about making new substances from old substances.

Fairy tales are very old. They come from many different countries. Many countries have a story like *Cinderella*, but the story is a little different depending on where it began. If you know fairy tales from other countries, you may realize that this one is similar to another story you know. This one is called *Rumpelstiltskin* (rum-pull-stilt-skin).

Often fairy tales use language that seems strange. For example, in this story a character uses words like *thereupon* and *alas*. You probably do not use these words, but you can still understand the story even when you do not know every word. What follows is the first part of *Rumpelstiltskin*. It is just enough of the story to get you thinking about some important things in science. The first character you meet is a miller. A miller makes flour out of grain.

Rumpelstiltskin, a fairy tale adapted from the brothers Grimm

Once there was a miller who was poor, but who had a beautiful daughter. Now it happened that he had to go and speak to the king, and in order to make himself appear important, he told the king he had a daughter who can spin straw into gold.

The king said to the miller, "That is an art which pleases me well. If your daughter is as clever as you say, bring her tomorrow to my palace, and I will put her to the test."

When the girl was brought to him, he took her into a room which was quite full of straw, gave her a spinning-wheel and a reel, and said, "Now set to work, and if by tomorrow morning early you have not spun this straw into gold during the night, you must die."

Thereupon he locked up the room, and left her in it alone. There sat the poor miller's daughter, and for the life of her could not tell what to do. She had no idea how straw could be spun into gold, and she grew more and more frightened, until at last she began to weep.

Suddenly the door opened, and in came a little man who said, "Good evening, mistress miller. Why are you crying so?"

"Alas," answered the girl, "I have to spin straw into gold, and I do not know how to do it."

"What will you give me," said the little man, "if I do it for you?"

"My necklace," said the girl.

The little man took the necklace, seated himself in front of the wheel, and whirr, whirr, whirr, three turns, and the reel was full. Then he put another on, and whirr, whirr, whirr, and the second was full too. So it went on until the morning, when all the straw was spun, and all the reels were full of gold.

These questions will help you think about how the fairy tale *Rumpelstiltskin* relates to science.

1. Do you think straw can be turned into gold? Give reasons for your answer.

2. a. If someone gave you flour, sugar, butter, eggs, baking soda, and salt, what could those ingredients turn into?

   b. What else would have to happen in order for those ingredients to be turned into something new? (Hint: If you just put all of the ingredients on the kitchen counter, nothing would happen. What else would you have to do?)

3. Why can certain things only be turned into certain other things? For example, if you mixed flour, sugar, eggs, and other ingredients, you will not make gold. You will not make rubber, or diamond, or straw either. Why not? In the following space, explain why someone cannot make gold by mixing flour, sugar, and eggs.

Reading 6.2 – What Is a Chemical Reaction?

Getting Ready

Have you ever baked a cake? First you combine flour, sugar, eggs, and other ingredients. Then you pour the batter in a pan and put it in the oven. When you take it out of the oven, it is a cake. Do you think the ingredients changing into a cake in the oven are a chemical reaction? Explain why you think baking a cake is or is not a chemical reaction.

In this reading, you will learn more about chemical reactions. You will also learn how to find out whether baking a cake is a chemical reaction.

In class you observed a chemical reaction when you mixed road salt and baking soda in water. First you put two white solids into a bag. Then you put a cup of water in the bag without spilling it. After you closed the bag, you tipped the cup, and the liquid and solids combined. Once the substances combined, changes occurred. For example, you may have seen bubbles, the bag expanding, and a white solid form that did not dissolve. These changes are evidence that a change, called a chemical reaction, occurred.

A chemical reaction happens when two or more substances combine with each other in a way that makes new substances form. The substances are new because they are different from the substances you started with. The substances that you started with changed into different substances.

How Can I Know Whether New Substances Formed?

Remember learning about smell and how to tell if two substances are different? You may have learned that when substances are different, the properties of the substances are also different. If old substances change into new substances, the properties of the new substances will be different from the properties of the old substances.

If substances have different properties before and after a process, then a chemical reaction occurs. If properties change, something has to have happened. The substances are not the same substances anymore. When there are different substances with different properties before and after a process, a chemical reaction occurred. In this example, the process was stirring the ingredients together.

The things you observed in the sandwich bag experiment are evidence that a chemical reaction occurred. They are evidence of new substances that have different properties from the old substances.

Your observation of bubbles, the expanding bag, and the white solid that did not dissolve are evidence of a property change. You did not do anything else to the bag except mix the

ingredients together. For example, you kept the bag at room temperature. Before mixing the substances, there was a little air in the bag, along with solids and a liquid. Then when you mixed the substances, you observed bubbles, and the bag got bigger. These observations are evidence that a gas formed. Before mixing, there was only a little gas in the bag, but after mixing, there was a lot of gas in the bag. That change is evidence that a new substance in the gas phase formed. You also know that the solids you started with dissolve in water, yet you ended up with a solid that was not soluble in water. A difference in the property solubility is more evidence that a new substance formed.

Remember that to tell for sure whether a chemical reaction occurred, a scientist must test the properties of the substances before and after a process. If a chemical reaction occurred, the properties of the materials will have changed. This is what always happens in a chemical reaction. New, different substances with different properties form.

What If I Mix Substances and the Properties Do Not Change?

If substances have the same properties before and after mixing or heating, a chemical reaction probably did not occur. This makes sense because the definition of a chemical reaction includes making new substances. If there are no changes in properties, there are probably no new substances. If there are no new substances, there was not a chemical reaction.

Now look at the Getting Ready in this lesson. Would you still give the same answer? In the space below, describe what you could do to determine whether baking a cake is a chemical reaction or not? What test(s) could you do?

The experiment you did in class was a very complex chemical reaction. It involved many new substances and old substances. When a reaction is very complex, an easy way to compare substances is to compare only the substances that are in the same state of matter. That means comparing only the solids, only the liquids, or only the gases.

The following table tells the names and properties of the solid ingredients that were in the bag before mixing and after mixing. The table also shows properties of the solid substances. In class, you focused on the state of matter at room temperature. You also know about other properties, like melting point, solubility, and density. This table describes all of these properties, but only for the solid substances.

Solids		**Properties**		
		Melting Point	Solubility in Water	Density (at 20°C)
Substances (Before Mixing)	Road Salt	775°C	Yes	2.15g/cm^3
	Baking Soda	None*	Yes	2.20g/cm^3
Substances (After Mixing)	Table Salt	800.7°C	Yes	2.17g/cm^3
	Chalk	1330°C	No	2.71g/cm^3

After mixing, you saw a white substance, called a precipitate, in the bag. If you filtered the precipitate, you would get solid chalk. If you put the chalk in water, you would see more clearly that it is not soluble. If you let the water evaporate after you filter out the precipitate, you would see that the solution also contains sodium chloride, which is salt. What you did in class is complicated. The table will help you focus on only the solid substances as you think about what happened in your investigation.

Properties of the Solid Substances in the Plastic Bag Experiment Before and After Mixing

When solid baking soda is heated, it breaks apart before it can become a liquid (melt). Scientists sometimes say that a substance that breaks apart before it can melt decomposes. Baking soda, for example, decomposes at approximately 55°C.

Did a chemical reaction occur in the plastic bag experiment? Construct an argument that uses data from the table as evidence to support your claim.

Can Straw Really Turn into Gold?

Now that you know a little more about chemical reactions, think about the *Rumpelstiltskin* story. In the fairy tale, one substance was involved in a process—spinning on the wheel—and then a different substance was made. Straw turned into gold. If the fairy tale were real, then that change would be called a chemical reaction. The substance that *Rumpelstiltskin* started with (straw) was different from the substance he ended with (gold). In real life, substances can change into other substances, but only in a fairy tale could straw turn into gold. Why? (Hint: Think about what gold is made of.) What is the scientific reason that straw cannot be turned into gold?

LESSON 7

Is Burning a Chemical Reaction?

ACTIVITY 7.1 – IS BURNING A CHEMICAL REACTION?

What Will We Do?

We will watch magnesium burn and then use data to determine whether burning is a chemical reaction.

What data will you need to determine whether a chemical reaction occurred?

Safety

- Wear safety goggles.
- Do not look directly at the burning magnesium.

Procedure

1. Observe both solids. Compare the solid magnesium (Mg) before burning and after burning.
2. Record color, hardness, and solubility data in the table.

Data

	Properties of Magnesium		
Solid	Color	Hardness	Solubility in Water
Before Burning			
After Burning			

Conclusion

Did a chemical reaction occur when your teacher burned magnesium? Use data from the preceding table as evidence for your argument.

Representing Chemical Reactions

In the following space write the word equation for burning magnesium. Label the reactants and products in the equation.

In the following space, draw a representation of the ball-and-stick model of the chemical reaction.

In the following space write the chemical equation using the chemical formulas.

Reading 7.1 – Is Burning a Chemical Reaction?

Getting Ready

Chemical reactions occur all around you. They do not happen just in the laboratory or in science class. For example, when you light a sparkler, you observe a chemical reaction. What do you think the old stuff and the new stuff are in the chemical reaction that makes a sparker light up?

Now read about sparklers and the chemical reaction that makes them light up.

Why Do Sparklers Light Up?

When your teacher burned magnesium in class, were you surprised by what happened? Burning is always a chemical reaction, even though it does not always make such a bright light.

The reaction you saw in class was similar to the reaction that occurs when you burn a sparkler. Sparklers can be made of different metals, but all sparklers work in a similar way. As a sparkler burns, the metal of the sparkler and oxygen from the air interact and form a new substance. The reaction would take a very long time if you just waited for it to happen. A flame gets the reaction started quickly. Often something needs to happen to get a chemical reaction started.

Substances may need to be mixed or heated first. Even if you mix all the right ingredients in the kitchen, they do not become a cake as they sit on the table. The ingredients need to be mixed and cooked. Then they interact to become something new—a cake.

In class, your teacher lit a magnesium strip with a flame. Then the oxygen and magnesium interacted to create magnesium oxide. Magnesium oxide was a new substance. As you saw in class, the reaction also produces bright light. This reaction is similar to the reaction that happens when you light a sparkler. Fireworks are another similar reaction. Once a flame lights the fuse, a chemical reaction happens to cause fireworks.

Fireworks can be many colors. You have probably seen green, red, and many other colors in the sky. Think about what you have learned about chemical reactions so far. What do you think makes fireworks different colors?

What Is the Chemical Reaction that Makes Fireworks Work?

Think about what you see and hear when you see fireworks. First, you hear a loud noise. Second, you see something shoot up into the sky. Third, you see a burst of color high in the air. What chemical reactions make this happen?

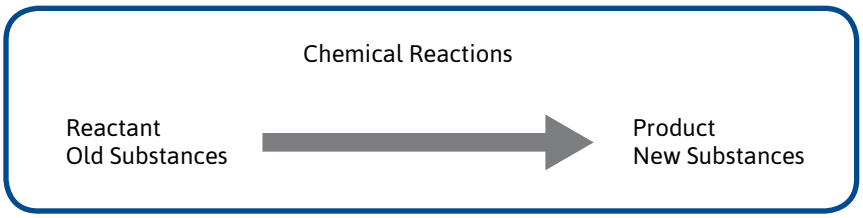
When a flame lights the fuel in a firework rocket, a chemical reaction occurs between the fuel and the oxygen. This reaction produces a gas. The gas escapes out of one end of the rocket, causing it to shoot into the sky. Once the rocket is in the sky, other substances inside the rocket are lit. Those substances react with the oxygen in the air. This reaction creates the burst of bright colors that you see in the sky. When you see many colors, it is because many chemical reactions are occurring. Each color and each sound is created by a different substance involved in different chemical reactions.

Reactants and Products in Chemical Reactions

In a chemical reaction, the old substances that interact with each other to form new substances are called reactants. The reactants are the starting substances in a chemical reaction. It may help you to think about the reactants as the substances that act together. In the sandwich bag experiment, the substances you started with in the bag were the reactants. The products are the substances you ended up with after you tipped over the test tube. The products of a chemical reaction are the substances you end up with. They are the new substances.

A reactant is a starting substance in a chemical reaction. → A product is the substance made by a chemical reaction.

Scientists represent chemical reactions in a variety of ways. In the representations that precede and follow, you see an arrow. The arrow is an important symbol scientists use when they write chemical equations. The arrow means *goes to form*. You could also think of it as *changes to*.



The paragraph about sparklers tells you some of the reactants and products when your teacher burned magnesium in class. Look back at that paragraph and find the reactants and products. In the following space, write a chemical equation that shows what the reactants and products were in that chemical reaction:

When you write about a reaction, you are writing a chemical equation. A chemical equation is a way to represent chemical reactions. The equations include plus (+) signs and an arrow. Notice that the reactants side of this chemical reaction has a plus (+) sign. Usually in math a plus sign means adding or combining. In a chemical equation, the plus sign means that the reactants are interacting. In some chemical reactions, the old substances interact by combining and forming one new substance. In other reactions, the old substances interact and form two or more new substances.

What Other Ways Can I Represent a Chemical Reaction?

Previously you represented the magnesium reaction with a chemical equation. It included the substances' names and the plus and arrow symbols. In class you represented the substances in other ways. For example, you used molecular formulas (numbers and letter-symbols of atoms) to represent substances. You also used marshmallows to model how magnesium metal and oxygen gas changed and a new substance formed.

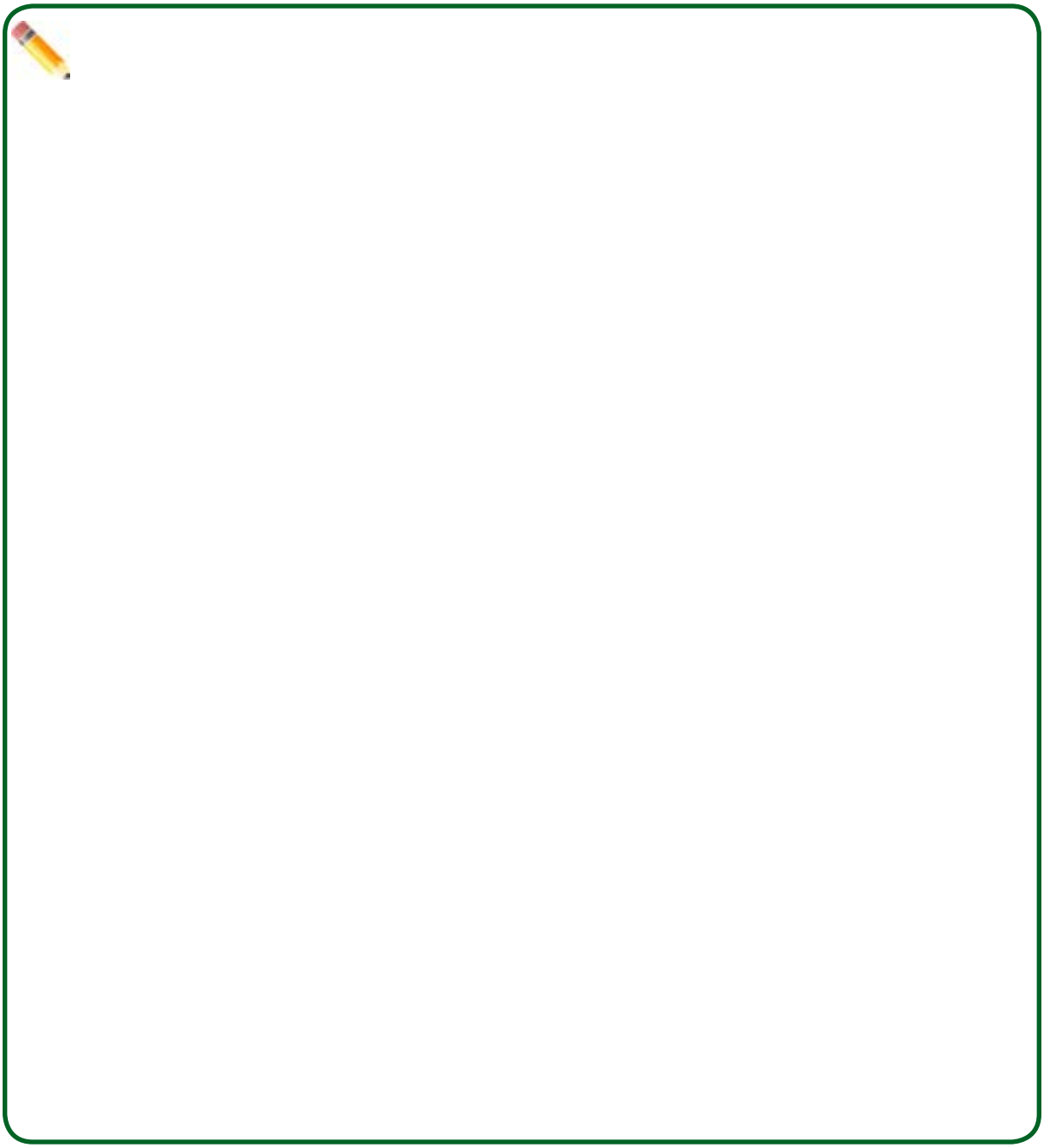
What follows is the magnesium reaction in a chemical equation—this time, using a molecular formula:

$$2Mg + O_2 \rightarrow 2MgO.$$

(two magnesium atoms) (one oxygen molecule) (two molecules of magnesium oxide)

This chemical equation tells more about the atoms and molecules of each substance. You can see the number of atoms and the types of atoms. You can see the number of molecules and the types of molecules. You can see which atoms and molecules react and what they form. A chemical equation can help you understand what is happening to the old substances and new substances in a chemical reaction.

Look at the symbols for magnesium, oxygen, and magnesium oxide shown previously. Use the following space to draw a model of what happened in this chemical reaction. You may choose to draw atoms as marshmallows if thinking about what you did in class is helpful to you.



LESSON 8

Does Acid Rain Make New Substances?

ACTIVITY 8.1 – HOW CAN I INVESTIGATE ACID RAIN IN MY CLASSROOM?

What Will We Do?

We will create a model to help us investigate whether acid affects copper.

Safety

- Wear safety goggles.
- Do not touch chemicals to your mouth.
    - Do not handle modeling clay if you are allergic to its ingredients.

Procedure

1. Pour some vinegar into a Petri dish so it covers the bottom of the dish.
2. Pour some water into a second Petri dish.
3. Stick the edge of a copper square into a piece of clay so the square stands upright.
4. Carefully place the piece of clay with the copper square into the Petri dish with the vinegar. Do not let the square touch the vinegar in the dish.
5. Stick the edge of another copper square into a second piece of clay so the square stands upright.
6. Carefully place this piece of clay with the square into the Petri dish with the water.

7. Label the bottom of each clear plastic cup with your group's name.

8. Place an upside-down cup into each Petri dish to cover the two copper squares.

Prediction

Write a prediction about what you think will happen to the copper squares.

Reading 8.1 – Why Is the Statue of Liberty Green?

Getting Ready

Have you ever seen a green steeple, or a green roof on a building? Did you know that they started out being the same color as a shiny new copper square? Some steeples and roofs have a layer of copper on them, just like a copper square does. A copper square and a roof can be made of similar materials, but they do not appear the same color.

Why do you think steeples and roofs might appear green, but a copper square does not?

Why Does Copper Sometimes Turn Green?

Copper is a brown-color metal. Sometimes it is shiny and sometimes it is not. Many steeples and roofs made with copper are not that brown color, however. Instead, they are green. Something happened to the copper on those buildings so that it no longer appears brown like the brown color of a copper penny.

Something also happened to the Statue of Liberty. If you have ever visited the Statue of Liberty or seen color photos of it, you know that the Statue of Liberty looks green. When it was completed in 1886, the Statue of Liberty was the color of a new penny. By the time 20 years had passed, the statue appeared to be green instead. The Statue of Liberty also has a surface made of copper. What happened so that these roofs, steeples, and the Statue of Liberty turned green?

The green color appeared because a chemical reaction took place. The chemical reaction occurred between two substances. One substance was copper, and the other was acid rain. Acid rain is a name for rainwater that has certain substances mixed in it. These substances get in the air as factories burn coal. Sulfuric acid is one pollutant that makes up acid rain. As acid rain fell on the Statue of Liberty, the sulfuric acid reacted with the copper. A new, green substance formed from the reaction. Most of the new green substance is copper sulfate. Copper sulfate is green. The Statue of Liberty appears green because the copper that forms its outside layer is covered in green copper sulfate.

In class, you will use a copper square to complete an investigation similar to the one that changed the way the Statue of Liberty looks. Since you do not want to be in this class for 20 years while you wait for the reaction to occur, you will change conditions so the reaction will go much faster than the one on the Stature of Liberty. Instead of sulfuric acid, you will use acetic acid. Acetic acid is a scientific name for a substance that makes up vinegar. You will place the copper square in a saturated environment of acetic acid.

ACTIVITY 8.2 – DOES ACID RAIN MAKE NEW SUBSTANCES?

What Will We Do?

We will examine the results of the experiment to determine whether a chemical reaction occurred.

What data will you need to determine whether a chemical reaction occurred?

Safety

- Wear safety goggles.
- Wash your hands after touching the copper squares from your experiment.
- Follow your teacher's directions for holding and shaking the test tube.

Procedure

1. Get your group's experiment from Activity 8.1.
2. Remove the copper square from the Petri dish containing the vinegar. Put the cup back over the Petri dish when you have removed the copper square.
3. Remove the copper square from the Petri dish containing the water.
4. Compare the copper square that was in the Petri dish with vinegar to the copper square that was in the Petri dish with water.
5. Record color and hardness information in the Data table.
6. Place each copper square into a separate test tube; label the test tubes.
7. Pour warm tap water into the test tube until it is 2/3 full.
8. Put a stopper on the test tube.
9. Carefully swirl the test tube for one minute. (Forceful shaking can cause the test tube to break.) Let it settle.
10. Record solubility data in the table.

11. Repeat steps 6–10 for the solid on the copper square after the experiment.

12. Keep your experiment set up for tomorrow.

Data

Substance		Properties				
		Color	Hardness	Solubility in Water	Density	Melting Point
Before Experiment						
	Vinegar	No color	Liquid	Soluble	1.04g/cm^3	17°C
After Experiment						

Additional Data

A scientist collected some additional data about the substances in your experiment. Add the following data to your table. Density of copper square before experiment: 8.96 g/cm^3 and melting point 1084°C, and density of the solid on the copper after the experiment: 1.88 g/cm^3 and melting point 115°C.

Conclusion

1. Does acid rain make new substances? Construct an argument that uses data from this investigation as evidence for your claim.

2. The solid on the copper square after the experiment is called copper acetate. Write a word equation to represent what happened to substances in the experiment. Label the reactants and products in the equation.

3. Give some other examples of everyday problems that you think involve the green substances copper acetate or copper sulfate.

Reading 8.2 – Does Acid Rain Make New Substances?

Getting Ready

You have learned that the Statue of Liberty turned green because of a chemical reaction. Perhaps you know that people's hair can also turn green. People with blonde hair may have experienced this. When you swim in a pool, a green substance can form on your hair. It shows on blonde hair, but it does not show on dark hair. It does not happen when people swim in lakes—only in pools.

Use what you know about statues, roofs, and pennies to make a guess about hair. How do you think the green substance on these other objects could be related to the green substance people get on their hair when they swim in a pool?

Copper Is Involved in Several Chemical Reactions

In class you completed an investigation in which copper reacted with acetic acid to produce copper acetate. You used a copper square and vinegar. The copper acetate that formed was a new substance. People who wear copper bracelets have probably seen this reaction. When someone wears copper jewelry, the sweat in their skin contains acids that react with copper. This reaction produces a green substance. The substance is similar to the one on the copper square or a penny and similar to the one on the Statue of Liberty.

Another example of this kind of reaction occurs when people swim in pools. Chlorine and other substances are added to pool water to kill harmful bacteria. Chlorine helps to make pools safer for everyone.

If the pipes that lead into the pool are made of copper, a chemical reaction can take place between the chlorine, other substances, and the copper. The reaction produces copper sulfate. Copper sulfate, like copper acetate, is green. People who swim in the pool get copper sulfate on their hair. People with dark hair will not be able to see it, even though it is there. People with light hair, especially blonde hair, can see it. They sometimes say that their hair turns green when they swim in pools. Their hair does not actually turn green, but it gets covered with a green substance.

The substance washes away with shampoo. This green substance is the product of a chemical reaction that occurs in the pipes leading to the pool, and then ends up on swimmer's hair.

Are All of These Green Substances the Same Thing?

The green substance on a copper square, a penny, the Statue of Liberty, and hair appear the same; they are all green. Are they the same substance?

Before you read three explanations, look at the following table. Use the information in the table to help you think about whether the products in these reactions are the same substance or different substances. They are all green; but are they all the same substance?

Comparison of Copper and Copper Sulfate

Substance	Color	Soluble in Water	Soluble in Alcohol	Melting Point	Density
Copper Acetate	Green	Yes	Yes	115°C	1.88 g/cm^3
Copper Sulfate	Green	Yes	No	Breaks Apart at 560°C	3.60 g/cm^3

What do you think? Are the substances the same? What follows are three explanations that other people have written. They looked at the data table and made a decision about whether they thought the green substances were the same or different. Then they wrote scientific explanations about their ideas. Read each explanation. In the space that follows each one, write what you could tell the person who wrote it so that they could improve their explanation. Here are some things to think about:

- Does the explanation have a clear claim? Is it accurate?
- Does the explanation use the data from the table as evidence?
- Does it use the right data?
- Does it use the data correctly?
- Does the explanation show good reasoning by stating the scientific principles that help the claim and evidence make sense together?
- What does each explanation leave out?

Explanation 1

These two substances are not the same. They are both green and they are both soluble in water. One substance has a melting point of 115°C, it is soluble in alcohol, and it has a density of 1.88g/cm^3. The other substance breaks apart at 560°C, is not soluble in alcohol, and it has a density of 3.60g/cm^3. They have different properties.

How could this explanation be improved?

Explanation 2

Now you know why people cry when they cut an onion. As you think about that, what are some ways that a person might be able to avoid this chemical reaction?

You might want to share what you have learned about onions with people you know who cook at your house. Next time they cook with onions, they can try to make the process less irritating to their eyes.

ACTIVITY 8.3 – REPRESENTING CHEMICAL REACTIONS IN WORDS AND SYMBOLS

What Will We Do?

We will make marshmallow models to demonstrate what happened when the copper reacted with the vinegar.

Describe the Reaction

In the last investigation, you used the following word equation to describe the reaction between the copper and the vinegar.

Copper + Vinegar → Green Solid.

1. Rewrite the word equation using the scientific names of each substance.

2. Your teacher will give you the chemical formulas for the substances in the chemical reaction. Rewrite the equation using the chemical formulas.

3. Write a few sentences that relate these three equations with your observations of the copper and vinegar reaction. Be sure to identify the old and new substances in the chemical reaction.

4. You are going to build molecular representations of these substances. Create a key for your molecular representations. In the space that follows, record the color of the marshmallow you will use to represent each atom. (For example: red = carbon or C.)

5. Create marshmallow models of one copper and two acetic acid molecules.

6. Draw your models of copper and acetic acid in the following space.

7. Take apart your models and create a model of copper acetate. Draw your model in the following space.

8. Do you have any atoms left over? If so, what might happen to them?

9. Rewrite what happens during the chemical reaction. First write it out in words, and then write it out with numbers and the chemical formulas.

10. Our current definition of a chemical reaction is a process where substances interact to form new substances. Write a new definition of a chemical reaction based on what you now know occurs with the atoms and molecules.

Reading 8.3 – What Are the Many Ways of Representing Any Chemical Reaction?

Getting Ready

In the lesson you burned magnesium. Burning is always a chemical reaction. When wood in a campfire or bonfire burns, a chemical reaction is taking place. When a car burns gasoline, a chemical reaction is taking place. When a candle burns, a chemical reaction is taking place. If burning is a chemical reaction, then burning has to have reactants and products. As you read, pay attention to the different ways that you can represent the reactants and products of any chemical reaction, including burning. The first example you will read about is burning natural gas for cooking.

A Closer Look at Cooking and Heating

Some gas stoves, furnaces, and water heaters burn natural gas. The main component of natural gas is methane. Methane is a colorless, odorless gas. You may have learned that scientists add a rotten egg odor to methane so that if natural gas leaks a person can smell it before it explodes. Lighting a gas stove causes methane to react with oxygen in the air. The atoms recombine to form carbon dioxide and water vapor, and the reaction releases heat. The heat is what cooks food when using natural gas.

This is the chemical equation that represents burning methane gas:

$$\text{Methane} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water}.$$

This is one way to read the equation.

Methane interacts with oxygen and changes to carbon dioxide and water.

Another way to write the equation is to use the chemical formula for each substance. Methane is a molecule with four hydrogen atoms connected to one carbon atom. It is written CH_4. You already have seen the chemical formulas for oxygen (O_2), carbon dioxide (CO_2), and water (H_2O). The equation with all of the chemical formulas is:

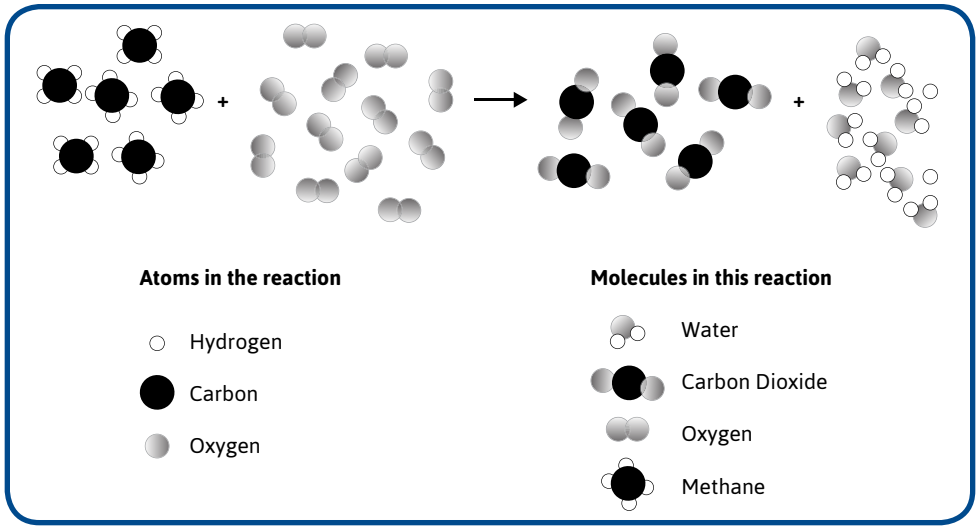
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O.$$

You can read the equation the same way:

Methane interacts with oxygen and goes to form carbon dioxide and water.

You can also use other representations of substances to show what happens when methane burns. If you saw only the following model, you could tell what chemical reaction occurred.

Notice that all of the same atoms are still there. Do you notice what is different about the atoms? They have combined in new ways. Do you notice the new arrangements? Different arrangements of atoms give substances different properties.



You can count to see that all of the same atoms are in the old and the new substances. The substances before and after the reaction are different because their atoms are arranged in different ways. Notice that there are no new atoms. It is something that scientists have learned. Atoms cannot be created or destroyed in chemical reactions. They move around, rearrange, and they form new molecules, but they do not disappear.

All of the same atoms are there before and after the reaction, but they have combined in new ways. The new arrangement of atoms gives the new substances different properties from the old substances. The table shows the properties of the old substances and the new substances when methane gas burns.

Reactants and Products When Methane Gas Burns

	Substance	Color	Solubility In Water	Melting Point	Density
Before Mixing	Methane	Colorless	Yes	−182.47°C	0.466g/cm^3
	Oxygen	Colorless	Somewhat	−218.79°C	0.00131g/cm^3
	Carbon dioxide	Colorless	Yes	−56.56°C	0.001799g/cm^3
After Mixing	Water	Colorless	Yes	0°C	1.0g/cm^3

You can represent any chemical reaction by using chemical equations. Now you can test what you read. Look at Reading 7.1. Find the section about representing burning magnesium. Now answer two questions about burning magnesium (7.1) and burning methane (8.3).

1. How is burning magnesium similar to burning methane?

2. How is burning magnesium different from burning methane?

You might find it interesting to look at the differences between different fuels that people burn. For example, methane, coal, gasoline, kerosene, ethanol, and other fuels have different benefits and dangers for the environment. The amount of pollution and type of pollution, for example, are different for each fuel. If you are interested in the environment or in this type of chemical reaction, you may wish to explore burning other fuels. You may wish to examine why hybrid cars have been invented.

LESSON 9

Is This a New Substance?

ACTIVITY 9.1 – DOES ELECTROLYSIS OF WATER MAKE NEW SUBSTANCES?

What Will We Do?

We will observe the electrolysis of water to determine whether it is a chemical reaction.

Safety

Wear safety goggles.

Prediction

Do you think running electricity through water makes a new substance? What data will you need to determine whether a chemical reaction occurred?

Procedure

1. Watch your teacher demonstrate how to set up the equipment.
2. Pour 300mL of water into a 500mL beaker.
3. Set up equipment as shown. Label the test tubes *1* and *2*.
4. After you have set up all of the equipment, add 50mL of 1M sulfuric acid into the beaker. Stir with a stirring rod.

Data

1. Record your observations in the table.

	Observations
Before Electrolysis	
During Electrolysis	
After Electrolysis	
Match Tests After Electrolysis	

2. Draw a molecular representation of a water molecule. What atoms are present in the water molecule?

3. Build two molecules of water using marshmallows and toothpicks, and label which color marshmallow represents which atoms.

   _____ represents the atoms.

   _____ represents the atoms.

4. If water does break down by electrolysis to form new substances, what might be formed?

5. Take apart water molecules you just created to make hydrogen and oxygen molecules. Each hydrogen molecule is composed of two hydrogen atoms connected together. Each oxygen molecule is composed of two oxygen atoms connected together. How many hydrogen molecules do you need to make from two water molecules? How many oxygen molecules do you make?

6. Use the numbers and chemical formulas to describe your word equation.

Conclusion

Construct an argument to convince someone else that electrolysis is a chemical reaction.

Reading 9.1 – What Is the Same and Different about Boiling Water and Electrolysis?

Getting Ready

You may already have learned what happens to molecules when you boil water. Now, you have investigated what happens during the process of electrolysis of water. In the following space, list your ideas about how boiling water and electrolysis compare.

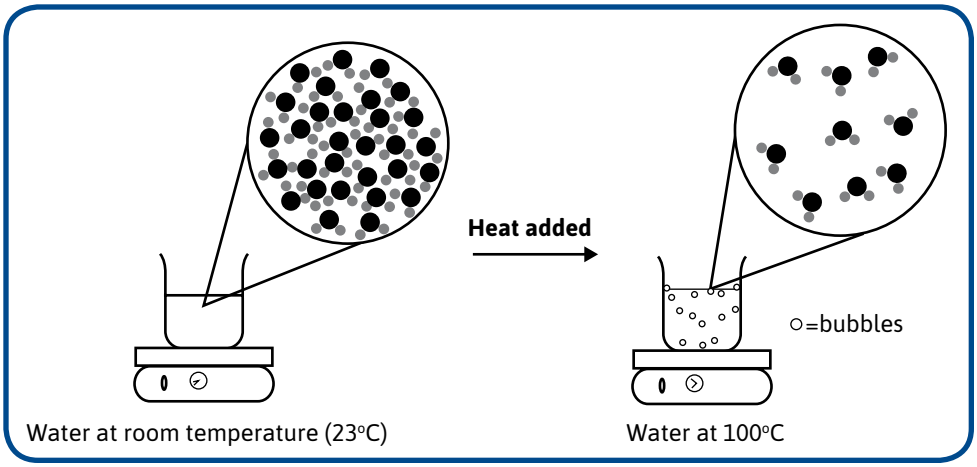
As you read, you will learn more about similarities and differences between water during boiling and electrolysis.

How Are Boiling and Electrolysis of Water the Same?

The experiments of boiling water and electrolysis used the same substance—water. This water was in the liquid state to begin both experiments. Both times, energy was added to the water. This, however, is where the similarities end.

How Are Boiling and Electrolysis of Water Different?

First, think about when you boil water. Thermal energy is added to the water from a hot plate or from your stove. Look at the pictures. A beaker of water is on a hot plate.

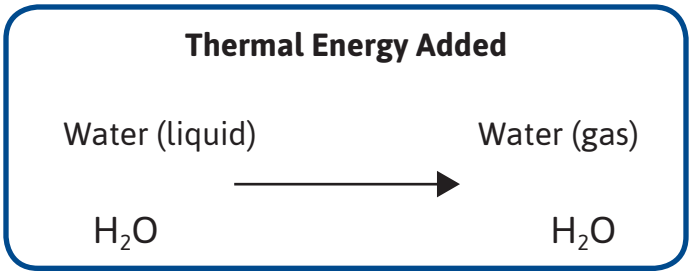


Each water molecule, H_2O, is represented by three circles. The big, dark circle represents an oxygen atom and the two little gray circles represent two hydrogen atoms. The beaker of water contains billions of water molecules in the liquid state. In the liquid state, each water molecule is attracted to the neighboring water molecules. When thermal energy is added to water, the water molecules gain energy and move faster and faster until they can overcome the attraction of other molecules and go into the gaseous state. When a water molecule gets enough energy, it can break away from the rest of the molecules. Then it can move from the beaker into the air as a gas molecule. This process is called evaporation.

Evaporation is when liquid water molecules gain enough energy to become gas molecules and go into the air. The picture on the right side is a representation of water in the gaseous state or phase. You cannot see molecules moving from liquid water to gaseous water. What you do see are bubbles in the water.

If you compare the liquid and the gas molecules, they have the same arrangement of atoms in H_2O molecules. This means that the same substance—water—is there before and after boiling. The molecules are just farther apart after adding energy. If you remove the thermal energy, the molecules will slow down and condense back into the liquid phase. The properties of the water before boiling and after cooling would still be the same.

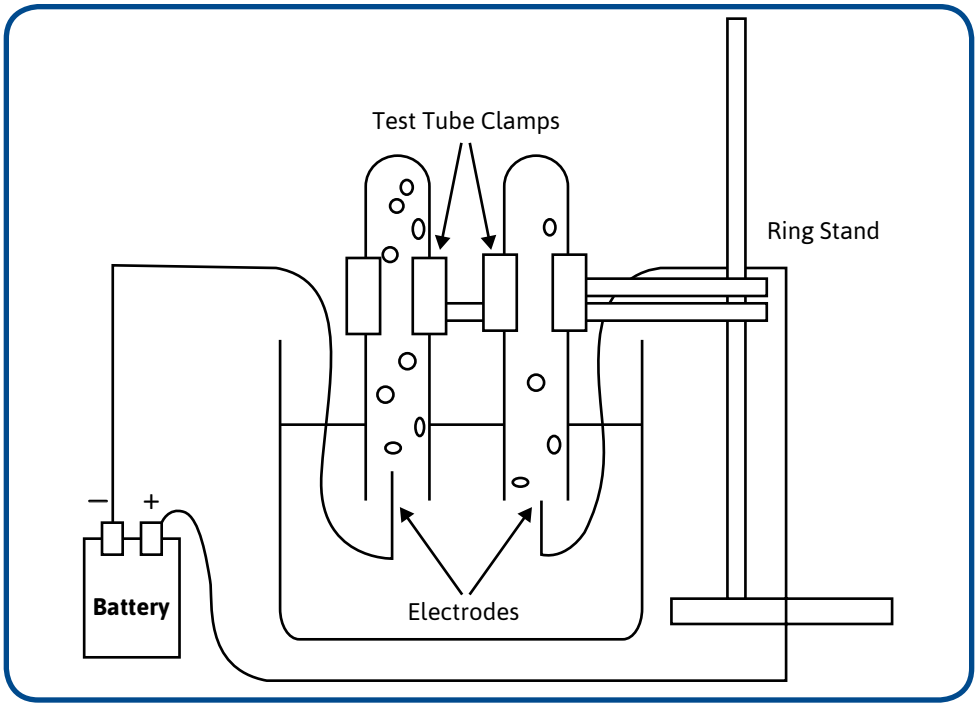
An equation can represent boiling of water. The following is a word equation for boiling.



Rewrite the equation using the chemical names. Is boiling a chemical reaction? Explain your ideas.

Now think about electrolysis. Just as with boiling, you began with water, H_2O, in the liquid state. Just like with boiling, energy was added. This time, however, the energy came from batteries. Instead of the energy going to making the water molecules move faster until some of them were eventually able to evaporate, electrical energy from the batteries was able to split the water molecules apart into oxygen and hydrogen. You cannot see molecules splitting apart, but you did see bubbles. This time, the bubbles were a sign of new substances. (You also saw bubbles during boiling.) You also did a flame test to get evidence that oxygen and hydrogen were formed. Oxygen and hydrogen are both gases at room temperature. They are different substances from water. They have different properties from water. If you remove the batteries that provide the energy, the hydrogen gas and oxygen gas will not go back to form water.

The following picture illustrates the electrolysis process. Each water molecule (H_2O) is represented by three circles. The big, dark circle represents an oxygen atom and the two little gray circles represent two hydrogen atoms. The beaker of water contains billions of water molecules in the liquid state. The electrical energy breaks apart the H_2O molecules. The newly formed H_2 molecules accumulate in one test tube and the newly formed O_2 molecules accumulate in the other test tube.



The electrolysis experiment you did can be described by the following word equation.

Water (liquid) electrolysis——electrolysis——Hydrogen (gas) + Oxygen (gas)

You created marshmallow models of this process in class. The following equation of electrolysis is written using the chemical formulas:

$2H_{2(l)}$——electrolysis——$2H_{2(g)}$ + $0_{2(g)}$

Were new substances created from old substances during electrolysis? Explain.

In Order to Make New Substances, Do You Always Have to Start with Two or More Reactants?
Right now your definition of a chemical reaction is:

Think back to boiling water. Is this a chemical reaction? When water boils, atoms do not rearrange and no new substances are formed. You begin with water and end with water. It is just that water is in either the liquid phase or the gaseous phase. There is only one substance. Boiling is not a chemical reaction.

Now think back to electrolysis. Is this a chemical reaction? When water undergoes electrolysis, the water molecules split apart, so the atoms no longer have the arrangement of H_2O. They are in new arrangements. They are now O_2 and H_2 gas molecules. New substances are formed from the old substance (water). These new substances have different properties from water. Electrolysis is a chemical reaction.

It only has one reactant—water. Based on this new understanding that a chemical reaction can involve one, two, or more substances, you need to revise your old definition of a chemical reaction.

Write your new definition of a chemical reaction.

An Everyday Example of a Chemical Reaction with Only One Reactant

What do you think happens to grass that has been cut and left on a lawn? What happens to dead leaves? What about dead animals, trees, or plants in a forest or park? Dead matter decomposes. When matter decomposes, it breaks down from a complex form to a simpler form. This occurs with the help of bacteria and fungi. The old substance—dead grass, a dead animal, or a dead plant—has complex molecules. Through decomposition, these complex molecules split apart and the atoms combine in new ways to form new substances that have more simple molecules, or substances with only one type of atom. When plants break down, they form mainly carbon dioxide and water. These simpler substances become basic ingredients for healthy soil. It is a good thing that decomposition occurs. Otherwise, there would be dead plants and animals piled everywhere.

Electrolysis is an example of a decomposition process. The more complex molecules of water are broken down into more simple molecules of oxygen and hydrogen.

LESSON 10

How Is a Mixture Different from a Chemical Reaction?

ACTIVITY 10.1 – DO I ALWAYS MAKE NEW SUBSTANCES WHEN I PUT SUBSTANCES TOGETHER?

What Will We Do?

We will investigate whether putting water and powdered drink mix together causes a chemical reaction.

Safety

- Wear safety goggles.
- Use caution around the hot plate and boiling liquid to avoid burns.

Predictions

First read the procedure. Then write your predictions in the table.

1. Boil the drink solution in Flask 1.

2. What should you collect in Flask 2 if the drink solution is . . . (complete the table.)

1) . . . a new substance?	2) . . . not a new substance?

Procedure

1. Measure 50mL of water into a beaker.

2. Record the color and density of water before the experiment in the table. You can use your data for water before boiling from Activity 9.1.

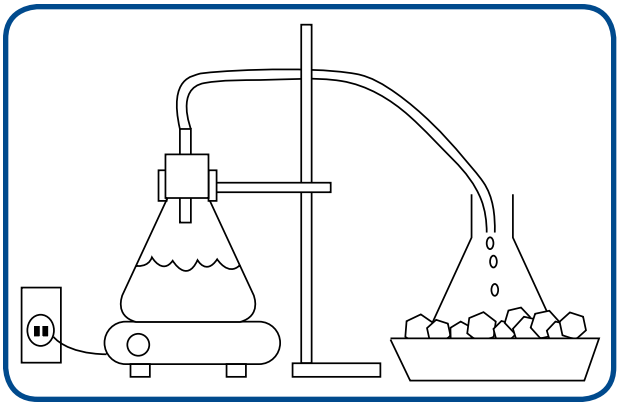
3. Observe some powdered drink mix. Record your observations in the table.

4. Add 1 spoonful of powdered drink mix to the water. Stir well.

5. Pour the 50mL of drink solution into a 250mL Erlenmeyer flask, and label it *Flask 1*.

6. Set up your equipment like the boiling water experiment in Activity 9.1. Use the following diagram.

The flask in the ice bath is Flask 2. Do not put a stopper into Flask 2.



7. Turn the hot plate on high.

8. When the drink solution is boiling, observe what is happening in Flask 1 and Flask 2. Record your observations in the table.

9. Allow the solution to boil until there is a small amount of liquid in Flask 1. Be careful that the contents of the flask do not burn. Turn off the hot plate.

10. Determine the color and density of the liquid in Flask 2 (after experiment). Record your data in the table.

11. When Flask 1 is cool to the touch, pour the remaining contents onto filter paper.

12. The next day, observe the filter paper. Record your observations in the table.

Data

		Color	Density
Before Experiment	Water		
After Experiment	Liquid in Flask #2		

Observations

Before Experiment	powdered drink mix	
During Experiment	flask #1	
	flask #2	
After Experiment	filter paper	

Data Interpretation

Based on your data, was the drink solution in Flask 1 a new substance? Explain your ideas.

Conclusion

1. Is combining water and powdered drink mix a chemical reaction? Construct an argument to support your claim.

2. Why do you think you had to observe the powdered drink mix instead of determining its properties?

Reading 10.1 – What Happens to Atoms and Molecules When I See Different Processes?

Getting Ready

If you had a glass of clear water and you poured red drink powder in it, the liquid would turn red. Did a chemical reaction occur? The following questions will help you think about whether this is a chemical reaction.

1. What observations could be evidence that a chemical reaction occurred?

2. What must happen to the atoms and molecules of the substances for this to be a chemical reaction?

This reading will help you think about whether mixing drink powder in water results in a chemical reaction or not. After the reading, you will look at these two questions again to see if you have any new ideas.

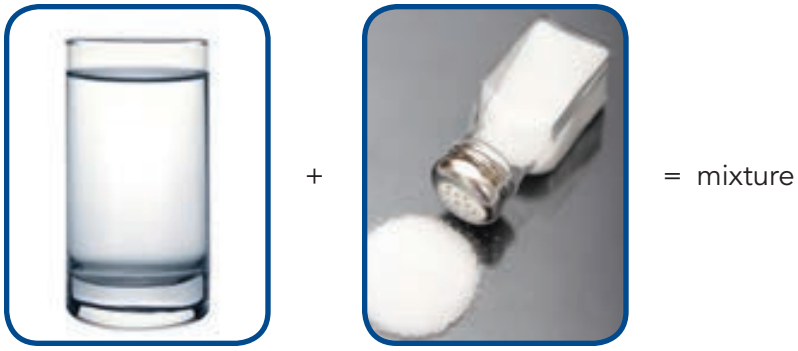
Do Atoms Always Rearrange?

A can of soda fizzes when you open it, but that is not a chemical reaction. When you boil water, it bubbles, but that is not a chemical reaction. You learned in Lesson 6 that bubbles might be evidence that a chemical reaction occurred. These are two examples when bubbles can fool you. How can you tell when a chemical reaction results in new substances and when substances are mixing, but not changing, into new substances?

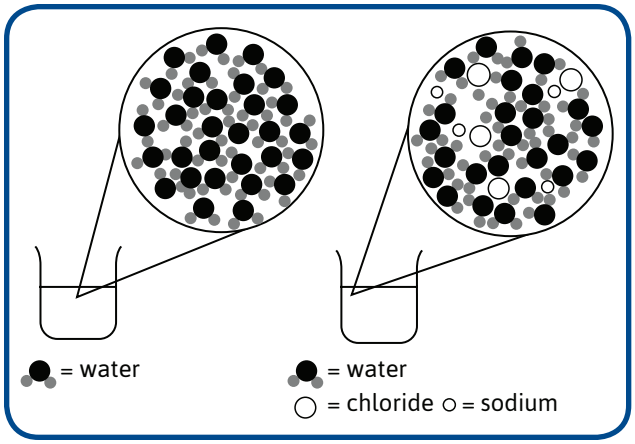
Two different things can happen when you mix substances together. One, the atoms arrange in new ways to create new substances. This is a chemical reaction. Two, the atoms and molecules do not rearrange. They do not interact chemically to create new substances. Early in this unit, you read about chocolate milk as an example of a mixture. It might be helpful to reread those pages to help you understand the difference between chemical reactions and mixtures. In that example, the atoms and molecules in the chocolate and the milk all stay next to each other in the glass, but they do not break apart and recombine.

Another Example: Salt Water

When you put a little salt in a glass of water, do you create a mixture or start a chemical reaction? You end up with salt water—is that a new substance?



Water is a substance. It is made of H_2O molecules all the way through. Salt is a substance made of NaCl (sodium chloride) all the way through. When you add salt to water, the substances do not interact with each other to form new substances. The atoms from water do not rearrange with salt atoms. Instead, think about the atoms of salt as sitting next to the water molecules. In the following graphic, you can see how the atoms from salt are all around the water molecules. Imagine even more of those atoms around the water molecules. That is what happens in a mixture of substances.



A mixture is made of two or more substances. Salt water is a mixture. No new substances are created. Each substance can also be separated from the other substances. If you left the glass of salt water on a shelf, the water would evaporate, but there would still be salt in the glass. The atoms in the salt and the water do not rearrange to form new substances. They just sit next to each other in a mixture. Remember that a glass of salt water or chocolate milk has billions and billions of atoms in it, so they are far too small for you to see. Only diagrams or models of mixtures, like the previous diagram, can help you to understand what it means for particles to sit next to each other in a mixture.

You could do this saltwater investigation at home. First, pour some salt in the palm of your hand and taste it. Salt has a very distinct taste. Now pour the salt from your hand into a drinking glass. Add some water and stir. Add enough water to dissolve the salt in the glass, but if you add a small, rather than a large, amount of water, this investigation will not take as long. Leave the glass in a safe place until the water has evaporated. Taste the substance left in the glass. You will be able to taste for yourself that what is left is the same substance you started with—salt. (Remember never to taste anything in the lab or that you mix at home unless you know for sure that the materials you are using are safe. Otherwise, tasting can be very dangerous.)

This activity is another fun way to think about how atoms and molecules behave in a mixture that you can see for yourself. You will need a glass, cup, or jar filled with water, and another container with some extra water in it. You will also need some sugar. Set the filled glass of water on the table or a countertop. Use your cup of extra water to add even more water to it. Add as much water as you can so that the water rises above the top of the glass a bit. You want the glass to be so full of water that it will not hold another drop.

Predict what will happen when you add a bit of sugar to the water.

Now, take a pinch of sugar (or a little bit in a spoon), and very slowly add the sugar to the water in the cup without touching the spoon to the cup or to the water. Do not stir. Even though you quit filling the cup with water because you thought it could not hold another drop, it should hold more sugar without spilling. Slowly add another pinch or spoon of sugar and see what happens. Keep adding sugar a little at a time until you cannot add any more.

You know that the sugar is dissolving in the water, but what does dissolving mean in terms of the molecules in the water and the sugar? The water in the cup is in a liquid phase, which means there are microscopic spaces between the molecules. When you add sugar to the water, the sugar molecules fill in the tiny spaces between the water molecules. You cannot see these spaces, but you can tell that they are there. You can keep adding sugar until the spaces have been filled. The sugar molecules fill in the holes, and sit next to the water molecules.

You might do this activity with a parent, relative, or friend, and predict what will happen. Explain to the person with you what is happening. He or she might agree that it is quite amazing.

Comparing Phase Changes, Mixtures, and Chemical Reactions

The following chart is one way to organize what you have learned about the differences among phase changes, mixtures, and chemical reactions.

Comparison of Phase Change, Mixture, and Chemical Reaction			
Process	**Before a Process**	**After a Process**	**Atoms and Molecules**
Phase Change	1 substance	Still have the same substance	Move closer together or farther apart, speed up or slow down
Mixture	2 or more substances	Have the same 2 or more substances that you started with	Atoms do not rearrange to form new substances.
Chemical Reaction	1 or more substances	Have 1 or more different substances than the ones you started with	Atoms break apart and rearrange in new ways to form new substances.

Use what you know about phase changes, mixtures, and chemical reactions to answer the following questions.

Which of these is a chemical reaction?

A. freezing water

B. melting fat

C. making hot chocolate

D. baking bread

Circle one and tell why it is a chemical reaction. Be as detailed as you can.

Choose any one (A, B, C, or D) of the others and tell whether it is a phase change or a mixture. Be as detailed as you can.

LESSON 11

How Can I Make Soap from Fat?

ACTIVITY 11.1 – HOW CAN I MAKE SOAP FROM FAT?

What Will We Do?

We will conduct an experiment to explore how some surprising substances can be combined (fat and sodium hydroxide) to make soap.

Safety

Sodium hydroxide can burn your skin. **Wear safety goggles and gloves at all times**. If you get sodium hydroxide on your skin, tell your teacher immediately and rinse your skin with cold water.

Procedure

1. Put on safety goggles and gloves.
2. Put 50g of table salt and 175mL of water into the large container and stir to dissolve. Label the container with your group's name. Place this container to the side.
3. Put 11g of fat and 20mL of rubbing alcohol into the small beaker. Stir the mixture with the stirring rod for three minutes. The fat will not completely dissolve.
4. Have your teacher pour 20mL sodium hydroxide solution into the small beaker.
5. Place the small beaker on a hot plate on low. Stir the mixture with the stirring rod.
6. Stir the mixture for about 10 minutes. Use a stopwatch to keep track of the time. The fat should dissolve and then liquid will become clear. After the liquid is clear, it will become slightly yellow. When it turns yellow, it is done. Do not let the mixture boil. Do not put your face directly over the beaker.
7. After the liquid becomes slightly yellow, ask your teacher to pour the mixture into the large container that contains the salt solution. Do not stir. The large container will need to sit overnight.

Next Class Period

8. Wear gloves and safety goggles. Pour off the liquid in the large container. Rinse the material that remains in the container with water and let sit on a paper towel for several days to complete reacting and hardening.

Data

	Observations
During Mixing and Heating of Substances	
After Pouring Soap into Salt Water	
After Removing Soap from Salt Water	

Conclusion

1. You made soap (new stuff) from some surprising ingredients (old stuff). Based on your observations, do you think what happened was a chemical reaction? Explain your ideas.

2. What additional evidence would you need to verify whether this experiment involved a chemical reaction?

Reading 11.1 – Do People Really Make Soap from Fat?

Getting Ready

You have learned a lot about substances and mixtures. Do you think that the soap you buy in the grocery store is usually a substance or a mixture? Give reasons for your response.

In this reading, you will learn more about making soap. As you read, decide whether your answer to the Getting Ready question is right, or whether you should revise it.

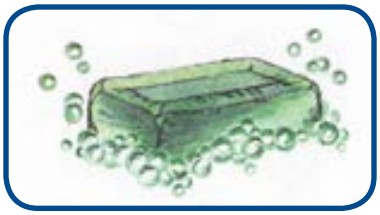
Making Soap: Today and Long Ago

Today most people buy soap at the store, but there was a time when people made their own soap. Most people who made soap in the past did not really understand what happened in the process. They made soap by trial and error. That means they tried different ways of mixing and cooking until they got soap that was just right. Over time, they developed a procedure for making soap that they could repeat every time they needed to make more. Today scientists understand the chemical reaction involved in making soap. They know which substances to start with so that they end with good soap every time.

Three Steps to Making Soap

In the 17th and 18th centuries, people followed three steps to make soap:

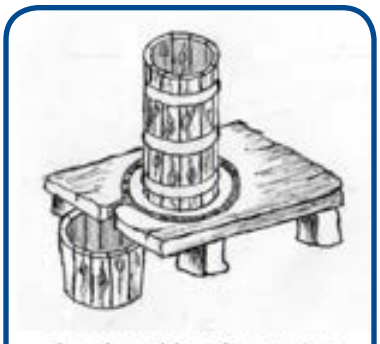
1. Make a lye solution from wood ash and water.
2. Prepare the fats.
3. Combine the fat and lye and heat them.



As you read the following steps in the process, think about how these steps compare with what you do in class.

1. Make the lye.

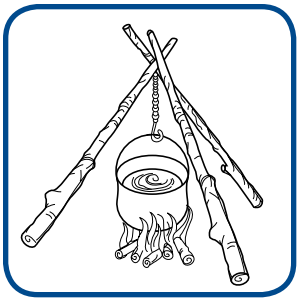
During colonial times, the first ingredient required to make soap was a liquid solution of lye. Lye is similar to the sodium hydroxide you used to make soap in class. The American colonists made a lye solution by placing ashes from burned wood into a barrel. The barrel had no bottom. It sat on a stone slab with a groove carved in it. The slab rested on a pile of rocks. The colonists poured water slowly over the ashes until a brownish liquid oozed out the bottom of the barrel. This liquid was a lye solution. The process was called leaching.



Lye Leaching Apparatus

2. Prepare the fats.
The next step was preparing the fats to be used in making soap. The colonists used fat from animals they had killed for food. They had to remove all of the parts that they did not want in their soap. For example, when animal fat was removed from dead animals, it still had pieces of muscle attached to it. The muscle tissue had to be removed. This was the smelliest part of making soap.

3. Heat the ingredients.
Colonists poured the fat and the lye solution into a large pot. Then they put the pot over a fire outdoors. The ingredients were boiled. The colonists boiled the fat and lye until a chemical reaction occurred that formed soap. This procedure is very similar to what you did in class. You slowly heated the solution of sodium hydroxide and fat to make soap.



Comparing the Colonists' Soap to My Soap

Compare the reactants and products in the two chemical reactions. How do the reactants and products in the colonists' soap compare to the reactants and products in the soap you made in class? Remember that to compare you should tell what is alike and what is different about the reactants and products.

Soft and Hard Soap

Some chemical reactions occur in minutes or hours. Other chemical reactions, like making soap, can take days or weeks. The reaction that made the Statue of Liberty appear green took years. This is why you will wait a week or two before testing the properties of your soap. The chemical reaction needs to be completely finished first.

The same thing was true when the colonists made soap. Even after they put out the fire, the fat and lye continued to react to make soap. The next day the soap was a brown jelly-like substance. The colonists poured this soft soap into a wooden barrel.

Whenever they needed soap, they dipped some out with a wooden ladle. The soap made with lye was very soft. If they wanted hard soap, the colonists put salt in the pot at the end of boiling. If they did this, a hard cake of soap formed in a layer at the top of the pot. That is why you poured your hot soap into a solution of sodium chloride.

In the process, the colonists made a new substance. The atoms in the substances that they started with interacted to form new substances. Their soap had the same type of molecules all the way through. If the colonists had added other substances to their soap, then it would have been a mixture. Remember that a mixture is a combination of two or more substances. If the colonists had added flower petals to their soap to improve the odor, the soap would have been a mixture.

ACTIVITY 11.2 – TESTING THE PROPERTIES OF SOAP

LESSON 12

Does Mass Change in a Chemical Reaction?

ACTIVITY 12.A – MAKING GLOOP

What Will We Do?

We will conduct an experiment to determine whether mass stays the same or changes when we make a substance called gloop.

Safety

Wear safety goggles.

Prediction

Do you think the mass will change when you make gloop? Why?

Procedure

1. Measure 6tsp of glue and add to Cup 1.
2. Measure 5mL of water and add to Cup 2.
3. Measure 15mL of the sodium borate solution and add to Cup 3.
4. Use a balance to find the total mass of the three cups, the reactants, and the craft stick. Record the total mass before the reaction.
5. Add the water to Cup 1 with the glue. Stir with the craft stick.
6. Add the sodium borate solution to Cup 1. Stir with a craft stick until it is thick.

7. Use a balance to find the total mass of the cups, the products, and the craft stick. Record the total mass after reaction.

8. Use your fingers and knead the resulting gloop for a minute or two to finish forming the product.

Data

	Before the Reaction	After the Reaction
Total Mass (grams)		
Observations of Reaction		

Conclusion

1. Write a scientific explanation that answers the question: Does mass stay the same or change when you make gloop?

2. Look at your prediction at the beginning of the sheet. Did your findings for Conclusion Question 1 support your prediction? Why do you think your findings did or did not support your prediction?

ACTIVITY 12.1 – DOES MASS CHANGE WHEN SELTZER TABLETS REACT?

What Will We Do?

We will conduct an experiment to determine whether mass stays the same or changes when seltzer tablets reacts in water.

Safety

Wear safety goggles.

Prediction

Do you think mass will stay the same or change when seltzer tablets reacts in water? Why or why not?

Procedure

1. Pour 50mL of water into an empty soda pop bottle.

2. Put three seltzer tablets tablets into a small cup. Crush the tablet with your finger or the eraser end of a pencil.

3. Use a balance to find the total mass of the soda pop bottle containing water and the cup containing crushed seltzer tablets. Record the total mass before the reaction.

4. Add the crushed seltzer tablets to the water in the bottle. Record your observations.

5. Use a balance to find the total mass of the bottle containing the reacted seltzer tablets in water and the empty cup. Record the total mass after the reaction.

Data

	Before the Reaction	After the Reaction
Total Mass (grams)		
Observations of Reaction		

Conclusion

1. What happened to the mass when the seltzer tablets reacted in water?

2. Look at your prediction at the beginning of the sheet. Why do you think you observed these results in this investigation?

Reading 12.1 – What Happens to Mass During a Chemical Reaction in an Open System?

Getting Ready

Think about a chemical reaction you probably already know—rusting. Make a list of everything you know about rust. You might think about what rust looks like. What kinds of objects rust? What makes objects rust?

An Everyday Reaction in an Open System

Rust is a product that forms on the surface of metal as a result of a chemical reaction. In that way, rust is like the copper acetate or copper sulfate that forms on copper. Maybe you know that rusting involves metal. Maybe you know that the particular metal involved in rusting is iron. The same chemical reaction causes rust to form on many objects that contain iron, like nails, tools, cars, bicycles, cars, and some fences.

Rusting is a complex chemical reaction. It involves reactants and products, like all chemical reactions do, but the reaction has to occur in the presence of water. You may already know this. In fact, when you wrote what you know about rust, you may have written that rusting happens when some objects get wet.

For now, you are going to look at the main reactants and products, but not at the water. Water is necessary for rusting to take place, but the water is not considered one of the reactants.

One way to represent the chemical reaction called rusting is this.

Chemical Reaction: Rusting

Reactants		Products
Iron + Oxygen	→	Iron Oxide
(In the Presence of Water)		(In the Presence of Water)

Compare the chemical reaction that causes the Statue of Liberty to look green with the chemical reaction that causes a bike to rust.

The reaction that causes the Statue of Liberty to look green, and the reaction that causes a bike to rust, both occur outdoors. In any reaction that occurs outdoors, something could be added or something could escape from the reaction. Scientists call this an open system.

You might guess that an open system is when something is added or allowed to escape. In class you observed chemical reactions occurring in both open and closed systems.

When you did the plastic bag experiment using baking soda and road salt, you sealed the bag shut before you mixed the ingredients. By doing this, you created what scientists call a closed system. A closed system is when nothing is added or allowed to escape from the system.

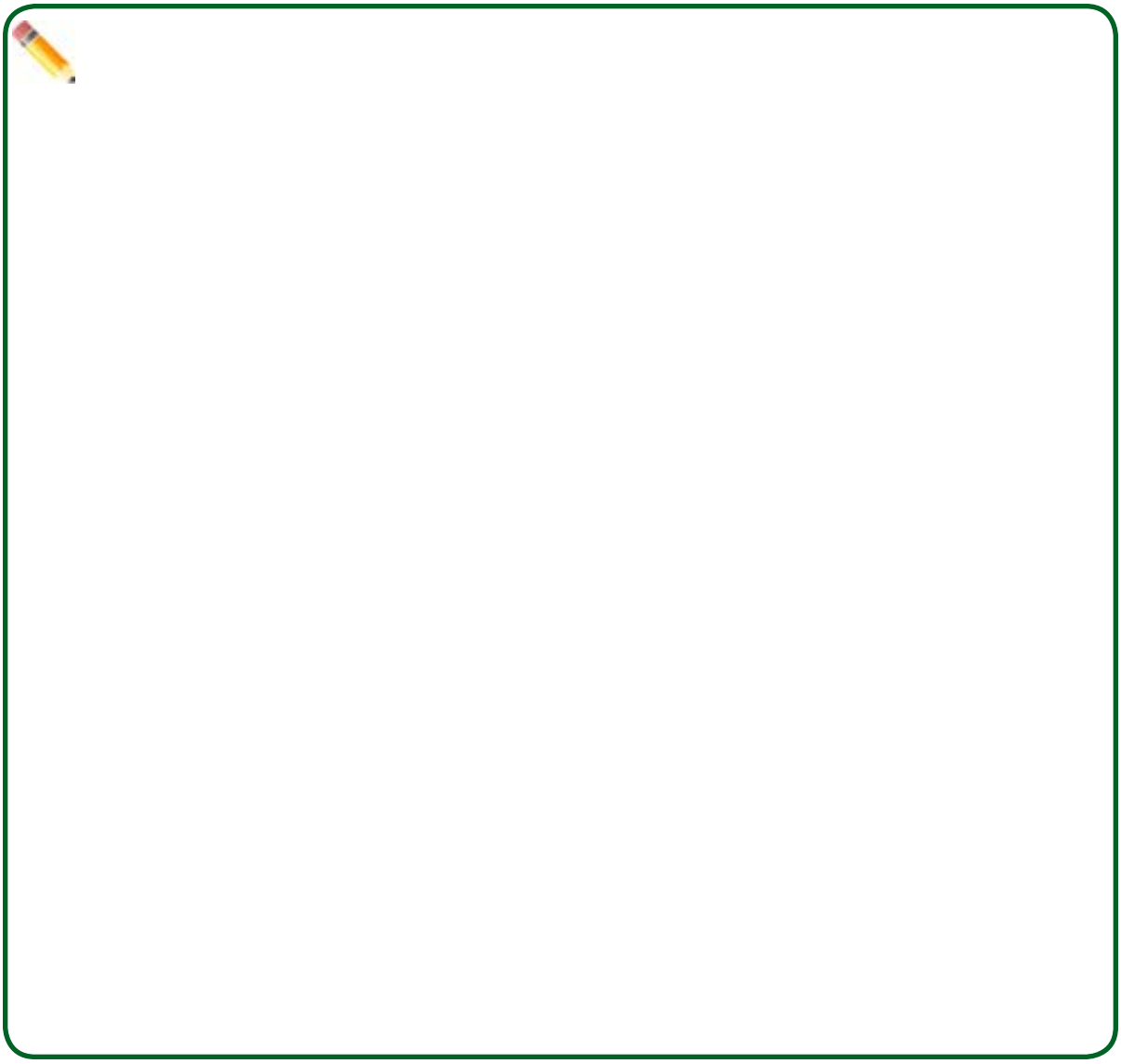
How does paint (on cars and bicycles) help prevent rusting?

Think back to the investigation with the reactants you mixed in a plastic bag. When you combined the two reactants, you observed that the substances bubbled, a precipitate formed, and a temperature change occurred. First, imagine that you had measured the mass of the plastic bag of reactants before you mixed the ingredients. Second, imagine that you tipped over the container of water and measured the plastic bag again.

Mass of Bag + Reactants	Mass of Bag + Reactants
Before Mixing	After Mixing
?	?

Imagining these two measurements of mass will help you answer the following question.

In the plastic bag experiment, do you think the mass of the products after the chemical reaction would be greater than, less than, or the same as the mass of the reactants before the chemical reaction? Give reasons for your answer.



ACTIVITY 12.2 – DOES MASS REALLY CHANGE WHEN SELTZER TABLETS REACT?

What Will We Do?

We will redesign the experiment for seltzer tablets in water in a closed system to see what happens to mass.

Safety

Wear safety goggles.

Purpose of Investigation

Write why you are conducting this new investigation and how your design helps you.

Procedure

With your group, redesign the experiment. Draw and write the procedure for your experiment.

Data

Create a data table or other way of recording the results of your experiment.

Conclusion

What happens to mass in a chemical reaction? Use data from all of your investigations in this lesson to write an explanation of your results.

Reading 12.2 – What Happens to Mass during a Chemical Reaction in a Closed System?

Getting Ready

Did you know that when you play with glow sticks, you are watching a chemical reaction in a closed system? In class, you learned about what it means for a chemical reaction to take place in a closed system. The sandwich bag experiment was an example. When you combined the reactants in the bag, you observed a chemical reaction inside a sealed bag. Scientists call this a closed system. Nothing was added to the chemical reaction while it was taking place, and nothing was allowed to escape.

This reading helps you to think about why open and closed systems are important. Read to find out more about how glow sticks work. As you read, pay attention to the difference between measuring mass in an open system and measuring mass in a closed system.

An Everyday Reaction in a Closed System: Glow Sticks

Have you ever played with glow sticks, necklaces, or other items that you can buy at parades, concerts, fairs, and festivals? All of these glow items are examples of a chemical reaction in a closed system. When you buy these items, they may already be glowing. In that case, someone has started the chemical reaction. They do this so you will see the colors and want to buy something. If you buy a glow item that is not already glowing, you need to start the reaction yourself. Some emergency lights that people keep in their cars need someone to start the reaction. Some hand warmers work the same way.

Here is what happens. Inside any of these items is a tiny, thin glass tube. The tube contains substances that will glow when they are mixed with the materials in the outer container. To start the reaction, a glow stick has to be bent. When you bend a glow stick, you break the tube and the substances inside of it spill into the glow stick. When those substances mix with other substances already in the glow stick, a chemical reaction takes place. This particular chemical reaction produces new substances and also a glowing light.

Glow sticks cannot be used again. This should make sense to you now. Once the tube is broken and the substances have interacted, there is no way for the reaction to start over again. The chemical reaction has made new substances. All of the original atoms from the starting substances are still there, but the atoms have rearranged to form new substances.

The reaction inside glow sticks is similar to the reaction that causes fireflies to glow. You may want to look in science books or on the Internet if you would like to learn more about how that happens.

Conservation of Mass: Thinking about the Plastic Bag Experiment and a Glow Stick

In the plastic bag experiment, if you had placed the bag on a balance before and after you mixed the reactants, you would have observed that the mass stayed the same. The mass would have been the same before and after the chemical reaction because the bag would have contained all the same atoms. If you placed a glow stick on a balance before you

broke the tube and after you broke it, you would have seen that the mass stayed the same. A chemical reaction does not create any atoms or destroy any atoms. Instead, a chemical reaction rearranges atoms to make new substances. This is why the mass stays the same. This scientific principle is the conservation of mass. Conservation of mass is the principle that, regardless of how substances interact with each other, the total mass of the system always remains the same.

Conservation of mass means that regardless of how substances interact with each other the total mass of the system remains the same.

What If You Had Opened the Plastic Bag?

In the plastic bag investigation, if you had opened the plastic bag, the gas would have been allowed to escape. Once you opened the bag, it became an open system. The mass of the plastic bag filled with products from the reaction would have changed because gas would escape from the bag and gases from the air could go into the bag.

You do not have to add the air yourself. The molecules in the air will move into the bag by themselves, and the molecules of gas in the bag will escape without your help.

Looking Closely at Mass in a Closed System

Look at the following table. Imagine that Tiffani determined the mass of the reactants before a chemical reaction. Then she determined the mass of the products after the chemical reaction in a closed system. Her results are in the following table.

sulfuric acid + sodium hydroxide $\rightarrow$ water + sodium sulfate

Substance	Mass
Sulfuric Acid	49g
Sodium Hydroxide	40g
Water	18g
Sodium Sulfate	?

According to the principle of the conservation of mass, the mass of the sodium sulfate was the following.

A. 71g

B. 89g

C. 31g

D. 10g

Circle your answer. How do you know that your answer is correct? Write a scientific explanation about how you know what the mass of the sodium sulfate has to be in this reaction.

Thinking about the Type of Atoms in a Chemical Reaction

In everyday language, people say that an object rusts. Now you know that the scientific name for rust is iron oxide. Iron oxide is the product when iron and oxygen come together (in the presence of water) and interact. The chemical reaction, called rusting, can only happen when there are iron atoms as one of the reactants. Use what you know about the atoms involved in a chemical reaction to answer the following two questions.

You may have wiry cleaning pads at home for cleaning the grill or for pots and pans in the kitchen. These cleaning pads often contain soap, but the metal in them is called steel wool. Steel wool rusts if you use it and then leave it on the edge of the sink. What must steel wool be made of in order to rust? (If you have steel wool cleaning pads at home you can actually see evidence of this reaction.)

Why do you think rust cannot form on other substances like plastic or rubber or even other metals like aluminum?

Thinking about the Number of Atoms in a Chemical Reaction

You now know that not only do the type of atoms in a chemical reaction stay the same, but the number of atoms also stays the same because mass is always conserved. You can look at the number of atoms involved in the process of rusting as an example of this.

The chemical reaction that causes rusting can be written as the following chemical equation:

iron + oxygen $\rightarrow$ iron oxide.

Another way to write the equation is to use the chemical formulas:

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$.

Using the chemical formulas, you can count the atoms on each side of the arrow to be sure that the number of atoms is the same. When the number and type of atoms are the same on both sides, scientists call the equation balanced. The number in front of the element or compound tells you how many atoms or molecules you have. In the preceding equation, the 4 in front of the Fe means there are four atoms of iron. The subscript in the oxygen (O_2) means there are two oxygen atoms in every molecule of oxygen. All together, there are four iron atoms (Fe) and six oxygen atoms (O) on each side of the arrow. The atoms are arranged differently, but they are all still there. The equation balances because of the principle of conservation of mass. In a chemical reaction, the atoms rearrange, but the number of atoms always stays the same.

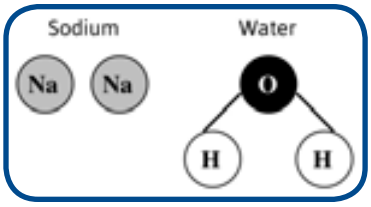
Why Does Mass Stay the Same in a Chemical Reaction?

Mass stays the same in a chemical reaction because the same atoms that are in the reactants rearrange to form the products. All the atoms are still there, so the mass stays the same before and after the reaction.

Applying What You Have Learned about Chemical Reactions and Conservation of Mass

In class your teacher burned magnesium so that you could see a chemical reaction similar to the one that occurs in sparklers and fireworks. When the magnesium was lit, the oxygen in the air interacted with the magnesium to form a new substance, magnesium oxide. In this unit, you have talked about several metals—magnesium, gold, copper, and aluminum. Sodium is another metal. In the following investigation that is represented, a student places a piece of sodium (Na) in water (H_20). Remember that the model shows only a few atoms even though millions of atoms are actually in the samples of the substances. Think about the principle of conservation of mass as you look at the diagrams.

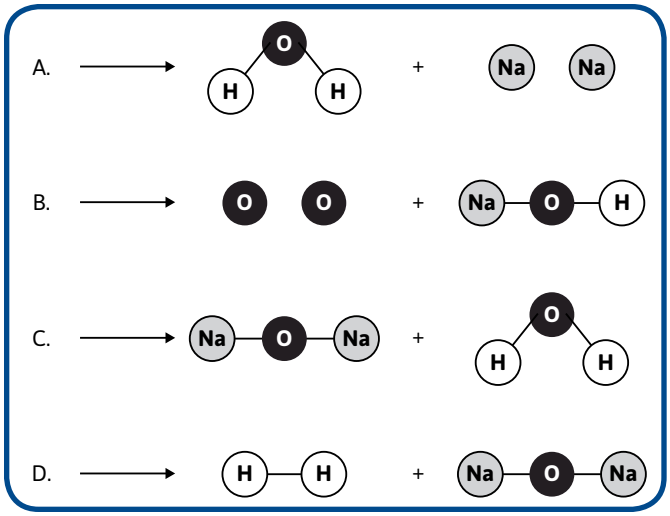
A student places a piece of sodium in water. When sodium reacts with water, two atoms of sodium react with each water molecule. Here is a model to represent the reactants.



Here are some ways to represent one molecule of each substance after they were put together. Some of these are possible and some are not.

Use the previous diagrams—choices A, B, C, and D—to answer the following questions:

1. Which of the choices (A, B, C, or D) could represent the products of a chemical reaction in a closed system? Give reasons for your answer.



2. Choose any one of the other choices (A, B, C, or D) that you did not use to answer Question 1, and describe what you think that example shows.

LESSON 13

Is My Soap a New Substance?

ACTIVITY 13.1 – IS MY SOAP A NEW SUBSTANCE?

What Will We Do?

We will compare the properties of the soap we made with the properties of fat. We will use Activity Sheets 2.1, 3.1, and 4.1 to copy our old data, and to remind us of the procedures and safety notes for measuring solubility, melting point, and density.

⚠ Safety

Wear gloves at all times when handling your soap.

Prediction

Do you think the properties of your soap will be similar to the properties of fat? Why?

Procedures

Create a data table to record the properties you measure. After completing each procedure for measuring the properties of your soap, record the properties in your data collection table.

Color Procedure

1. Observe your soap and record the color.

Hardness Procedure

1. Wear gloves.

2. Break a small piece off of your soap. Squeeze it in your hand to determine the hardness.

Solubility Procedure

1. Wear safety goggles and gloves during your solubility test.

2. Refer back to Activity Sheet 2.1 for procedure and safety notes.

Melting Point Procedure

1. Wear safety goggles during this investigation.

2. Refer back to Activity Sheet 3.1 for procedure and safety notes.

Density Procedure

1. Wear safety goggles and gloves when measuring density.

2. Refer back to Activity Sheet 4.1 for procedure and safety notes.

Data

Complete each procedure for color, hardness, density, solubility, and melting point. Create a table for recording your data. Fill in your table; record the properties of your soap.

Conclusion

How can you explain what happens when fat and sodium hydroxide are combined so that they make soap?

Reading 13.1 – How Does My Soap Compare with Colonial Soap and Modern Soap?

Getting Ready

In colonial times, making soap was a difficult and dangerous job. Usually the women in a family, or the female slaves, made the soap. Even their clothing could make the job dangerous. Sometimes their skirts would catch on fire as they stirred the soap. In this reading, you will learn more about soap in colonial times and compare it to modern soap.

If the women got lye on their skin or in their eyes, the lye could burn them or even cause blindness. They also had difficulties adding the right amount of each ingredient. If they had understood the chemical reaction, this might have helped. They often did not add the correct amount of lye to react with the fat. Adding too much lye created a harsh soap, which made the colonists' skin rough and red. The soap was harsh because lye is a chemical that corrodes and burns.

The lye that the colonists used is similar to the sodium hydroxide you used in class. What are some reasons why your homemade soap might also be harsh? You may not have measured your reactants precisely. You may not have heated the soap to a high enough temperature. You may not have waited long enough for the chemical reaction to finish. This is why you need to be careful handling the soap that you made in class.

Modern Soap

The colonists' soaps (and maybe your soap) looked very different from the soaps used today. Today we use different reactants to make soap. Instead of solid fat, soap is often made from different types of liquid fats or oils. Instead of lye made from potash, soap is often made with different chemicals—a solution of sodium hydroxide.

One job of scientists is to test the ingredients in the chemical reaction to make better soaps for people. After soap is made, it is tested to make sure it is not too harsh. Fragrances, colors, and moisturizers are added to make people want to buy the soap. This is why commercial soap that you buy in the store is usually a mixture and not a substance. The soap created in colonial times was usually a substance because it consisted of soap without added fragrance, color, or moisturizer.

Do you think the soap you made in class was more like the soap made in colonial America or like soap that you can buy in the store today? Explain your ideas.

LESSON 14

How Does My Soap Compare or How Can I Improve My Soap?

ACTIVITY 14.1 – HOW DOES MY SOAP COMPARE WITH COMMERCIAL BRAND SOAP?

What Will We Do?

We will design and conduct an experiment to determine how our soap is similar and different from commercial brand soap.

What kind of test will your group conduct to compare the soaps?

Prediction

Do you think your soap or the commercial brand soap will perform better on your comparison test? Why?

Safety

Wear safety goggles and gloves when handling and testing soap.

Procedure

Design an experiment with your group to test your soap versus commercial-brand bar soap. Draw and write your procedure in the following box and lines. Include how you will collect and keep track of your data.

Conclusion

1. Which soap performed better than the other in your investigation?

2. If you were going to make soap again, what would you do to make a better soap? Why would that make it better?

Reading 14.1 – The Science behind *Rumpelstiltskin*

Getting Ready

Think back to the *Rumpelstiltskin* fairy tale at the beginning of Learning Set 2. You might choose to reread *Rumpelstiltskin* before you do this activity.

Even before you learned about chemical reactions, you knew that straw could not be turned into gold. You already understood that could not happen except in a fairy tale. It probably seemed like common sense. Now you can understand the scientific principles that apply to something you already knew. You can use science to talk about Rumpelstiltskin changing straw into gold.

The molecules in straw are made up of carbon, hydrogen, and oxygen atoms. Gold is made of gold atoms. Describe why straw cannot be turned into gold. In your answer, be sure to include what you have learned about chemical reactions, atoms and molecules, and reactants and products. Be as thorough as you can as you put together everything you have learned.

ACTIVITY 14.2 – HOW CAN I IMPROVE MY SOAP?

What Will We Do?

We will try to make a better soap by altering the soap-making procedure.

What variable do you plan to change? How do you plan to change it?

Prediction

Do you think your new procedure will make a better soap? Why?

Safety

Sodium hydroxide can burn your skin. You must wear safety goggles and gloves at all times. If you get sodium hydroxide solution on your skin, tell your teacher immediately and rinse your skin with cold water.

Procedure

You will need to refer to Activity Sheet 12.1 for the procedure for making soap. Record your new procedure.

Data

	Observations
during mixing and heating of substances	
after pouring soap into salt water	
after removing soap from salt water	

Conclusion

1. Do you think that your new soap is better than your original soap? Why?

2. What kind of tests would you conduct to determine whether your new soap is a better soap?