Chapter 6, Lesson 1: What is a Chemical Reaction?

Key Concepts:

- A physical change, such as a state change or dissolving, does not create a new substance, but a chemical change does.
- In a chemical reaction, the atoms and molecules that interact with each other are called *reactants*.
- In a chemical reaction, the atoms and molecules produced by the reaction are called *products*.
- In a chemical reaction, only the atoms present in the reactants can end up in the products. No new atoms are created, and no atoms are destroyed.
- In a chemical reaction, reactants contact each other, bonds between atoms in the reactants are broken, and atoms rearrange and form new bonds to make the products.

Summary

The teacher will use a small candle flame to demonstrate a chemical reaction between the candle wax and oxygen in the air. Students will see a molecular animation of the combustion of methane and oxygen as a model of a similar reaction. Students will use atom model cut-outs to model the reaction and see that all the atoms in the reactants show up in the products.

Objective

Students will be able to explain that for a chemical reaction to take place, the bonds between atoms in the reactants are broken, the atoms rearrange, and new bonds between the atoms are formed to make the products. Students will also be able to explain that in a chemical reaction, no atoms are created or destroyed.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. Be careful when lighting the candle. Be sure that the match and candle are completely extinguished when you are finished with the demonstration.

Materials for the Demonstration

- Tea light candle or other small stable candle
- Matches
- Glass jar, large enough to be placed over the candle

Materials for Each Student

- Atom cut-outs from the activity sheet
- Sheet of colored paper or construction paper
- Colored pencils
- Scissors
- Glue or tape

ENGAGE

1. Review what happens during a physical change and introduce the idea of chemical change.

Tell students that in previous chapters they have studied different aspects of physical change. When atoms and molecules speed up or slow down, that is a physical change. When they change state from liquid to solid or from gas to liquid, that is a physical change. When a substance is dissolved by water or some other solvent, a new substance has not really been formed. The ions or molecules can still come back together to form the original substance.

Let students know that in this chapter they will explore what happens during a *chemical* change. In a chemical change, the atoms in the reactants rearrange themselves and bond together differently to form one or more new products with different characteristics than the reactants. When a new substance is formed, the change is called a chemical change.

2. As a demonstration, light a candle and explain what is happening using the terms *reactants*, *products*, and *chemical reaction*.

Explain that in most chemical reactions, two or more substances, called *reactants,* interact to create different substances called *products*. Tell students that burning a candle is an example of a chemical reaction.

Materials for the Demonstration

- Tea light candle or other small stable candle
- Matches
- Glass jar, large enough to be placed over the candle

Procedure

1. Carefully light a tea light candle or other small candle.
2. Keep the candle burning as you ask students the questions below. You will put the candle out in the second part of the demonstration.

Expected Results

The wick will catch on fire and the flame will be sustained by the chemical reaction.

The following question is not easy and students are not expected to know the answer at this point. However, thinking about a candle burning in terms of a chemical reaction is a good place to start developing what it means when substances react chemically.

Ask students:

- **What do you think are the reactants in this chemical reaction?**
  Wax and oxygen from the air are the reactants.

Students often say that the string or wick is burning. It is true that the string of the wick does burn but it's the wax on the string and not so much the string itself that burns and keeps the candle burning. Explain that the molecules that make up the wax combine with oxygen from the air to make the products carbon dioxide and water vapor.

Point out to students that this is one of the major characteristics of a chemical reaction: **In a chemical reaction, atoms in the reactants combine in new and different ways to form the molecules of the products.**

Students may be surprised that water can be produced from combustion. Since we use water to extinguish a fire, it may seem strange that water is actually produced by combustion. You may want to let students know that when they "burn" food in their bodies, they also produce carbon dioxide and water.

3. Place a jar over the candle to help students realize that oxygen is a reactant in the burning of a candle.

Remind students that air is a mixture of gases. Explain that when something burns, it reacts with the oxygen in the air.

Ask students to make a prediction:

- **Will the candle still burn if one of the reactants (wax or oxygen) is no longer available?**
  Students may guess that the candle will not burn because both reactants are required for the chemical reaction to continue.

Procedure

1. Carefully place a glass jar over the lit candle.

Expected Results
The flame goes out.

Ask students:

- **Why do you think the flame goes out when we put a jar over the candle?**
  Placing a jar over the candle limits the amount of oxygen in the air around the candle. Without enough oxygen to react with the wax, the chemical reaction cannot take place and the candle cannot burn.

When a candle burns for a while, it eventually gets smaller and smaller. Where does the candle wax go?
When a candle burns, the candle wax seems to "disappear." It doesn't really disappear, though: It reacts chemically, and the new products go into the air.

***Note**: Some curious students may ask what the flame is made of. This is a great question and not trivial to answer. The flame is burning wax vapor. The light of the flame is caused by a process called chemiluminescence. Energy released in the chemical reaction makes electrons from different molecules move to a higher energy state. When the electrons come back down, energy is released in the form of light.*

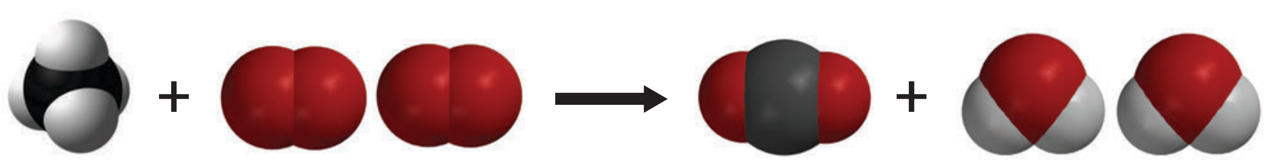
EXPLAIN

4. Introduce the chemical equation for the combustion of methane and explain that atoms rearrange to become different molecules.

Explain to students that wax is made of long molecules called *paraffin* and that paraffin is made up of only carbon atoms and hydrogen atoms bonded together. Molecules made of only carbon and hydrogen are called *hydrocarbons*. Tell students that you will use the simplest hydrocarbon (methane) as a model to show how the wax, or any other hydrocarbon, burns.

Project the image *Methane and Oxygen React*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson1#chemical_reaction_methane

Show students that there is methane and oxygen on the left side of the chemical equation and carbon dioxide and water on the right side. Explain that the molecules on the left side are the *reactants* and the ones on the right side are the *products*. When the candle was burning, the paraffin reacted with oxygen in the air to produce carbon dioxide and water, similar to the chemical reaction between methane and oxygen.



CH_4 methane — $2O_2$ oxygen — CO_2 carbon dioxide — $2H_2O$ water

Explain to students that the chemical formula for methane is CH_4. This means that methane is made up of one carbon atom and four hydrogen atoms.

Show students that the other reactant is two molecules of oxygen gas. Point out that each molecule of oxygen gas is made up of two oxygen atoms bonded together. It can be confusing for students that oxygen the atom, and oxygen the molecule, are both called *oxygen*. Let students know that when we talk about the oxygen in the air, it is always the molecule of oxygen, which is two oxygen atoms bonded together, or O_2.

Ask students:

- **Where do the atoms come from that make the carbon dioxide and the water on the right side of the equation?**
  The atoms in the products come from the atoms in the reactants. In a chemical reaction, bonds between atoms in the reactants are broken and the atoms rearrange and form new bonds to make the products.

***Note**: Leave this equation projected throughout the activity in the Explore section of this lesson. Students will need to refer to it as they model the chemical reaction.*

Give Each Student an Activity Sheet.

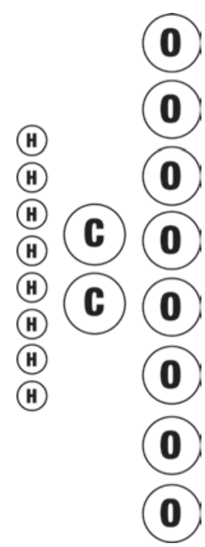
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms and Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

EXPLORE

5. Have students make a model to show that in a chemical reaction the atoms of the reactants rearrange to form the products.

Question to Investigate

Where do the atoms in the products of a chemical reaction come from?



Materials for Each Student

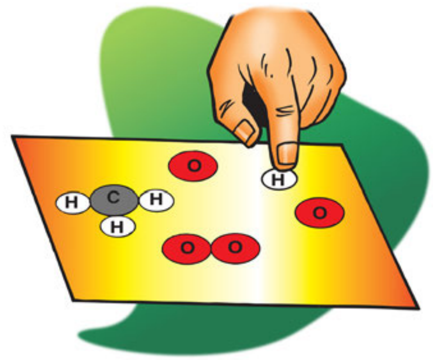
- Atom model cut-outs (carbon, oxygen, and hydrogen)
- Sheet of colored paper or construction paper
- Colored pencils
- Scissors
- Glue or tape

Procedure

Prepare the Atoms

1. Color the carbon atoms black, the oxygen atoms red, and leave the hydrogen atoms white.
2. Use scissors to carefully cut out the atoms.

Build the Reactants



3. On a sheet of paper, place the atoms together to make the molecules of the reactants on the left side of the chemical equation for the combustion of methane.
4. Write the chemical formula under each molecule of the reactants. Also draw a + sign between the reactants.

After you are sure that students have made and written the formula for the reactant molecules, tell students that they will rearrange the atoms in the reactants to form the products.

Build the Products

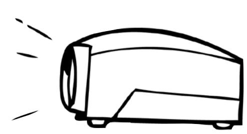
5. Draw an arrow after the second oxygen molecule to show that a chemical reaction is taking place.
6. Rearrange the atoms in the reactants to make the molecules in the products on the right side of the arrow.
7. Write the chemical formula under each molecule of the products. Also draw a + sign between the products.

Tell students that in a chemical reaction, the atoms in the reactants come apart, rearrange, and make new bonds to form the products.

Represent the Chemical Equation

8. Have students use their remaining atoms to make the reactants again to represent the chemical reaction as a complete chemical equation.
9. Glue or tape the atoms to the paper to make a more permanent chemical equation of the combustion of methane.

EXPLAIN



6. Help students count up the number of atoms on each side of the equation.

Project the animation *Combustion of Methane.*
www.middleschoolchemistry.com/multimedia/chapter6/lesson1#combustion_of_methane

Show students that the atoms in methane and oxygen need to come apart just like in their models. Also point out that the atoms arrange themselves differently and bond again to form new products. This is also like their model. Be sure that students realize that the atoms in the products only come from the reactants. There are no other atoms available. No new atoms are created and no atoms are destroyed.

Explain to students that chemical reactions are more complicated than the simplified model shown in the animation. The animation shows that bonds between atoms in the reactants are broken, and that atoms rearrange and form new bonds to make the products. In reality, the reactants need to collide and interact with each other in order for their bonds to break and rearrange. Also, the animation shows all of the atoms in the reactants coming apart and rearranging to form the products. But in many chemical reactions, only some bonds are broken, and groups of atoms stay together as the reactants form the products.

Guide students as you answer the following question together:

- **How many carbon, hydrogen, and oxygen atoms are in the reactants compared to the number of carbon, hydrogen, and oxygen atoms in the products?**
  Show students how to use the big number (coefficient) in front of the molecule and the little number after an atom of the molecule (subscript) to count the atoms on both sides of the equation. Explain to students that the subscript tells how many of a certain type of atom are in a molecule. The coefficient tells how many of a particular type of molecule there are. So if there is a coefficient in front of the molecule and a subscript after an atom, you need to multiply the coefficient times the subscript to get the number of atoms.

  For example, in the products of the chemical reaction there are $2H_2O$. The coefficient means that there are two molecules of water. The subscript means that each water molecule has two hydrogen atoms. Since each water molecule has two hydrogen atoms and there are two water molecules, there must be 4 (2×2) hydrogen atoms.

Read more about the combustion of methane in the additonal teacher background section at the end of the lesson.

Atoms	Reactant side	Product side
Carbon	1	1
Hydrogen	4	4
Oxygen	4	4

__Note__: The coefficients actually indicate the ratios of the numbers of molecules in a chemical reaction. It is not the actual number as in two molecules of oxygen and one molecule of methane since there are usually billions of trillions of molecules reacting. The coefficient shows that there are twice as many oxygen molecules as methane molecules reacting. It would be correct to say that in this reaction there are two oxygen molecules for every methane molecule.

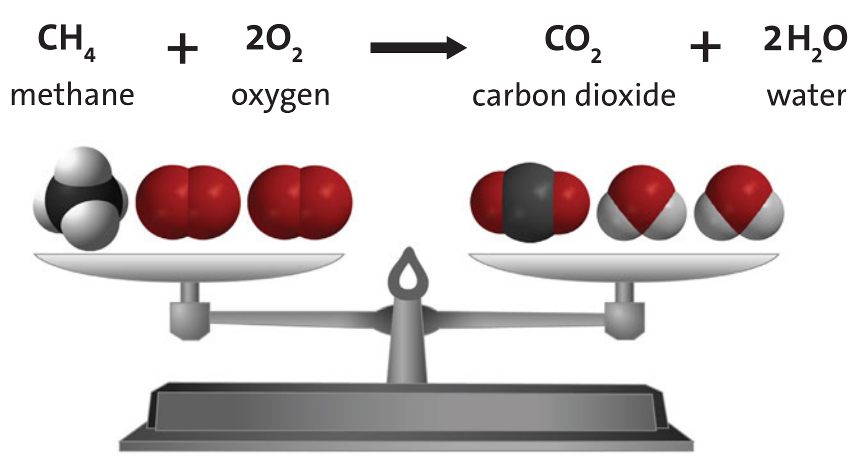
7. Explain that mass is conserved in a chemical reaction.

Ask students:

- **Are atoms created or destroyed in a chemical reaction?**
  No.
- **How do you know?**
  There are the same number of each type of atom on both the reactant side and the product side of the chemical equation we explored.
- **In a physical change, like changing state from a solid to a liquid, the substance itself doesn't really change. How is a chemical change different from a physical change?**
  In a chemical change, the molecules in the reactants interact to form new substances. In a physical change, like a state change or dissolving, no new substance is formed.

Explain that another way to say that no atoms are created or destroyed in a chemical reaction is to say, "Mass is conserved."

Project the image *Balanced Equation*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson1#balanced_equation
Explain that the balance shows the mass of methane and oxygen on one side exactly equals the mass of carbon dioxide and water on the other. When an equation of a chemical reaction is written, it is "balanced" and shows that the atoms in the reactants end up in the products and that no new atoms are created and no atoms are destroyed.



EXTEND

8. Introduce two other combustion reactions and have students check to see whether or not they are balanced.

Tell students that, in addition to the wax and methane, some other common hydrocarbons are propane (the fuel in outdoor gas grills), and butane (the fuel in disposable lighters). Have students count the number of carbon, hydrogen, and oxygen atoms in the reactants and products of each equation to see if the equation is balanced. They should record the number of each type of atom in the chart on their activity sheet.

CH_4
methane

C_3H_8
propane

C_4H_{10}
butane

Lighting an outdoor gas grill—Combustion of propane
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_20$

Using a disposable lighter—Combustion of butane
$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

After students have counted up each type of atom, review their answers to make sure they know how to interpret subscripts and coefficients.

Activity Sheet
Chapter 6, Lesson 1
What is a Chemical Reaction?

Name ______________________

Date ______________________

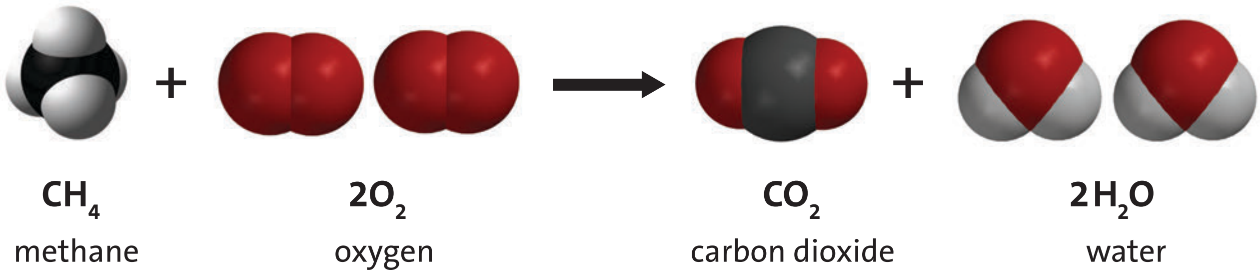
DEMONSTRATION

1. Your teacher lit a candle and told you that this was a chemical reaction. What are the *reactants* in this chemical reaction?

2. What are the *products* in this chemical reaction?

3. Why did the flame go out when your teacher put a jar over the candle?

4. Where do the atoms come from that make the carbon dioxide and the water on the right side of the equation?



ACTIVITY

Question to Investigate

Where do the atoms in the products of a chemical reaction come from?

Materials for Each Student

- Atom model cut-outs (carbon, oxygen, and hydrogen)
- Sheet of colored paper or construction paper
- Colored pencils
- Scissors
- Glue or tape

Procedure

Prepare the Atoms

1. Color the carbon atoms black, the oxygen atoms red, and leave the hydrogen atoms white.
2. Use scissors to carefully cut out the atoms.

Build the Reactants

3. On a sheet of paper, place the atoms together to make the molecules of the reactants on the left side of the chemical equation for the combustion of methane.
4. Write the chemical formula under each molecule of the reactants. Also draw a + sign between the reactants.

Build the products

5. Draw an arrow after the second oxygen molecule to show that a chemical reaction is taking place.
6. Rearrange the atoms in the reactants to make the molecules in the products on the right side of the arrow.
7. Write the chemical formula under each molecule of the products. Also draw a + sign between the products.

Tell students that in a chemical reaction, the atoms in the reactants come apart, rearrange, and make new bonds to form the products.

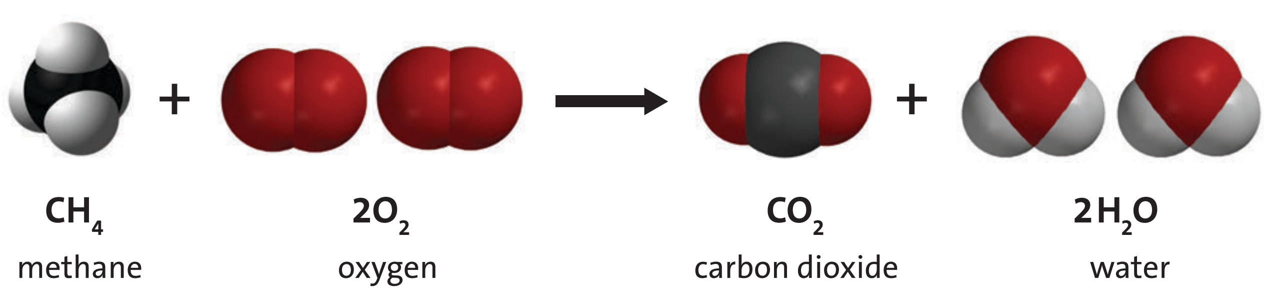
Represent the chemical equation

8. Use your remaining atoms to make the reactants again to represent the chemical reaction as a complete chemical equation.
9. Glue or tape the atoms to the paper to make a more permanent chemical equation of the combustion of methane.

EXPLAIN IT WITH ATOMS & MOLECULES

In a chemical equation, like the one below, you will notice that there are regular-sized numbers in front of some of the molecules and small numbers after certain atoms within a molecule. The little number is called the *subscript* and tells how many of a certain type of *atom* are in a molecule. The bigger number is called the *coefficient* and tells how many of a particular type of *molecule* there are.

If there is a coefficient in front of the molecule and a subscript after an atom, multiply the coefficient and the subscript to get the number of atoms. For example, in the products of the chemical reaction there are two water molecules, or $2H_2O$. The coefficient means that there are two molecules of water. The subscript means that each water molecule has two hydrogen atoms. Since each water molecule has 2 hydrogen atoms and there are two water molecules, there must be 4 (2×2) hydrogen atoms.

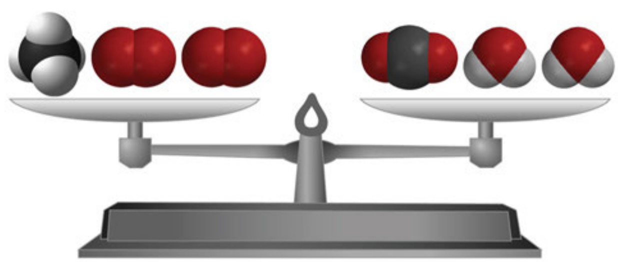


5. Count up the number of atoms on each side of the equation below and write this in the chart.

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$		
Atom	**Reactant side**	**Product side**
Carbon		
Hydrogen		
Oxygen		

6. Are atoms created or destroyed in a chemical reaction?

   How do you know?



7. In a physical change, like changing state from a solid to a liquid, the substance itself doesn't really change. How is a chemical change different from a physical change?

TAKE IT FURTHER

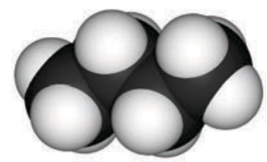
Molecules made up of only carbon and hydrogen are called *hydrocarbons*. The candle and the hydrocarbons listed below react with oxygen in a chemical reaction called *combustion*.

CH_4
methane

Fuel in gas stoves in many home kitchens

C_3H_8
propane

Fuel in outdoor gas grills



C_4H_{10}
butane

Fuel in disposable lighters

8. Count the number of carbon, hydrogen, and oxygen atoms in the reactants and products of each equation to see if the equation is balanced. Record the number of each type of atom in each chart.

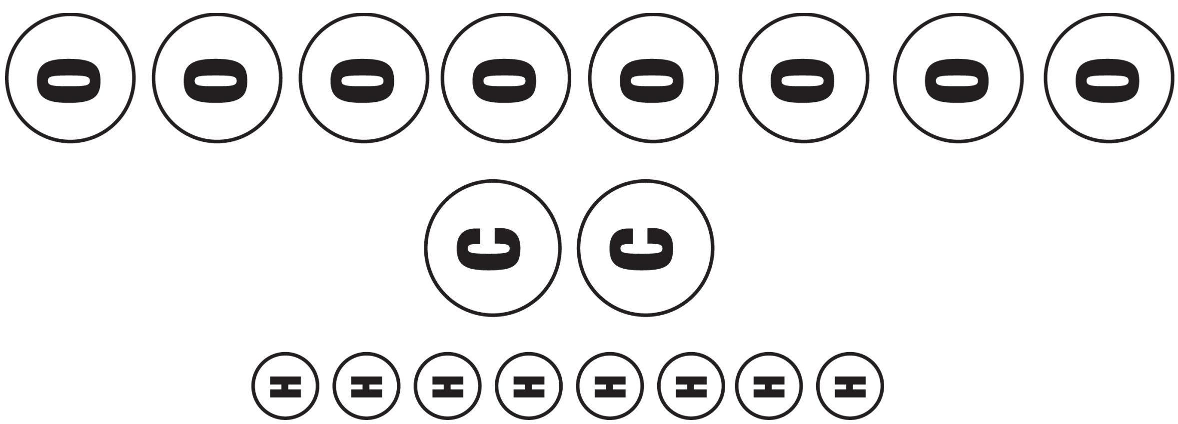
Combustion of Propane
$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_20$

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$		
Atom	**Reactant side**	**Product side**
Carbon		
Hydrogen		
Oxygen		

Combustion of Butane

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

$2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$		
Atom	**Reactant side**	**Product side**
Carbon		
Hydrogen		
Oxygen		



Additional Teacher Background
Chapter 6, Lesson 1, p. 529

In the reaction between methane and oxygen, why do the atoms in methane and oxygen switch around and bond to form carbon dioxide and water?

This is a very good question. One of the main reasons has to do with the attractions that protons and electrons in one atom have for the electrons and protons in other atoms. If the conditions are right and atoms get a chance to bond with different atoms so that electrons are attracted to and closer to more protons, the atoms will switch around and rebond.

In methane, the 4 hydrogen atoms are each bonded to the 1 carbon atom by a covalent bond. Remember that this bond happens because the electron from the hydrogen atom is attracted to the protons in the carbon atom and an electron from the Carbon atom is attracted to the proton in the hydrogen atom. These attractions bring the atoms together and they end up sharing electrons to form a covalent bond.

The same is true about the other reactant – the oxygen molecules. The electrons from each oxygen atom are attracted to the protons in the other oxygen atom. This is true for both atoms so they come together and share electrons to form a covalent bond.

But the big question is why do the atoms in the methane and oxygen switch around and bond to different atoms in a chemical reaction to form carbon dioxide and water?

The answer is that the electrons and protons feel stronger attractions for each other and can get closer together if they switch around and bond to different atoms. The hydrogen atoms that are bonded to the carbon atom in methane switch around and end up being bonded to oxygen atoms to make water. The electrons in the hydrogen atoms were near 6 protons in the carbon atom but are now near 8 protons in oxygen. They are more attracted to 8 protons than to 6 so the trade is good to satisfy the attractions of electrons and protons.

The carbon atom that was attracted to the hydrogen atoms in the methane switched around and is now bonded to 2 oxygen atoms in the carbon dioxide. This is a really good trade. The electron from the carbon atom was near 1 proton from a hydrogen atom is now near 8 protons from an oxygen atom. This also satisfies the attractions of electrons and protons.

So one of the main reasons why atoms rearrange themselves in a chemical reaction is that by bonding to the other atoms, electrons and protons feel more attraction and get closer together.

Note:
This explanation works well for combustion reactions and other exothermic reactions but cannot fully explain endothermic reactions. In endothermic reactions, the electrons and protons in the products are actually in a less favorable situation for mutual attraction than they were in the reactants. There is a concept called entropy which helps explain why endothermic reactions occur but concepts related to entropy are beyond the scope of middle school chemistry and will not be introduced in this material.

Chapter 6, Lesson 2:
Controlling the Amount of Products in a Chemical Reaction

Key Concepts

- Changing the amount of reactants affects the amount of products produced in a chemical reaction.
- In a chemical reaction, only the atoms present in the reactants can end up in the products.
- Mass is conserved in a chemical reaction.

Summary

Students will analyze the chemical equation for the reaction between vinegar (acetic acid solution) and baking soda (sodium bicarbonate). They will make the connection between the written chemical equation, the molecular model, and the real substances in the reaction. Students will see that the gas produced in the actual reaction is also written in the products of the equation. Students will also change the amount of one or more reactants and see how the change affects the amount of products.

Objective

Students will be able to explain that for a chemical reaction to take place, the bonds between atoms in the reactants are broken, the atoms rearrange, and new bonds between the atoms are formed to make the products. Students will be able to count the number of atoms on the reactant side and on the product side of a chemical equation. They will also be able to explain that the equal number of atoms on each side of the equation shows that mass is conserved during a chemical reaction. Students will also be able to explain, on the molecular level, why changing the amount of one or more reactants changes the amount of products. They will also be able to explain why simply adding more and more of one reactant will eventually not produce additional products.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. Use vinegar in a well-ventilated room. Have students wash hands after the activity.

Materials for the Demonstrations

- Vinegar
- Baking soda
- Water
- Alka-Seltzer
- Detergent solution
- Graduated cylinder (50 mL)
- Graduated cylinder (100 mL)
- Measuring spoon (½ teaspoon)
- 1 clear plastic cup
- Small cup
- Dropper
- Plastic waste container

Materials for Each Group

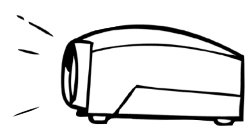
- Vinegar in a cup
- Baking soda in a cup
- Detergent solution in a cup
- Dropper
- Graduated cylinder (50 mL)
- Measuring spoons (⅛, ¼, and ½ teaspoon)
- Plastic waste container

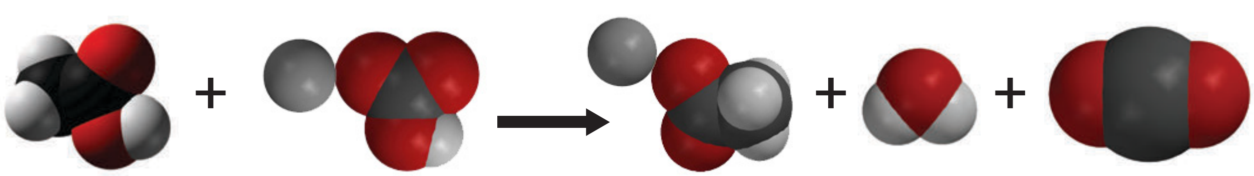
ENGAGE

1. Have students look at the chemical equation for the vinegar and baking soda reaction as you discuss the reactants.

Remind students that in the last lesson, they learned that in a chemical reaction, certain atoms in the reactant molecules unbond from one another and then rearrange and rebond in different ways to form the products. Students saw that the same type and number of atoms were in the reactants as were in the products. Let students know that although the reaction in this lesson looks more complicated, these same principles still apply.

Project the image *Reactants*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson2#reactants
Show students the chemical equation for the reaction between vinegar and baking soda.





$C_2H_4O_2$ acetic acid + $NaHCO_3$ sodium bicarbonate → $NaC_2H_3O_2$ sodium acetate + H_2O water + CO_2 carbon dioxide

Ask students about vinegar:

- **Acetic acid mixed with water is vinegar. Usually vinegar is a solution of about 5% acetic acid and 95% water. When a reactant is in solution, the water is usually not listed as a reactant. Which atoms make up a molecule of acetic acid (vinegar)?**
  Carbon , hydrogen, and oxygen (C, H, and O).
- **What do the little numbers below and to the right of each letter mean?**
  These are the number of that particular atom in the acetic acid molecule. There are two carbon atoms, four hydrogen atoms, and two oxygen atoms in an acetic acid molecule.
- **Do you think every acetic acid molecule has this formula?**
  Yes. The chemical formula for a substance is unique to that substance and defines what it is.

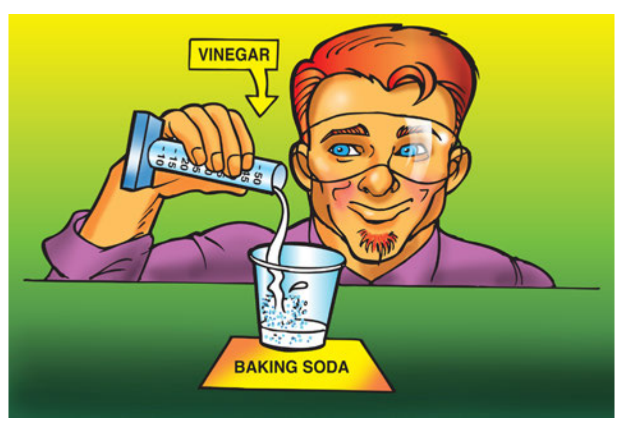
Ask students about baking soda:

- **Sodium bicarbonate is baking soda. What atoms is sodium bicarbonate made of?**
  Sodium, hydrogen, carbon, and oxygen (Na, H, C, and O).
- **How many of each type of atom are there in the compound sodium bicarbonate?**
  There are one sodium atom, one hydrogen atom, one carbon atom, and three oxygen atoms in every unit of sodium bicarbonate.

2. As a demonstration, combine vinegar and baking soda to show students the chemical reaction described in the equation.

Materials for the Demonstration

- Vinegar
- Graduated cylinder (50 mL)
- Baking soda
- Clear plastic cup



Procedure

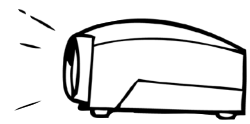
- Use a graduated cylinder to measure 10 mL of vinegar.
- Place about ½ teaspoon of baking soda in a clear plastic cup.
- While students watch, pour the vinegar into the baking soda.

Expected Results

Bubbles will form and rise up in the cup.

Ask students:

- **I combined a liquid and a solid, and you saw bubbling, which is made from gas. Do you think a chemical reaction occurred? Why?**
  A chemical reaction occurred because a different substance was produced when the reactants combined.



Project the image *Products*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson2#products
Point out the products in the chemical reaction.

$$C_2H_4O_2 + NaHCO_3 \longrightarrow NaC_2H_3O_2 + H_2O + CO_2$$

acetic acid + sodium bicarbonate → sodium acetate + water + carbon dioxide

Ask students:

- **Look at the chemical equation. What is the gas produced in the chemical reaction between vinegar and baking soda?**
  Carbon dioxide
- **What else is produced in this chemical reaction?**
  When vinegar and baking soda react, atoms rearrange to form sodium acetate (the salty and sour flavor in salt-and-vinegar-flavored potato chips), water, and carbon dioxide.

Continue to project the chemical equation as you and students count the number of atoms on both the reactant side and product side of the equation.

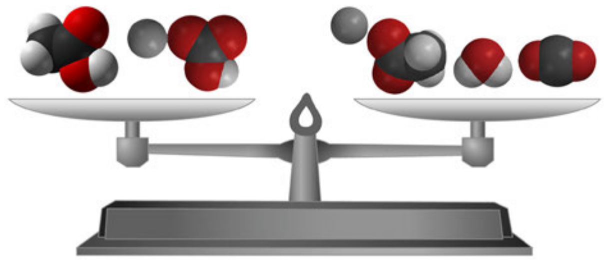
3. Review the concept that mass is conserved in a chemical reaction.

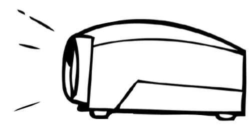
Help students count the atoms in the reactants and in the products of the vinegar-baking soda reaction. Make sure students see that every type of atom on the left side of the equation is also on the right. Also be sure that they see that there is an equal number of each type on both sides of the equation.

Guide students as you answer the following questions together:

- **Is every type of atom on the left side of the equation also on the right side of the equation?** Yes. **Why?**
  Atoms from the reactants rearrange to form the products. Atoms are not created or destroyed in a chemical reaction.
- **How many of each type of atom is on the reactant side of the equation?**
  3 carbon atoms, 5 hydrogen atoms, 5 oxygen atoms, and 1 sodium atom.
- **How many of each type of atom is on the product side of the equation?**

3 carbon atoms, 5 hydrogen atoms, 5 oxygen atoms, and 1 sodium atom.





Project the image *Mass is Conserved*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson2#mass_is_conserved

Point out that the type and number of atoms in the reactants and in the products are exactly the same. This is an important concept in chemistry: In a chemical reaction, all the atoms in the reactants end up in the products. When an equation of a chemical reaction is written, it is "balanced" to show this. A balanced chemical equation shows that no atoms are destroyed and no new atoms are created in the chemical reaction. Explain to students that another way of saying that no atoms are created or destroyed in a chemical reaction is that *mass is conserved*.

EXPLORE

4. As a demonstration, combine vinegar, detergent, and baking soda in a graduated cylinder so that foam rises and spills over the top.

Teacher Preparation for the Demonstration and for Each Group

- Make a detergent solution by adding 1 teaspoon of liquid dish detergent to 2 tablespoons of water. Divide this detergent solution equally into one small cup for each group.
- Place about 1 tablespoon of vinegar in a small cup for each group.
- Place about 2 teaspoons of baking soda in a small cup for each group.

Materials for the Demonstration

- Vinegar
- Baking soda
- Detergent solution
- Dropper
- Graduated cylinder (50 mL)
- Measuring spoon (½ teaspoon)

- Plastic waste container
- Small cup

Procedure

1. Use a graduated cylinder to measure 10 mL of vinegar.
2. Pour the vinegar in a small cup and add 1 drop of detergent. Swirl gently to mix.
3. Add ½ teaspoon of baking soda to the empty graduated cylinder.
4. Place the graduated cylinder in a plastic waste container.
5. Pour the vinegar and detergent from the cup into the graduated cylinder. Have students observe the level of foam in the graduated cylinder.
6. Rinse the graduated cylinder over the waste container.

Expected Results
White foam will rise up in the graduated cylinder and overflow.

5. Discuss how to change the amount of foam produced so that it rises to the top of the cylinder without overflowing.

Ask students:

- What could you change to create a foam that rises as close as possible to the top of the cylinder without overflowing?
  Students might mention variables such as:
  - The amount of vinegar, detergent, or baking soda.
  - The order in which the substances are added to the graduated cylinder.

Explain that the amount of detergent should not be varied in this activity because it is used as an indicator to help measure the amount of gas produced in the reaction. Also, the baking soda should be added to the cylinder first. The vinegar is poured in afterwards to cause better mixing of reactants.

Remind students that 10 mL of vinegar and ½ teaspoon of baking soda caused the foam to overflow. Students should consider these amounts as they plan how much of each reactant they will use as they start their trials.

Ask students:

- **Can you add the baking soda first and then the vinegar on one trial and then switch it for the other trials?** No**. Why not?**
  Every test should be conducted the same way. For example, in the demonstration baking soda was placed in the graduated cylinder before the vinegar and detergent were added. This method mixes the baking soda and vinegar well. All new trials should be conducted this same way.
- **Should you rinse the graduated cylinder each time?** Yes. **Why?**
  Any products or leftover reactants that remain in the graduated cylinder may affect the next reaction. It is best to rinse the cylinder after each trial.
- **How will you remember the amounts you used in each trial?**
  Students should realize the necessity of making and recording accurate measurements in the chart provided.

Give each Student an Activity Sheet.

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

6. Have each group experiment with different amounts of vinegar and baking soda in order to get the foam to rise to the top of the graduated cylinder without overflowing.

Tell students that they should try to get the foam to stop as close as possible to the top of the cylinder without overflowing. You may choose to limit students to a maximum of three tries or let them experiment further if time and supplies allow.

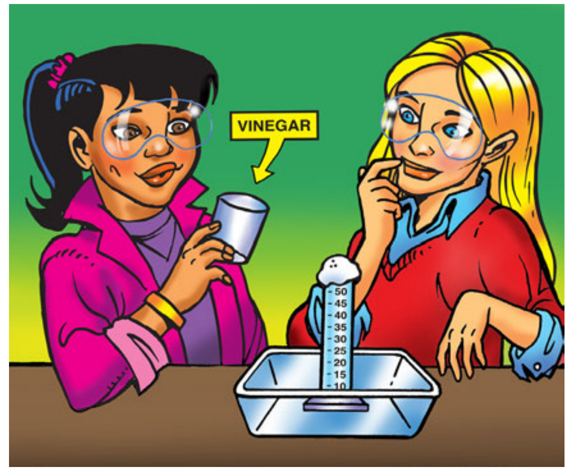
Question to Investigate

How can you make just the right amount of foam that rises to the top of the graduated cylinder without overflowing?

Materials for Each Group

- Vinegar in a cup
- Baking soda in a cup
- Detergent solution in a cup
- Dropper
- Graduated cylinder (50 mL)

- Measuring spoons (⅛, ¼, and ½ teaspoon)
- Plastic waste container



Procedure

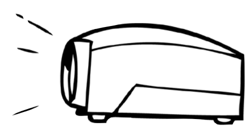
1. Decide on how much vinegar and baking soda you will use and write these amounts in the chart on the activity sheet.
2. Use a graduated cylinder to measure the amount of vinegar your group agreed on.
3. Pour the vinegar in a small cup and add 1 drop of detergent. Swirl gently to mix.
4. Add the amount of baking soda your group agreed on to the empty graduated cylinder.
5. Place the graduated cylinder in a plastic waste container.
6. Pour the vinegar and detergent from the cup into the graduated cylinder. Observe the level of foam in the graduated cylinder.
7. Rinse the graduated cylinder over the waste container.

Expected Results

Using ⅛ teaspoon of baking soda, 5 mL of vinegar, and 1 drop of detergent will probably cause the foam to rise to the top of the cylinder without overflowing. Results may vary.

Have groups share their findings about the amounts of baking soda and vinegar that came closest to reaching the top of the cylinder. Did each group use similar amounts of baking soda and vinegar?

EXPLAIN

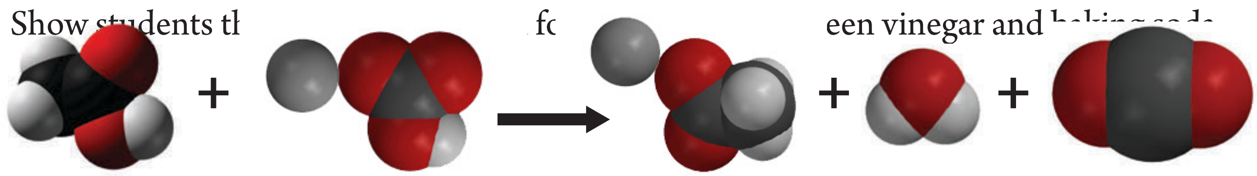


7. Discuss why adjusting the amount of reactants affects the amount of products.

Project the image *Controlling Amount of Products Formed.*

www.middleschoolchemistry.com/multimedia/chapter6/lesson2#controlling

Show students th fo een vinegar and



$C_2H_4O_2$ acetic acid + $NaHCO_3$ sodium bicarbonate → $NaC_2H_3O_2$ sodium acetate + H_2O water + CO_2 carbon dioxide

Ask students:

- **Why, on the molecular level, does changing the amount of baking soda or vinegar affect the amount of carbon dioxide gas produced?**
  Products are made from the reactants, so adding more reactants will produce more of the products.

The important point for students to realize is that atoms from *both* reactants are necessary to produce the products. Using less baking soda, for instance, produces less carbon dioxide gas because there are fewer atoms from the baking soda to produce the carbon dioxide. In general, using more of one or more reactants will result in more of one or more products. Using less of one or more reactants will result in less of one or more products. Let students know that this principle has limits.

Note*: It is not necessary for students at the middle school level to know which particular atom in the reactants ended up in which product. It might seem strange, but sometimes a product can be made up of atoms from only one reactant. In the vinegar and baking soda reaction, the atoms in the* CO_2 *only come from the sodium bicarbonate.*

Ask students:

- **What would you do if you wanted to make more carbon dioxide?**
  Add more vinegar and more baking soda.
- **Could you just keep adding more and more baking soda to the same amount of vinegar to get more carbon dioxide?**
  No. This might work for a while, as long as there is extra vinegar, but eventually there would be no atoms left of vinegar to react with the extra baking soda, so no more carbon dioxide would be produced.

EXTEND

5. Do a demonstration using Alka-Seltzer or a similar effervescent tablet in water to show that citric acid reacts with sodium bicarbonate to produce carbon dioxide gas.

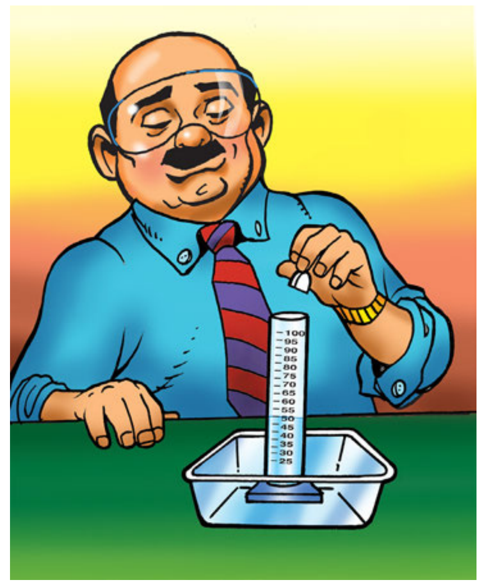
Tell students that an Alka-Seltzer tablet contains aspirin, sodium bicarbonate, and citric acid. Citric acid interacts with the sodium bicarbonate similar to the way the acetic acid in vinegar interacts with sodium bicarbonate.

Ask students to make a prediction:

- **What will happen when an Alka-Seltzer tablet is placed in water with a drop of detergent solution?**

Materials for the Demonstration

- Alka-Seltzer
- Water
- Graduated cylinder (100 mL)
- Detergent solution
- Dropper



Procedure

1. Place 50 mL of water in a 100 mL graduated cylinder.
2. Add 1 drop of detergent solution and swirl gently to mix.
3. Drop half of an Alka-Seltzer tablet in the graduated cylinder.
4. Place the graduated cylinder in a waste container.

Expected Results

White foam will rise up in the graduated cylinder and overflow as the tablet becomes smaller and smaller.

Ask students:

- **Do you think this is a chemical reaction?** Yes. **Why?**
  Because a gas was produced. This gas was not in one of the reactants, so it must have been produced during the chemical reaction.
- **Why do you think this reaction is similar to the reaction of vinegar and baking soda?**
  Citric acid and vinegar are both acids and so interact with sodium bicarbonate in a similar way to produce carbon dioxide gas.

Activity Sheet
Chapter 6, Lesson 2
Controlling the Amount of
Products in a Chemical Reaction

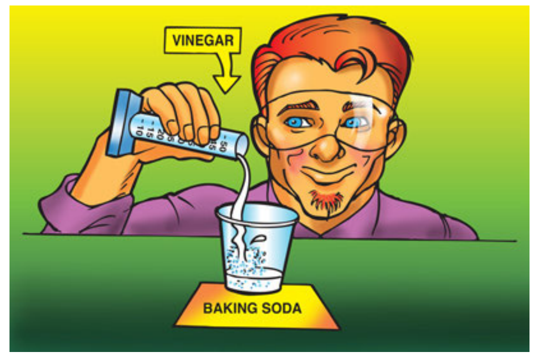
Name ______________________

Date ______________________

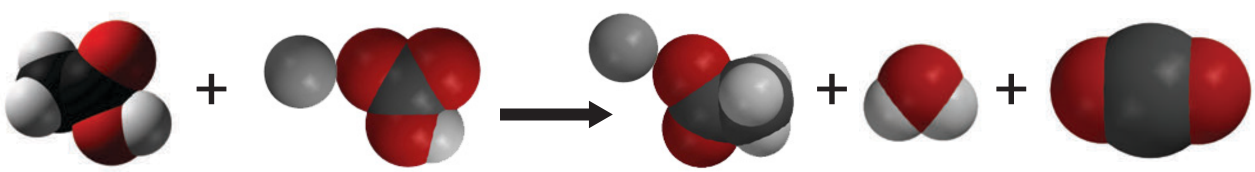
DEMONSTRATION

1. Your teacher combined a liquid (vinegar) and a solid (baking soda). You observed bubbling, which is made from gas. Do you think a chemical reaction occurred?

   Why?



2. Look at the chemical equation for the reaction between vinegar and baking soda to answer the following questions.



$C_2H_4O_2$	+	$NaHCO_3$	→	$NaC_2H_3O_2$	+	H_2O	+	CO_2
acetic acid		sodium bicarbonate		sodium acetate		water		carbon dioxide

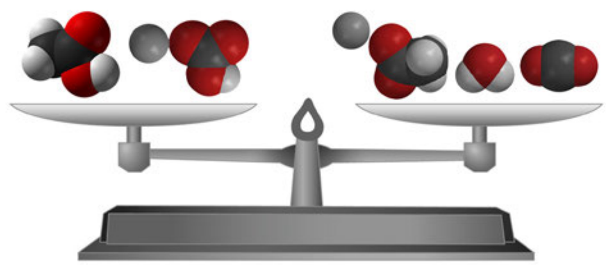
What are the *reactants* in this chemical reaction?

What are the *products* in this chemical reaction?

How many of each type of atom appears on each side of the chemical equation?

$C_2H_4O_2 + NaHCO_3 \longrightarrow NaC_2H_3O_2 + H_2O + CO_2$		
Atom	**Reactant side**	**Product side**
Carbon		
Hydrogen		
Oxygen		
Sodium		

3. What does the statement "*Mass* is conserved during a chemical reaction" mean?



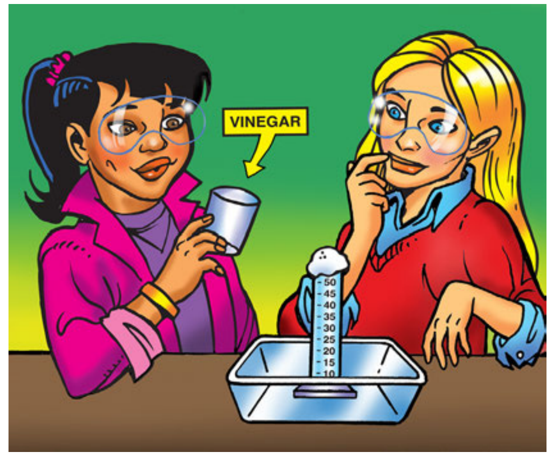
ACTIVITY

Question to investigate
How can you make just the right amount of foam that rises to the top of the graduated cylinder without overflowing?

Materials for each group

- Vinegar in a cup
- Baking soda in a cup
- Detergent solution in a cup
- Dropper
- Graduated cylinder (50 mL)
- Measuring spoons (⅛, ¼, and ½ teaspoon)
- Plastic waste container

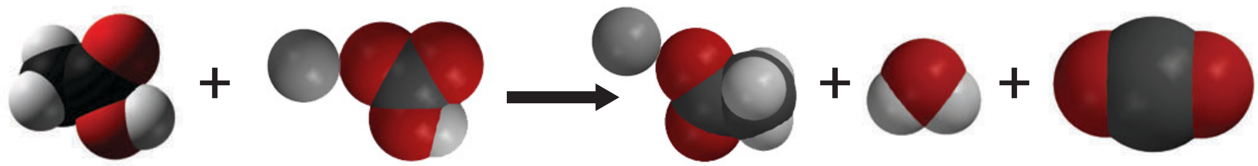
Procedure



1. Decide on how much vinegar and baking soda you will use and write these amounts in the chart on the activity sheet.
2. Use a graduated cylinder to measure the amount of vinegar your group agreed on.
3. Pour the vinegar in a small cup and add 1 drop of detergent. Swirl gently to mix.
4. Add the amount of baking soda your group agreed on to the empty graduated cylinder.
5. Place the graduated cylinder in a plastic waste container.
6. Pour the vinegar and detergent from the cup into the graduated cylinder. Observe the level of foam in the graduated cylinder.
7. Rinse the graduated cylinder over the waste container.

Adjust the amounts of baking soda and vinegar to create just enough foam to rise to the top of the graduated cylinder without overflowing.				
	Demonstration	**First try**	**Second try**	**Third try**
Vinegar	10 mL			
Baking soda	½ teaspoon			
Detergent	1 drop	1 drop	1 drop	1 drop
How close did the foam get to the top of the cylinder?	Overflowed			

EXPLAIN IT WITH ATOMS & MOLECULES



$C_2H_4O_2$ acetic acid + $NaHCO_3$ sodium bicarbonate → $NaC_2H_3O_2$ sodium acetate + H_2O water + CO_2 carbon dioxide

4. Why, on the molecular level, does changing the amount of baking soda or vinegar affect the amount of carbon dioxide gas produced?

5. What would you do if you wanted to make more carbon dioxide?

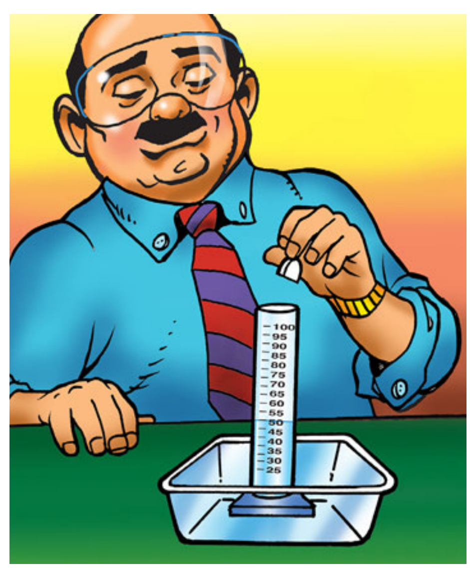
6. Could you just keep adding more and more baking soda to the same amount of vinegar to get more carbon dioxide?

   Why or why not?

TAKE IT FURTHER

7. An Alka-Seltzer tablet contains aspirin, sodium bicarbonate, and citric acid. Your teacher placed an Alka-Seltzer tablet in water with a drop of detergent. Do you think placing an Alka-Seltzer in water causes a chemical reaction?

   Why?



Chapter 6, Lesson 3: Forming a Precipitate

Key Concepts

- The ions or molecules in two solutions can react to form a solid.
- A solid formed from two solutions is called a *precipitate*.

Summary

Students will combine two clear colorless solutions (baking soda solution and calcium chloride solution) and see the formation of a solid and a gas. Students will analyze the chemical equation for the reaction and see that all atoms in the reactants end up in the products. They will make the connection between the chemical equation and the real substances and see that the solid and gas produced in the actual reaction are also in the products of the equation.

Objective

Students will be able to explain that for a chemical reaction to take place, the reactants interact, bonds between certain atoms in the reactants are broken, the atoms rearrange, and new bonds between the atoms are formed to make the products. Students will also be able to explain that this definition applies to the production of a solid called a *precipitate*.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. If you do the demonstration with copper II sulfate solution, ammonia, and hydrogen peroxide at the end of the lesson, pour the resulting solution and precipitate in a cup or beaker and allow it to evaporate. Put the small amount of solid in a paper towel and dispose in the trash or use a disposal method required by local regulations. Sodium carbonate may irritate skin. Wash hands after the activity. Magnesium sulfate dust can irritate respiratory tract.

Materials for the Demonstrations

- Sodium carbonate
- Epsom salt (magnesium sulfate)
- 2 clear plastic cups
- Test tube
- Water
- Copper II sulfate
- Household ammonia
- Hydrogen peroxide (3%)
- Graduated cylinder
- 2 droppers

Materials for Each Group

- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Measuring spoon (½ teaspoon) or balance
- 2 clear plastic cups
- Masking tape
- Pen

About the Materials
Copper II sulfate is available from various chemical suppliers, including Sargent Welch, Product #WLC94770-06 or Flinn Scientific, Product #C0110. Follow all safety precautions regarding use, storage, and disposal of copper II sulfate and sodium carbonate. Sodium carbonate is Product #WLC94291-06 or #S0052.

ENGAGE

1. Do a demonstration by combining two clear colorless solutions that produce a white solid and introduce the term *precipitate*.

Materials for the Demonstration
- Magnesium sulfate (Epsom salt)
- Sodium carbonate
- Water
- 2 clear plastic cups
- 1 tablespoon
- 1 teaspoon

Teacher Preparation
- Pour 100 mL of water in one clear plastic cup and add 10 g (about 1 tablespoon) of magnesium sulfate. Stir until the solution is clear.
- Pour 50 mL of water in another clear plastic cup and add 5 g (about 1 teaspoon) of sodium carbonate. Stir until the solution is clear.

Procedure
1. Hold up the two clear colorless solutions and slowly pour the smaller amount into the larger.

Expected Results
Particles of a white solid will form.

Ask students:
- **Would you consider adding a sodium carbonate solution to a magnesium sulfate solution a chemical reaction?**
  Yes.
  Why or why not?
  Combining the two clear colorless liquids is a chemical change because a different solid substance is formed.

Tell students that a precipitate is an insoluble solid that forms when two solutions are combined and react chemically. Insoluble means that the solid will not dissolve.

Give Each Student an Activity Sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

EXPLORE

2. Have students combine two liquids to observe another precipitate.

Question to Investigate
How do you know when a precipitate is formed in a chemical reaction?

Materials for Each Group

- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Measuring spoon (½ teaspoon) or balance
- 2 clear plastic cups
- Masking tape
- Pen

Note*: If you would like students to practice using a balance to weigh grams, have them weigh two grams each of baking soda and calcium chloride.*

Procedure

1. Use masking tape and a pen to label 2 plastic cups *baking soda solution* and *calcium chloride solution*.
2. Use a graduated cylinder to add 20 mL of water to each cup.
3. Add 2 g (about ½ teaspoon) of calcium chloride to the water in its labeled cup. Swirl until as much of the calcium chloride dissolves as possible.
4. Add 2 g (about ½ teaspoon) of baking soda to the water in its labeled cup. Swirl until as much

of the baking soda dissolves as possible. There may be some undissolved baking soda remaining in the bottom of the cup.

5. Carefully pour the baking soda solution into the calcium chloride solution. Try not to pour in any undissolved baking soda. Observe.

Expected Results
Bubbling and a white precipitate appear.

3. Discuss student observations.

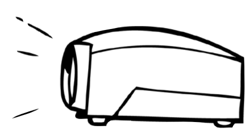
Ask students:

- **What did you observe when you mixed the baking soda solution and the calcium chloride solution?**
  The solutions bubbled and little white particles of solid formed.
- **Did you observe a precipitate?**
  Yes. The white particles appeared after the two solutions were combined.
- **Do you think this was a chemical reaction?** Yes. **Why?**
  The two substances that were combined were liquids and the substances that were produced were a solid and a gas. These products seem to be different from the reactants.

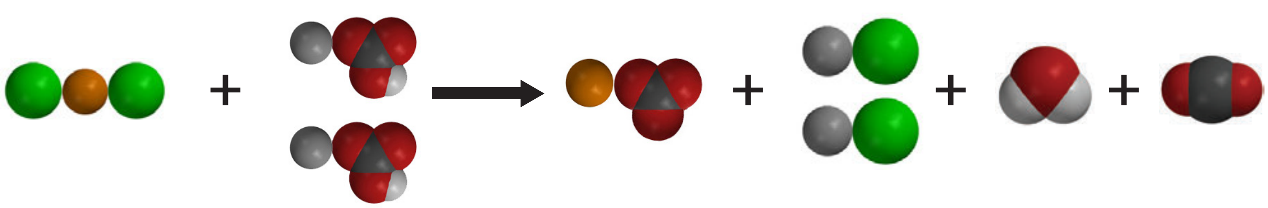
EXPLAIN

4. Discuss the products produced in this chemical reaction.

Remind students that in the chemical reactions they have seen so far, certain atoms in the reactant molecules unbond from one another and then rearrange and rebond in different ways to form the products. They saw that the same type and number of atoms were in the reactants as were in the products.



Project the image *Calcium Chloride and Sodium Bicarbonate.*
www.middleschoolchemistry.com/multimedia/chapter6/lesson4#calcium_chloride



$CaCl_2$	$2NaHCO_3$	$CaCO_3$	$2NaCl$	H_2O	CO_2
calcium chloride	sodium bicarbonate	calcium carbonate	sodium chloride	water	carbon dioxide

Ask students:

- **What products of the reaction do you recognize?**
  Students should recognize sodium chloride ($NaCl$), water (H_2O), and carbon dioxide (CO_2).
- **Look at the product side of the chemical equation. What gas is produced in the chemical reaction?**
  Carbon dioxide gas.
- **What do you think is the precipitate?**
  The salt and water are clear and colorless as a solution, so the precipitate must be $CaCO_3$, which is calcium carbonate. Tell students that calcium carbonate is ordinary chalk.
- **How many of each type of atom is on the reactant side of the equation?**
  1 calcium atom, 2 chlorine atoms, 2 sodium atoms, 2 hydrogen atoms, 2 carbon atoms, and 6 oxygen atoms.
- **How many of each type of atom is on the product side of the chemical equation?**
  1 calcium atom, 2 chlorine atoms, 2 sodium atoms, 2 hydrogen atoms, 2 carbon atoms, and 6 oxygen atoms.
- **Is this a balanced chemical equation?** Yes. **Why?**
  The same type and number of atoms are in the reactants and products.

Make sure students see that every type of atom on the left side of the equation is also on the right. Also be sure that they see that there is an equal number of each type on both sides of the equation.

EXPLORE

5. Separate the products to show that the precipitate is a solid.

Ask students:

- **How do you think we could separate the precipitate from the other products?**

Question to Investigate

Can you separate the calcium carbonate from the rest of the products?

Materials for Each Group

- Coffee filter or paper towel
- Tall clear plastic cup

Procedure

1. Use a large enough coffee filter (or paper towel) so that you can push it about ⅓ of the way into the cup and still have enough left to hold it around the outside of the

cup.

2. While holding the coffee filter in place, pour the products into the center of the coffee filter.
3. Allow the liquid to drip through the filter. This may take a while.
4. Set the precipitate aside and allow the water to evaporate.

Expected results
A white solid will remain in the coffee filter. After the water evaporates, the calcium carbonate will be a white powder.

Note*: If you'd like to separate the sodium chloride from the water that flowed through the filter, pour the liquid into a clean empty cup and allow the water to evaporate for a few days. As the water evaporates, students will begin to see cubic-shaped salt crystals forming in the solution. Eventually only salt crystals will remain in the cup.*

Ask students:

- **What is the solid white substance on the paper?**
  Calcium carbonate (chalk).
- **Is filtering out the calcium carbonate and allowing the water to evaporate a chemical change or a physical change?** Physical change. **Why?** These substances were already present in the water, so no new chemicals are made.
- **What evidence was there that a chemical reaction occurred when you combined baking soda solution and calcium chloride solution?**
  A gas and a white solid were formed.

6. Confirm that a chemical reaction took place.

Ask students:

How could we compare the precipitate to the reactants to be sure that the precipitate is actually different from both of them?
Do a solubility test on all three substances.

Question to Investigate
Is the solubility of the precipitate different than the solubility of baking soda and calcium chloride?

Ask students:
How should we set up the solubility test?

- Should we use the same amount of each substance?
  Yes
- **Should we use the same amount of water?**
  Yes

Materials for Each Group

- Dry precipitate on paper towel
- Balance
- 3 small plastic cups
- Graduated cylinder
- ¼ teaspoon
- Popsicle stick (optional)
- Calcium chloride
- Baking soda
- Water

Procedure

1. Label 3 cups sodium bicarbonate, calcium chloride, and precipitate.
2. Use a spoon or popsicle stick to scrape the precipitate into a pile.
3. Scoop up the precipitate into a ¼ teaspoon until it is as full as possible. Place the ¼ teaspoon of precipitate into its labeled cup.
4. Place ¼ teaspoon of sodium bicarbonate and calcium chloride into their labeled cups.
5. Add 25 mL of water to each cup and gently swirl until the solids dissolve as much as possible. Look to see the amount of solid that remains undissolved in each cup.

Expected results
The sodium bicarbonate and calcium chloride dissolve but the precipitate does not.

Since the precipitate does not dissolve like either of the reactants, it must be a different substance than the reactants. Therefore, a chemical reaction must have occurred.

EXTEND

7. Do a demonstration to show students another example of a precipitate and a color change.

Tell students that you will show them another reaction that forms a precipitate and a little something extra.

Materials for the Demonstration

- Copper II sulfate
- Household ammonia
- Hydrogen peroxide (3%)
- Water
- Graduated cylinder
- Test tube
- 2 droppers
- 1 clear plastic cup (empty)

***Note**: The copper compound is called "copper II" because copper can make different types of ions. It can lose one electron and be just Cu^+ or it can lose two electrons and be Cu^{2+}. This type of copper ion is called copper II. The "sulfate" in copper II sulfate is also an ion. This ion is made up of more than one atom. It is one of the polyatomic ions discussed in Chapter 4, Lesson 3. The sulfate ion is made up of a sulfur atom bonded to four oxygen atoms and is treated as one ion (SO_4^{2-}).*

Teacher Preparation

Make a copper II sulfate solution by adding 5 g of copper II sulfate to 50 mL of water.

Procedure

1. Pour 15–20 mL of copper II sulfate solution into a test tube so it is about ½ full.
2. Add about 10–20 drops of ammonia.
3. Add about 10–20 drops of hydrogen peroxide.

Expected Results

After adding the ammonia, a whitish precipitate will form at the top of the copper II sulfate solution. As more ammonia is added, the color on top of the liquid will change to a deeper darker blue. As the hydrogen peroxide is added, the dark blue area at the top of the solution will turn dark green and a dark precipitate will form.

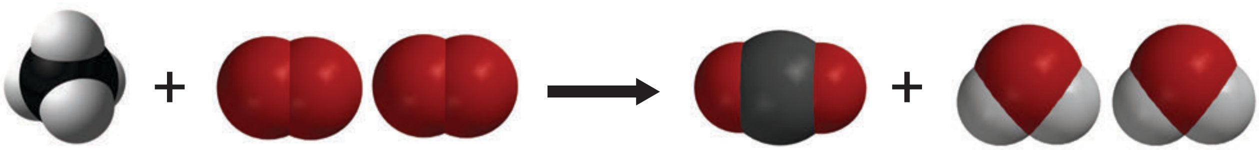
***Note**: The details of the chemical reactions that produce the different precipitates and different color changes are fairly complicated. The main idea for students is that atoms or groups of atoms in the reactants rearranged and bonded in different ways to form different substances in the products.*

Let students know that when they see the production of a gas, a precipitate, or a color change, that this is evidence that a chemical reaction has taken place.

Ask students:

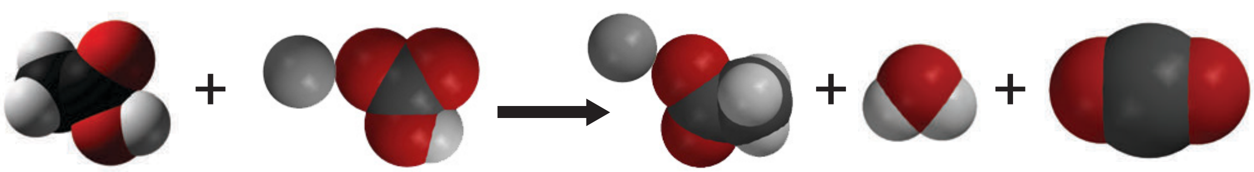
- **How can you tell that something new was made when the copper II sulfate and ammonia reacted?**
  A precipitate was produced.
- **How can you tell that something new was made when these substances reacted with hydrogen peroxide?**
  The color change and other precipitate are evidence of another chemical reaction.

In-Class or At-Home Project.
Have students use objects such as gum drops, beads, M&Ms, Legos, or other small objects to represent the atoms in two of the three reactions they have explored so far. Students can tape or glue the objects to poster board and write down the chemical formula for the reactants and products.



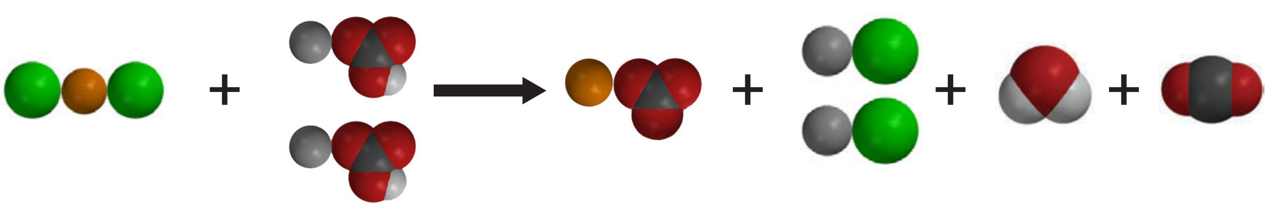
CH_4 methane + $2O_2$ oxygen → CO_2 carbon dioxide + $2H_2O$ water

---



$C_2H_4O_2$ acetic acid + $NaHCO_3$ sodium bicarbonate → $NaC_2H_3O_2$ sodium acetate + H_2O water + CO_2 carbon dioxide

---



$CaCl_2$ calcium chloride + $2NaHCO_3$ sodium bicarbonate → $CaCO_3$ calcium carbonate + $2NaCl$ sodium chloride + H_2O water + CO_2 carbon dioxide

Activity Sheet
Chapter 6, Lesson 3
Forming a Precipitate

Name ____________________

Date ____________________

DEMONSTRATION

1. Your teacher combined two clear colorless solutions. One was a sodium carbonate solution and the other was a magnesium sulfate solution. Do you think a chemical reaction occurred when these two substances were combined?

   Why or why not?

2. What is a precipitate?

ACTIVITY

Question to Investigate
How do you know when a precipitate is formed in a chemical reaction?

Materials for Each Group
- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Measuring spoon (½ teaspoon) or balance
- 2 clear plastic cups
- Masking tape
- Pen

Procedure

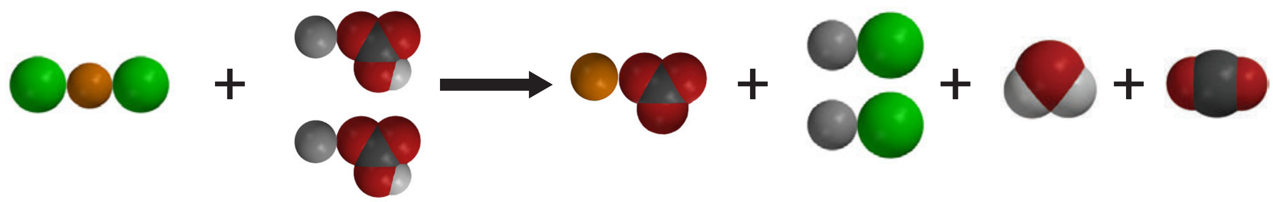
1. Use masking tape and a pen to label 2 plastic cups *Baking Soda Solution* and *Calcium Chloride Solution*.
2. Use a graduated cylinder to add 20 mL of water to each cup.
3. Add 2 g (about ½ teaspoon) of calcium chloride to the water in its labeled cup. Swirl until as much of the calcium chloride dissolves as possible.
4. Add 2 g (about ½ teaspoon) of baking soda to the water in its labeled cup. Swirl until as much of the baking soda dissolves as possible. Some undissolved baking soda may remain in the bottom of the cup.
5. Carefully pour the baking soda solution into the calcium chloride solution. Try not to pour in any undissolved baking soda. Observe.

3. What do you observe when you combine baking soda solution and calcium chloride solution?

4. How do you know that a chemical reaction occurs when you combine baking soda solution and calcium chloride solution?

EXPLAIN IT WITH ATOMS & MOLECULES

5. Take a look at the chemical equation for the reaction between calcium chloride and sodium bicarbonate and answer the following questions.



$CaCl_2$	$2NaHCO_3$	$CaCO_3$	$2NaCl$	H_2O	CO_2
calcium chloride	sodium bicarbonate	calcium carbonate	sodium chloride	water	carbon dioxide

What gas is produced in the chemical reaction?

What do you think is the precipitate?

How many of each type of atom appears on each side of the chemical equation?		
Atom	**Reactant side**	**Product side**

ACTIVITY

Question to Investigate
Can you separate the calcium carbonate from the rest of the products?

Materials for Each Group

- Coffee filter or paper towel
- Tall clear plastic cup

Procedure

1. Use a large enough coffee filter (or paper towel) so that you can push it about ⅓ of the way into the cup and still have enough left to hold it around the outside of the cup.
2. While holding the coffee filter in place, pour the products into the center of the coffee filter.
3. Allow the liquid to drip through the filter. This may take a while.
4. Set the precipitate aside and allow the water to evaporate.

6. Is filtering the calcium carbonate and allowing the water to evaporate a chemical change or a physical change?

   Why?

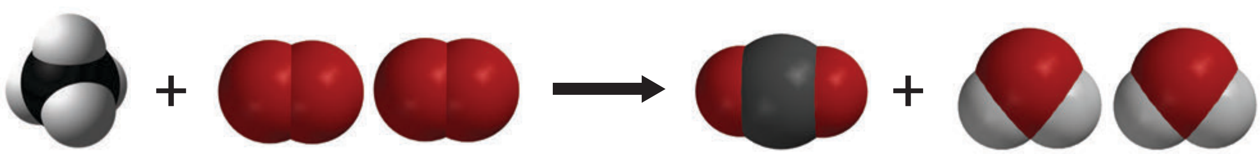
TAKE IT FURTHER

Your teacher added drops of ammonia to copper II sulfate solution.

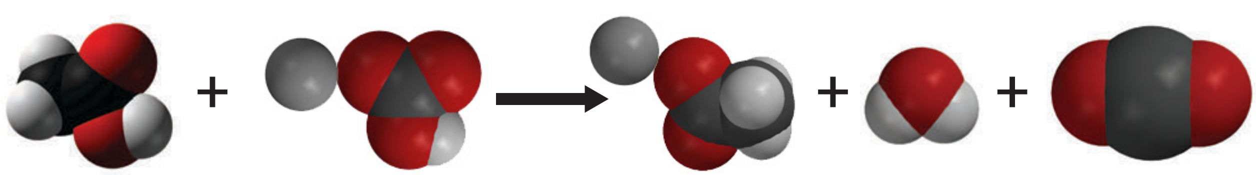
7. How can you tell that something new was made when the copper II sulfate and ammonia reacted?

8. How can you tell that something new was made when these substances reacted with hydrogen peroxide?

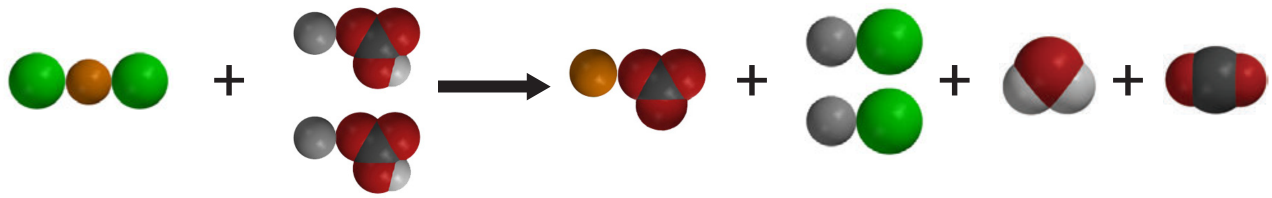
9. Use objects such as gum drops, beads, M&Ms, Legos, or other small objects to represent the atoms in two of the three chemical reactions you have covered in chapter 6. The three chemical equations are written below. Tape or glue the objects to poster board and write down the chemical formula for the reactants and products.



CH_4 methane + **$2O_2$** oxygen → **CO_2** carbon dioxide + **$2H_2O$** water



$C_2H_4O_2$ acetic acid + **$NaHCO_3$** sodium bicarbonate → **$NaC_2H_3O_2$** sodium acetate + **H_2O** water + **CO_2** carbon dioxide



$CaCl_2$	$2NaHCO_3$	$CaCO_3$	$2NaCl$	H_2O	CO_2
calcium chloride	sodium bicarbonate	calcium carbonate	sodium chloride	water	carbon dioxide

Chapter 6, Lesson 4:
Temperature and the Rate of a Chemical Reaction

Key Concepts

- Reactants must be moving fast enough and hit each other hard enough for a chemical reaction to take place.
- Increasing the temperature increases the average speed of the reactant molecules.
- As more molecules move faster, the number of molecules moving fast enough to react increases, which results in faster formation of products.

Summary

Students will make the same two clear colorless solutions (baking soda solution and calcium chloride solution) from Lesson 3. They will help design an experiment to see if the temperature of the solutions affects how fast they react. Students will then try to explain, on the molecular level, why the temperature affects the rate of the reaction.

Objective

Students will be able to identify and control variables to design an experiment to see if temperature affects the rate of a chemical reaction. Students will be able to explain, on the molecular level, why the temperature of the reactants affects the speed of the reaction.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. Use caution when handling hot water.

Materials for the Demonstration

- Hot water in an insulated cup
- Ice water in an insulated cup
- 2 glow sticks

Materials for Each Group

- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Balance or measuring spoon (teaspoon)
- 2 wide (9 oz) clear plastic cups
- 4 small clear plastic cups
- 2 plastic deli-style containers
- Hot water (40–50 °C)
- Cold water (0–5 °C)
- Masking tape
- Pen

ENGAGE

1. Do a demonstration with glow sticks to introduce the idea that temperature can affect the rate of a chemical reaction.

Question to Investigate

How does warming or cooling a glow stick affect its chemical reaction?

Materials for the Demonstration

- Hot water in an insulated cup
- Ice water in an insulated cup
- 2 glow sticks

Teacher preparation

Be sure not to start the glow sticks as you prepare for the demonstration. Place one glow stick in hot water and another in ice water before students arrive. The glow sticks will need to be in the water for at least a couple of minutes before the demonstration.

Tell students that you have heated one glow stick and cooled another.

Ask students:

- **How do you start a glow stick?**
  Bend the stick until you hear a popping sound.
- **What should you do if you want your glow stick to last longer?**
  Place the glow stick in the freezer when you are not using it.

Explain that when students bend the stick to start it, they are breaking a small container filled with a chemical inside the light stick. Once broken, the chemicals, which were separate, combine and react with each other. If putting a glow stick in the freezer makes it last longer, temperature may have something to do with the rate of the chemical reaction.

Procedure

1. Remove the glow sticks from both the hot and cold water.
2. Have two students bend and start the glow sticks.
3. Show students both glow sticks and ask them what they observe. You may pass the sticks around the class so that they can feel the difference in temperature.

Expected Results
The warm glow stick will be brighter than the cold one.

Ask students:

- **How can you tell whether the chemical reaction is happening faster or slower in each glow stick?**
  The warm glow stick is brighter, so the chemical reaction may be happening faster. The cool glow stick is not as bright, so the chemical reaction may be happening slower.
- **Some people place glow sticks in the freezer to make them last longer. Why do you think this works?**
  The chemical reaction that happens in a light stick is slower when cold.
- **Do you think that starting with warmer reactants increases the rate of other chemical reactions? Why?**
  It is reasonable to think that temperature will affect the rate of other chemical reactions because temperature affected this reaction.

EXPLORE

2. Ask students how they could set up an experiment to find out if the temperature of the reactants affects the speed of the reaction.

Review with students the chemical reactions they did in the last lesson. They combined a calcium chloride solution with a baking soda solution. They saw that when the solutions were combined, a solid and a gas were produced. Tell students that they will warm and cool a calcium chloride solution and a baking soda solution to find out whether temperature affects the rate of the chemical reaction.

Ask students:

- **How many sets of solutions should we use?**
  Students should use two sets—one that is heated and one which is cooled. Tell students that they will use hot and cold water baths, like in the demonstration, to warm and cool the solutions.
- **Should the warmed samples of baking soda solution and calcium chloride solution be the same as the samples that are cooled?**
  Yes. Samples of the same solution should be used and the same amount of cold solution as warm solution should be used
- **In the glow stick demonstration, we could tell that the reaction was happening faster if the light was brighter. How can we tell if the reaction is happening faster in this chemical reaction?**

The chemical reaction is happening faster, if more products are produced. We should look for more bubbling (carbon dioxide) and more white precipitate (calcium carbonate).

3. Have students warm a pair of reactants and cool another and compare the amount of products in each reaction.

Question to Investigate
Does the temperature of the reactants affect the rate of the chemical reaction?

Materials for Each Group

- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Balance or measuring spoon (½ teaspoon)
- 4 small plastic cups
- 2 plastic deli-style containers
- Hot water (about 50 °C)
- Cold water (0–5 °C)
- Masking tape
- Pen

Procedure
Make the Baking Soda Solution

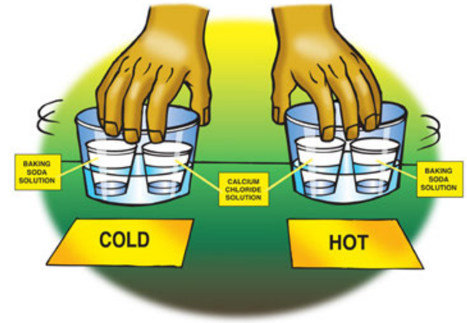
1. Use masking tape and a pen to label 2 small plastic cups baking soda solution, and 2 small plastic cups calcium chloride solution.
2. Use a graduated cylinder to add 20 mL of water to one of the baking soda solution cups.
3. Add 2 g (about ½ teaspoon) of baking soda to the water in its labeled cup. Swirl until as much of the baking soda dissolves as possible. (There may be some undissolved baking soda in the bottom of the cup.)
4. Pour half of your baking soda solution into the other baking soda solution cup.

Make the Calcium Chloride Solution

5. Use a graduated cylinder to add 20 mL of water to one of the calcium chloride solution cups.
6. Add 2 g (about ½ teaspoon) of calcium chloride to the water in its labeled cup. Swirl until the calcium chloride dissolves.
7. Pour half of your calcium chloride solution into the other calcium chloride solution cup.

Heat and Cool the Solutions

8. Pour hot water into one plastic container and cold water into the other until each is about ¼ filled. The water should not be very deep. These are your hot and cold water baths.



9. Place and hold one cup of baking soda solution and one cup of calcium chloride solution in the hot water. Gently swirl the cups in the water for about 30 seconds to heat up the solutions.
10. Your partner should place and hold one cup of baking soda solution and one cup of calcium chloride solution in the cold water. Gently swirl the cups in the water for about 30 seconds to cool the solutions.

Combine the Solutions

11. At the same time, you and your partner should combine the two warm solutions with each other, and the two cold solutions with each other.

Expected Results

The warm solutions will react immediately and much faster than the cold solutions. Bubbling and particles of white solid will quickly appear in the combined warm solutions. The cold solutions will turn a cloudy grayish and stay that way for a while. Eventually the combined solutions will gradually turn white and bubble, and particles of white solid will appear.

4. Discuss student observations.

Ask students:

- **Does the temperature of the reactants affect the rate of the chemical reaction?**
  Yes. The warm solutions react much faster than the cold solutions.

EXPLAIN

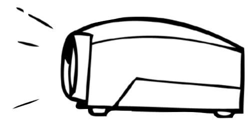
5. Show students that the faster moving molecules in the warm reactants hit each other with more energy and so are more likely to react.

Ask students:

- **On the molecular level, why do you think the warm solutions react faster than the cold solutions?**

Explain to students that for reactant molecules to react, they need to contact other reactant molecules with enough energy for certain atoms or groups of atoms to come apart and recombine to make the products. When the reactants are heated, the average kinetic energy of the molecules increases. This means that more molecules are moving faster and hitting each other with more energy. If more molecules hit each other with enough energy to react, then the rate of the reaction increases.

Project the animation *Molecules collide and react*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson4#molecules_collide



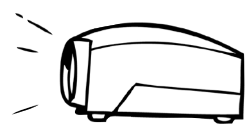
Point out that the slower-moving molecules hit and bounce off without reacting. But the faster-moving molecles hit each other with enough energy to break bonds and react.

EXTEND

6. Introduce the idea that energy must be added for some chemical reactions to occur.

Tell students that the reaction between baking soda solution and calcium chloride solution happens at room temperature. Students saw that the rate of the reaction can be sped up if the reactants are warmed and slowed down if the reactants are cooled.

Explain that there are many reactions that will not occur at all at room temperature. For these reactions to occur, the reactants need to be heated. When they are heated, the reactants have enough energy to react. Often, once a reaction has started, the energy produced by the reaction itself is enough to keep it going.



Project the video *Volcano*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson4#volcano
Tell students that this reaction requires heat to get started but produces enough heat to keep reacting. You could also mention to students that a common burning candle works the same way. The wax of the candle and oxygen do not react until the heat of a match is added. Then, the heat from the burning wax supplies the heat to keep the reaction going.

Activity Sheet
Chapter 6, Lesson 4
Temperature and the Rate of a Chemical Reaction

Name ______________________

Date ______________________

DEMONSTRATION

1. Your teacher warmed one glow stick and cooled another. Once the light sticks were started, there was a noticeable difference in their brightness.

   How can you tell whether the chemical reaction is happening faster or slower in each glow stick?

   Some people place glow sticks in the freezer to make them last longer. Why do you think this works?

   Do you think that starting with warmer reactants increases the rate of other chemical reactions?

   Why or why not?

ACTIVITY

Question to Investigate

Does the temperature of the reactants affect the rate of the chemical reaction?

Materials for Each Group

- Baking soda
- Calcium chloride
- Water
- Graduated cylinder
- Balance or measuring spoon (½ teaspoon)
- 4 small plastic cups
- 2 plastic deli-style containers
- Hot water (about 50 °C)
- Cold water (0–5 °C)
- Masking tape
- Pen

Procedure

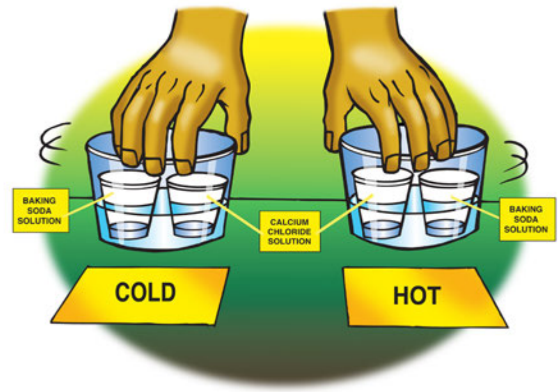
Make the Baking Soda Solution

1. Use masking tape and a pen to label 2 small plastic cups baking soda solution, and 2 small plastic cups calcium chloride solution.
2. Use a graduated cylinder to add 20 mL of water to one of the baking soda solution cups.
3. Add 2 g (about ½ teaspoon) of baking soda to the water in its labeled cup. Swirl until as much of the baking soda dissolves as possible. (Some undissolved baking soda may remain in the bottom of the cup.)
4. Pour half of your baking soda solution into the other baking soda solution cup.

Make the calcium chloride solution

5. Use a graduated cylinder to add 20 mL of water to one of the calcium chloride solution cups.
6. Add 2 g (about ½ teaspoon) of calcium chloride to the water in its labeled cup. Swirl until the calcium chloride dissolves.
7. Pour half of your calcium chloride solution into the other calcium chloride solution cup.

Heat and Cool the Solutions



8. Pour hot water into one plastic container and cold water into the other until each is about ¼ filled. The water should not be very deep. These are your hot and cold water baths.
9. Place and hold one cup of baking soda solution and one cup of calcium chloride solution in the hot water. Gently swirl the cups in the water for about 30 seconds to heat up the solutions.
10. Your partner should place and hold one cup of baking soda solution and one cup of calcium chloride solution in the cold water. Gently swirl the cups in the water for about 30 seconds to cool the solutions.

Combine the solutions

11. At the same time, you and your partner should combine the two warm solutions with each other, and the two cold solutions with each other.

EXPLAIN IT WITH ATOMS & MOLECULES

2. Does the temperature of the reactants affect the rate of the chemical reaction?

   How do you know?

3. On the molecular level, why do you think the warm solutions react faster than the cold solutions?

TAKE IT FURTHER

4. You saw a video showing the ammonium dichromate volcano. How is heat involved in this chemical reaction?

Chapter 6, Lesson 5: A Catalyst and the Rate of Reaction

Key Concepts

- A catalyst is a substance that can help the reactants in a chemical reaction react with each other faster.
- A catalyst does not actually become part of the products of the reaction.

Summary

Students watch a video and do a quick activity to see that a catalyst can increase the rate of the breakdown (decomposition) of hydrogen peroxide. Students will then use salt as a catalyst in a reaction between aluminum foil and a solution of copper II sulfate. Students will be introduced to the concept that a catalyst increases the rate of a chemical reaction but is not incorporated into the products of the reaction.

Objective

Students will be able to define a catalyst as a substance that increases the rate of a chemical reaction but is not incorporated into the products of the reaction.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. When using hydrogen peroxide, follow all warnings on the label. After students have conducted the activity with the copper II sulfate solution and aluminum foil, allow the contents of the cup to evaporate. Put the small amount of solid in a paper towel and dispose in the trash or use a disposal method required by local regulations.

Materials for Each Group

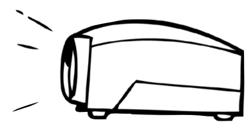
- Graduated cylinder (50 mL or 100 mL)
- Hydrogen peroxide (3%)
- Yeast
- 2 Popsicle sticks
- Detergent solution
- Dropper
- Small cup
- Clear plastic cup
- Copper II sulfate solution (in cup)
- Salt
- Aluminum foil (5 cm × 5 cm)
- Thermometer

Notes about the Materials
Copper II sulfate is available from various chemical suppliers including Sargent Welch, Product #WLC94770-06 or Flinn Scientific, Product #C0110.

ENGAGE

1. Show students two demonstrations and have them look for evidence that a gas is produced in the chemical reactions.

Tell students that you will show them video of two demonstrations where water vapor and oxygen gas are produced in the exact same chemical reaction. Because gases are invisible, ask students to watch closely for evidence that a gas is produced.



Project the video *Elephant's Toothpaste*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson5#elephant_toothpaste
The foaming shows that gases (oxygen and water vapor) are being produced very quickly. The amount of foam produced in a period of time is a way of measuring the rate of the reaction.

Project the video *Genie in a Bottle*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson5#genie_bottle
The steam coming out of the bottle is water vapor that is condensing as it leaves the bottle. Oxygen is also leaving the bottle but it is invisible.

Ask students:
- **How could you tell that a gas is produced in the chemical reaction?**
  The foaming in the elephant toothpaste demonstration means that a gas is produced. Production of a gas is a clue that a chemical reaction has occurred. The water vapor in the genie-in-a-bottle demonstration also shows the production of a gas.

Tell students that this lesson is about speeding up chemical reactions. Some reactions occur very slowly, but chemicals called catalysts can be added in order to make them happen faster. Both of these demonstrations relied on a catalyst.

EXPLAIN

2. Describe how the decomposition of hydrogen peroxide produced oxygen gas in both of the videos.

Tell students that both of the demonstrations use a 30% hydrogen peroxide solution. Typically the hydrogen peroxide you can by at the store is only 3% hydrogen peroxide.

Explain to students that the chemical formula for hydrogen peroxide is H_2O_2. Point out that hydrogen peroxide is not very stable and breaks down into water and oxygen on its own. This kind of change is a chemical reaction called *decomposition*. The decomposition of hydrogen peroxide is slow and is not usually noticeable.

Project the image *Decomposition of Hydrogen Peroxide*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson5#hydrogen_peroxide
Explain that hydrogen peroxide decomposes to form water and oxygen according to this chemical equation:

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

hydrogen peroxide → water + oxygen

Tell students that this chemical reaction happens on its own, and that even the energy from the light in a room can cause hydrogen peroxide to decompose faster. This is why hydrogen peroxide is sold in opaque containers.

Tell students that in the video, a substance (potassium permanganate or manganese dioxide) was used to make the decomposition of hydrogen peroxide happen a lot faster. Even though it made the reaction go faster, the substance itself didn't change during the reaction. A substance that increases the rate of a reaction but does not become part of the products of the reaction is called a *catalyst*.

Ask students:

- **Your teacher showed you a demonstration where a catalyst is added to hydrogen peroxide and a great deal of oxygen gas is produced. If the catalyst is involved in the chemical reaction, why isn't it included as a product in the chemical equation?**
  A catalyst does not end up in the products so is not included in the chemical reaction.
- **What does a catalyst do in a chemical reaction?**
  Catalysts help a reaction happen faster but do not change themselves during the reaction.

Give Each Student an Activity Sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

EXPLORE

3. Have students use yeast to catalyze the decomposition of hydrogen peroxide.

Question to Investigate
Can another substance catalyze the decomposition of hydrogen peroxide?

Materials for Each Group

- Graduated cylinder
- Hydrogen peroxide (3%)
- Yeast
- Popsicle stick
- Detergent solution
- Dropper

Teacher Preparation
Make a detergent solution by adding 1 teaspoon of liquid dish detergent to 2 tablespoons of water. Divide this detergent solution equally into one small cup for each group.

Procedure

1. Add 10 mL of hydrogen peroxide to a graduated cylinder. Add 1 drop of detergent solution. Swirl gently and watch the solution for any bubbling.

Explain to students that the detergent is added only to make bubbles if any gas is produced. Since the breakdown of hydrogen peroxide produces oxygen gas, bubbling shows that the hydrogen peroxide is breaking down or decomposing. The lack of bubbling shows that not much oxygen gas is being produced.

2. Use the end of a popsicle stick to add a small amount of yeast to the hydrogen peroxide in the graduated cylinder and swirl.
3. Place the graduated cylinder on the table and watch for any bubbling.
4. Hold the graduated cylinder to see if there seems to be any change in temperature.

Expected Results
Before the yeast is added, there is no observable bubbling. After the yeast is added, bubbling will cause foam to move up the graduated cylinder. Also, the graduated cylinder should feel a little warmer because the decomposition of hydrogen peroxide releases energy. Energy changes in chemical reactions will be investigated in more detail in Chapter 6, Lesson 7.

4. **Discuss student observations.**

Ask students:

- **What clues did you have that a chemical reaction occurred in this activity?**
  Bubbling. Tell students that a change in temperature is also a sign that a chemical reaction may be occurring. Endothermic and exothermic chemical reactions will be addressed in Chapter 6, Lesson 7.
- **What is the catalyst in this activity?**
  A substance in yeast.
- **What evidence do you have that hydrogen peroxide decomposed faster when you added yeast?**
  Bubbles of oxygen gas were produced after the yeast was added.
- **When you write the chemical equation for this reaction, should yeast be included on the product side of the chemical equation?**
  Explain to students that the catalyst in the yeast does not end up in the products but is a substance that helps the decomposition happen faster. Sometimes a catalyst is written above or below the arrow in a chemical equation, but it is never included with the reactants or products.

In general, catalysts work by providing a place where reactants can come together to react. Explain to students that cells in yeast and other organisms contain a catalyst called *catalase*. Through normal cell processes, living things produce hydrogen peroxide in their cells. But hydrogen peroxide is a poison so the cells need a way to break it down very quickly. Cells contain catalase, which breaks down hydrogen peroxide at a very fast rate. A single molecule of catalase can catalyze the breakdown of millions of hydrogen peroxide molecules every second.

Students may continue to explore the effect of catalase on hydrogen peroxide by adding a piece of raw fresh potato to a small amount of hydrogen peroxide.

EXTEND

4. **Have students identify the changes that occur when copper II sulfate reacts with a piece of aluminum foil.**

Note*: This is a reaction between copper II sulfate and aluminum. The copper is called "copper II" because copper can make different types of ions. It can lose one electron and be just* Cu^{+} *or it can lose two electrons and be* Cu^{2+}*. This type of copper ion is called copper II. Also the "sulfate" in copper II sulfate is also an ion. This ion is made up of more than one atom. It is one of the polyatomic ions discussed in Chapter 4, Lesson 3. The sulfate ion is made up of a sulfur atom bonded to four oxygen atoms and is treated as one ion (*SO_4^{2-}*).*

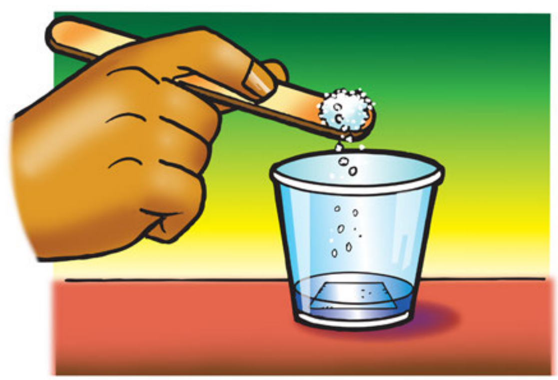
There are several interesting aspects of the reaction between copper II sulfate and aluminum, but it is different from the other reactions students have seen so far. In this reaction, the movement of electrons, rather than entire atoms, ions, or molecules, causes the reaction to occur. This type of reaction is called an oxidation/reduction reaction. This particular reaction is fun to do because it is exothermic, generates a gas, and copper metal appears as aluminum metal disappears.

Salt can be considered a catalyst in the reaction but has a different role than most catalysts. Copper II sulfate and aluminum react very slowly because aluminum is coated with a very thin layer of tarnish (aluminum oxide). This reaction can be sped up if the layer of aluminum oxide is removed or compromised. Adding salt does this and allows electrons from the aluminum to react with the copper ions in the solution, causing them to become copper metal.

Question to Investigate
What is the catalyst in the following activity?

Materials for Each Group
- Copper II sulfate solution (in cup)
- Clear plastic cup (empty)
- Salt
- Piece of aluminum foil
- Thermometer
- Popsicle stick

Teacher preparation
Make a copper II sulfate solution by adding 20 g of copper II sulfate to 200 mL of water.
Pour about 25 mL of copper II sulfate solution into a cup for each group.
Cut aluminum foil into pieces big enough to cover the bottom of a cup (about 5 cm long × 5 cm wide).



Procedure
1. Place the piece of aluminum foil in an empty cup. Use your fingers or a Popsicle stick to push the foil firmly down so that it lays flat and covers the bottom of the cup.
2. Add all of the copper II sulfate solution to the cup with the aluminum foil.
3. Gently swirl the solution for a few seconds and let it stand still. Watch the aluminum for any bubbling or color change.
4. Use your Popsicle stick to place a small amount of salt in the copper II sulfate solution. Gently swirl the solution for a few seconds and let it stand still. Watch for any bubbling or color change.
5. Carefully place a thermometer in the cup and see if the temperature changes.

Expected Results
Before the salt is added, there is no bubbling or color change. After the salt is added, the color turns greenish and bubbles begin to form on the aluminum. Soon, brownish material (copper) begins to form on the aluminum. The bubbling becomes more vigorous and the solution loses its blue color as the aluminum disappears and more copper is produced. The solution also gets warmer.

5. Discuss student observations.

Ask students:

- **How do you know that a chemical reaction occurs when a piece of aluminum foil and sodium chloride is placed in copper II sulfate solution?**
  There was bubbling, a color change, an increase in temperature, and a different solid was formed.
- **What is the catalyst in this activity?**
  Salt.
- **How is adding salt to the aluminum similar to adding yeast to the hydrogen peroxide?**
  Both can be seen as catalysts. Adding yeast helps the hydrogen peroxide decompose faster and adding salt helps the aluminum react with the copper II sulfate.

Tell students that the blue solution contains copper ions (Cu^{2+}). Adding salt to the solution helps remove a layer of tarnish from the piece of aluminum that was in the solution. This exposes some aluminum and allows electrons from the aluminum to react with the copper ions. These negative electrons are attracted to the positive copper ions. When the electrons join with the copper ions, the ions become neutral copper atoms and look like copper metal in the solution. As the aluminum loses its electrons, it becomes aluminum ions and goes into the solution and seems to disappear.

Activity Sheet
Chapter 6, Lesson 5
A Catalyst and the Rate of Reaction

Name ____________________

Date ______________________

DEMONSTRATION

1. Your teacher showed you videos of two chemistry demonstrations: Elephant's toothpaste and genie in a bottle. Are both of these chemical changes?

   How do you know?

EXPLAIN IT WITH ATOMS & MOLECULES

2. Even though the two demonstrations seem different, the chemical reaction behind both is exactly the same—the decomposition of hydrogen peroxide. Refer to the following equation as you answer the questions below.

$$\underset{\text{hydrogen peroxide}}{2H_2O_2} \longrightarrow \underset{\text{water}}{2H_2O} + \underset{\text{oxygen}}{O_2}$$

   Which new substances are created when hydrogen peroxide decomposes?

   Each demonstration used a substance called a catalyst. What does a catalyst do in a chemical reaction?

   If the catalyst is involved in the chemical reaction, why isn't it included as a product in the chemical equation?

ACTIVITY

Question to Investigate
Can another substance catalyze the decomposition of hydrogen peroxide?

Materials for Each Group
- Graduated cylinder
- Hydrogen peroxide (3%)
- Yeast
- Popsicle stick
- Detergent solution
- Dropper

Procedure
1. Add 10 mL of hydrogen peroxide to a graduated cylinder. Add 1 drop of detergent solution. Swirl gently and watch the solution for any bubbling.
2. Use the end of a Popsicle stick to add a small amount of yeast to the hydrogen peroxide in the graduated cylinder and swirl.
3. Place the graduated cylinder on the table and watch for any bubbling.
4. Hold the graduated cylinder to see if there seems to be any change in temperature.

3. What clues did you have that a chemical reaction occurred in this activity?

4. What is the catalyst in this activity?

3. What evidence do you have that hydrogen peroxide decomposed faster when you added yeast?

4. When writing the chemical equation for this reaction, should yeast be included on the product side of the chemical equation?

TAKE IT FURTHER

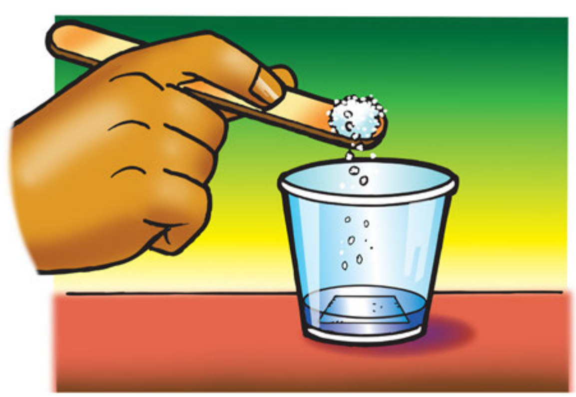
Question to Investigate
What is the catalyst in the following activity?

Materials for Each Group

- Copper II sulfate solution (in cup)
- Clear plastic cup (empty)
- Salt
- Piece of aluminum foil
- Thermometer
- Popsicle stick

Procedure

1. Place the piece of aluminum foil in an empty cup. Use your fingers or a popsicle stick to push the foil firmly down so that it lays flat and covers the bottom of the cup.
2. Add all of the copper II sulfate solution to the cup with the aluminum foil.
3. Gently swirl the solution for a few seconds and let it stand still. Watch the aluminum for any bubbling or color change.
4. Use your Popsicle stick to place a small amount of salt in the copper II sulfate solution. Gently swirl the solution for a few seconds and let it stand still. Watch for any bubbling or color change.
5. Carefully place a thermometer in the cup and see if the temperature changes.



7. How do you know that a chemical reaction occurs when a piece of aluminum foil and sodium chloride is placed in copper II sulfate solution?

8. What is the catalyst in this activity?

9. How is adding salt to the aluminum similar to adding yeast to the hydrogen peroxide?

Chapter 6, Lesson 6: Using Chemical Change to Identify an Unknown

Key Concepts
- Substances react chemically in characteristic ways
- A set of reactions can be used to identify an unknown substance

Summary

Students will use test liquids on different known powders and observe their reactions. Then students will use these characteristic chemical changes to help them identify an unknown powder.

Objective

Students will be able to identify and control variables to develop a test to identify an unknown powder. Students will be able to explain that a substance reacts chemically in characteristic ways and that these characteristics can be used to identify an unknown substance.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles. When using tincture of iodine, follow all warnings on the label. Have students wash hands after the activity.

Materials for the Demonstrations
- Baking soda
- Cornstarch
- Cream of tartar
- Tincture of iodine
- Vinegar
- Water
- Universal indicator
- Graduated cylinder or beaker
- 2 droppers
- ¼ teaspoon
- 5 clear plastic cups
- 3 Popsicle sticks

Materials for Each Group
- Baking soda
- Baking powder
- Cream of tartar
- Cornstarch
- Water
- Vinegar
- Tincture of iodine
- Universal indicator
- 10 small plastic cups
- 4 droppers
- 8 Popsicle sticks
- Testing chart (laminated or covered with wax paper)

ENGAGE

1. Add iodine solution to baking soda and cornstarch to introduce the idea that different substances react chemically in characteristic ways.

Materials for the Demonstration

- Tincture of iodine
- Baking soda
- Cornstarch
- Water
- Graduated cylinder or beaker
- 2 Popsicle sticks
- Dropper
- ¼ teaspoon
- 3 clear plastic cups

Teacher Preparation

- Make a dilute tincture of iodine solution by adding about 10 drops of tincture of iodine to 100 mL of water. Pour 50 mL of this solution into a clear plastic cup for this demonstration.
- Set the other 50 mL aside for the student activity. Instructions for preparing the rest of the materials for the student activity are in the *Explore* section of this lesson.
- Place ¼ teaspoon corn starch in a clear plastic cup and ¼ teaspoon baking soda in another cup. Do not tell students which powder is in each cup.

Procedure

1. Tell students that you have a different powder in each cup. Both are white and look alike, but they are chemically different.
2. Pour about 25 mL of the iodine solution in each cup and swirl.

Expected Results

The iodine solution stays light brown when added to the baking soda. The iodine solution and corn starch turns a very dark purple.

Ask students:

- **Both powders looked similar at first. How do you know that they are different?**
  The iodine changed color in one powder, but not in the other.

- **Which do you think is probably a chemical change?**
  The iodine and the cornstarch are probably the chemical change because the dramatic color change seems like something new may have been produced. The iodine does not change color when it combines with the baking soda.
- **What other tests could you conduct with baking soda and cornstarch to compare their characteristic properties?**
  Let students know that there can be no tasting or smelling of the powders. Students might suggest adding water to see if they dissolve differently or maybe adding another substance to see if a different chemical reaction takes place.

Give Each Student an Activity Sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

Give Each Group a Testing Chart.
Make one copy of the testing chart, found at the end of the downloaded lesson, for each group. Either laminate this testing chart or have students lay a piece of wax paper over it.

EXPLORE

2. Introduce the activity and ask students how they might test and compare the four different powders with four different test solutions.

Tell students that in this activity they will test four different similar-looking powders with four different test solutions. The four powders are baking soda, baking powder, cream of tartar, and cornstarch. The four test solutions are water, vinegar, iodine solution, and universal indicator. Explain that each powder will react in a certain way with each solution used to test it. Each powder and solution pair is one set of reactants. Let students know that in some cases, no chemical reaction will occur.

Students will need to observe and record the reactions the liquids have with each powder.

Have students look at the testing chart. Point out that the names of the four test solutions are on the left and the names of the different powders are on the top.

Test solutions	Baking Soda	Baking Powder	Cream of tartar	Cornstarch	Unknown
Water					
Vinegar					
Iodine					
Indicator					

There is also one column for an unknown powder. Explain that after testing all four known powders and recording their observations, you will give students an unknown powder to identify.

Ask students questions like the following to help them plan how they will organize and conduct their tests:

- **Do we need more than one pile of each powder placed on the chart?**
  Yes. Each powder will be tested with each of the four solutions so there needs to be four piles of each powder in the squares under its name.
- **Should all the squares on the entire chart have samples of powder on them before you start testing?**
  It is best if students place the four samples of one particular powder in its column on the testing sheet. Then students should test that powder with each of the four solutions. Students should test a single powder with each of the test liquids before moving on to the next powder.
- **Do the piles have to be about the same size?**
  The size of the piles is not particularly important as long as enough powder is used to see a reaction, if there is one. When testing the unknown, try to make the piles of unknown about the same size as the piles of the other powders.
- **Should the number of drops placed on each pile be the same?**
  The precise number of drops is not particularly important, although enough liquid should be added to see if there is a reaction. When testing the unknown, be sure that the number of drops used on the unknown is the same as the number used on the other powders.
- **How will you remember your observations for each reaction?**
  Students should record their observations immediately after a single test solution is added to a powder. These will be recorded in a chart in the corresponding box on the activity sheet.

3. As an example, guide the class as they test baking soda with water, vinegar, iodine solution, and universal indicator.

Question to Investigate
Can you use the characteristic ways substances react to tell similar-looking substances apart?

Materials for Each Group

- Baking soda in cup
- Baking powder in cup
- Cream of tartar in cup
- Cornstarch in cup

- Water in cup
- Vinegar in cup
- Tincture of iodine solution in cup
- Universal indicator solution in cup
- 4 Popsicle sticks
- Testing chart, either laminated or with a piece of wax paper over it
- 4 droppers

Teacher Preparation

Each group will need five labeled cups each containing one of the powders and four labeled cups each containing one of the four test solutions to complete all three of the activities in this lesson.

Prepare the powders

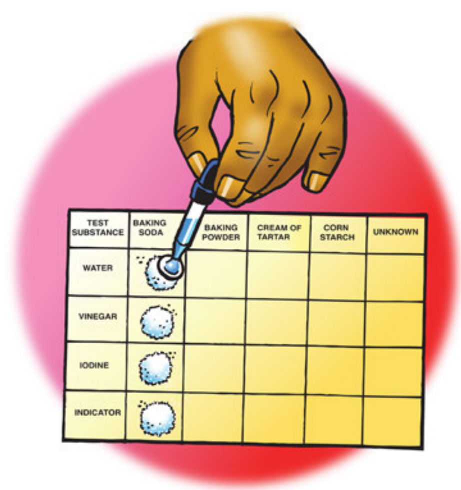
1. Label five small cups Baking Soda, Baking Powder, Cream of Tartar, Cornstarch and Unknown.
2. Place about ½ teaspoon of each powder into its labeled cup. These powders will be tested in this activity.
3. Place about ½ teaspoon of baking powder in the cup labeled unknown. Place the unknown cups aside. Students will test this unknown powder after they have tested each of the "known" powders and recorded their observations.

Prepare the Test Solutions

4. Label four cups Water, Vinegar, Iodine, and Indicator.
5. Use the iodine solution left over from the demonstration or make a new solution by adding 5 drops of tincture of iodine to 50 mL of water. Place about 5 mL iodine solution in a small labeled cup for each group.
6. Make a universal indicator solution by adding 5 mL of universal indicator to 100 mL of water. Place about 5 mL (or 1 teaspoon) indicator solution in a small labeled cup for each group. Some indicator solution will be left over for the demonstration at the end of the lesson.
7. Place about 5 mL of water and vinegar into their small labeled cups.

Procedure

1. Use the end of a popsicle stick to place four equal piles of baking soda on the testing chart in the baking soda column. Let students know that they should not use all of the powder at this time. The remaining powder will be used in the *Extend* portion of this lesson.



2. Add 5 drops of water to the first pile of baking soda. Record your observations in the chart on the activity sheet.
3. Continue testing each pile of baking soda with a different test solution and recording your observations.

Expected Results
There will be no change with water, bubbling with vinegar, and little to no change with the iodine or indicator solutions.

Ask students:

- **What did you observe when each test solution was added to a sample of baking soda?**
  Baking soda bubbles with vinegar. There is no change with water or iodine solution. Students may see a slight color change with the indicator solution. Explain to students that their results show them the characteristic set of reactions that baking soda has with these four test solutions.
- **Would you expect each test solution to react with baking powder the same way as it did with baking soda?**
  No. Each powder should have a different set of reactions.

Have students conduct the tests on the remaining powders and record their observations.

Procedure

4. Test each of the powders with the test solutions the way you tested baking soda and record your observations.

Expected Results

Test solution	Baking soda	Baking powder	Cream of tartar	Cornstarch
Water	No change	Bubbling	No change	No change
Vinegar	Lots of bubbling that ends quickly	Bubbling	No change	No change
Iodine	No change	Bubbling, purple	Orange	Purple
Indicator	Greenish-blue	Bubbling, orange changes to yellow with some green	Dark orange or pink	Brighter green, may have some orange

4. Give students the unknown powder and have them use their test solutions and observation chart to identify it.

Give each group the unknown powder. Explain to students that the unknown is one of the four powders they have tested and their job is to find out which one.

Ask students:

- **How could you test the unknown powder so that you could identify it?**
  Students should realize that they will need to test the unknown powder the same way they tested all of the other known powders and compare the results. If the unknown powder reacts with each test solution the same way one of the known powders did, then these two powders must be the same.

Question to Investigate
Can you use the characteristic ways substances react to identify an unknown powder?

Materials for each group

- Unknown in cup
- 1 Popsicle stick
- Testing sheet
- 4 test solutions
- 4 droppers

Note: *The unknown is baking powder.*

Procedure

1. Place four samples of your group's unknown powder in the "Unknown" column on the testing chart.
2. Test the unknown with each test solution in the same way you tested each of the other powders.
3. Compare the set of reactions for the unknown with those of the other powders.

Expected Results
The unknown will react with each test solution the same way that baking powder does because the unknown is baking powder.

EXPLAIN

5. Have students report the identity of the unknown and discuss what evidence led them to their conclusion.

Tell students that they were able to use their observations to identify the unknown because each powder had its own set of characteristic chemical reactions with the test solutions.

Ask students:

- **What is the identity of the unknown?**
  Baking powder is the unknown.
- **Which observations led you to your conclusion?**
  The unknown reacted with each test solution the same way baking powder did.

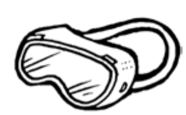
Explain that each substance is made up of certain molecules which interact with the molecules in each test liquid in a characteristic way. Some of these interactions result in a chemical reaction and others do not. However, each observation students made is based on the way the molecules of each powder interact with the molecules of each test solution.

EXTEND

6. Have students identify the two substances in baking powder that make it bubble when water is added.

Remind students that baking powder was the only substance that bubbled when water was added to it. Bubbling in a chemical reaction is a sign that a gas is one of the products. Tell students that baking powder is a combination of different powders—baking soda, cream of tartar, and cornstarch. Two of these three react with one another and produce a gas when water is added. Students will need to test all of the possible combinations of two powders with water. This way they can figure out which two powders cause baking powder to bubble with water.

Question to Investigate
Which two substances in baking powder react with one another and produce a gas when water is added?



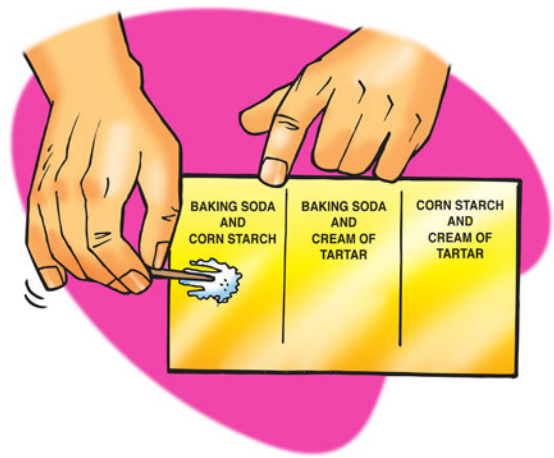
Materials for Each Group

- Baking soda in a cup
- Cornstarch in a cup
- Cream of tartar in a cup
- 3 Popsicle sticks

- Toothpicks
- Wax paper
- Water
- Dropper

Procedure

1. Use separate popsicle sticks to place a small amount of two powders on a piece of wax paper.
2. Use a toothpick to mix the powders.
3. Use a dropper to add about 5 drops of water to the combined powders and record your observations.
4. Repeat steps 1 and 2 until you have tested all three combinations.



Expected results

The two combined powders that bubble with water are baking soda and cream of tartar.

7. Demonstrate that vinegar and cream of tartar are both acids.

Point out that the mixture of baking soda and cream of tartar reacts with water to produce a gas. Baking soda and vinegar also react to produce a gas. Explain that carbon dioxide gas is produced in both reactions. Tell students that cream of tartar and vinegar have something else in common that they will investigate in the next demonstration.

Question to Investigate

Will vinegar turn universal indicator solution pink the way that cream of tartar does?

Materials for the Demonstration

- Universal indicator
- Cream of tartar
- Vinegar
- 2 clear plastic cups
- Popsicle stick
- Dropper

Teacher Preparation

- Use the indicator left over from the lesson.
- Use vinegar and cream of tartar left over from one of the student groups.

Procedure

1. Pour about 25 mL of universal indicator solution in two separate clear plastic cups.
2. Add 2 or 3 drops of vinegar to one cup.
3. Scoop up a small amount of cream of tartar with the tip of a popsicle stick and add it to the other cup.
4. Swirl both cups.

Expected Results

The indicator in both cups will turn pink.

Tell students that the color changes of indicator solution can tell you whether a substance is an acid or not. Because universal indicator turns pink when acids are added to it, we can say that both vinegar and cream of tartar are acids. When an acid reacts with baking soda, carbon dioxide gas is produced.

Ask students

- **Why do you think the baking soda and cream of tartar reaction is similar to the baking soda and vinegar reaction?**
  Cream of tartar and vinegar are both acids and interact with sodium bicarbonate in a similar way to produce carbon dioxide gas.

Activity Sheet
Chapter 6, Lesson 6
Using Chemical Change to Identify an Unknown

Name ______________________

Date ______________________

DEMONSTRATION

1. Your teacher poured iodine solution on top of two white powders. How do you know that these two similar-looking powders are really different?

2. Adding iodine solution to one powder caused a physical change, while adding the iodine solution to the other powder caused a chemical change. Which powder probably reacted chemically with the iodine solution?

   How do you know?

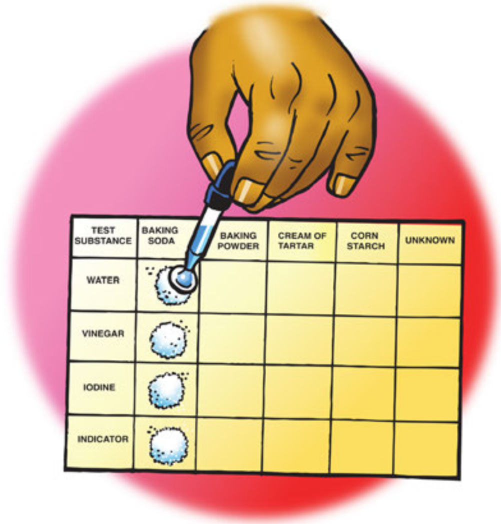
ACTIVITY

Question to Investigate
Can you use the characteristic ways substances react to tell similar-looking substances apart?

Materials for Each Group
- Baking soda in cup
- Baking powder in cup
- Cream of tartar in cup
- Cornstarch in cup
- Water in cup
- Vinegar in cup
- Tincture of iodine solution in cup
- Universal indicator solution in cup
- 4 Popsicle sticks
- Testing chart, either laminated or with a piece of wax paper over it
- 4 droppers

Procedure

1. Use the end of a Popsicle stick to place four equal piles of baking soda on the testing chart in the baking soda column. Let students know that they should not use all of the powder at this time. The remaining powder will be used in the *Extend* portion of this lesson.
2. Add 5 drops of water to the first pile of baking soda. Record your observations in the chart on the activity sheet.
3. Continue testing each pile of baking soda with a different test solution and recording your observations.
4. Test each of the powders with the test solutions the way you tested baking soda and record your observations.



Question to Investigate

Can you use the characteristic ways substances react to identify an unknown powder?

Materials for Each Group

- Unknown in cup
- 1 Popsicle stick
- Testing sheet
- 4 test solutions
- 4 droppers

Procedure

1. Place four samples of your group's unknown powder in the "Unknown" column on the testing chart.
2. Test the unknown with each test solution in the same way you tested each of the other powders.
3. Compare the set of reactions for the unknown with those of the other powders.

Test solutions	Unknown
Water	
Vinegar	
Iodine solution	
Indicator solution	

3. What is the identity of the unknown?

Which observations led you to your conclusion?

EXPLAIN IT WITH ATOMS & MOLECULES

3. On the molecular level, why did the different substances react in a characteristic way with the test solutions?

TAKE IT FURTHER

Baking powder is a combination of different powders—baking soda, cream of tartar, and cornstarch. Two of these three powders react with one another and produce carbon dioxide gas when water is added.

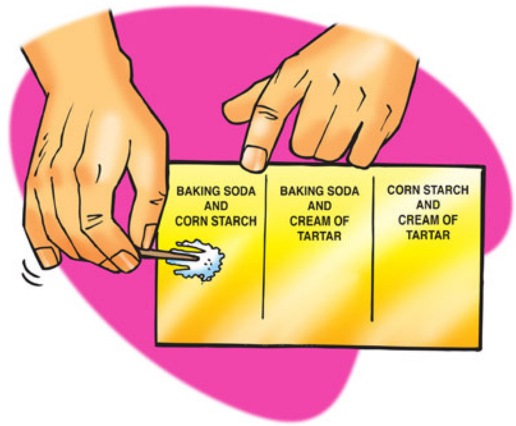
Question to Investigate
Which two substances in baking powder react with one another and produce a gas when water is added?

Materials for Each Group

- Baking soda in a cup
- Cornstarch in a cup
- Cream of tartar in a cup
- 3 Popsicle sticks
- Toothpicks
- Wax paper
- Water
- Dropper

Procedure

1. Use separate popsicle sticks to place a small amount of two powders on a piece of wax paper.
2. Use a toothpick to mix the powders.
3. Use a dropper to add about 5 drops of water to the combined powders and record your observations.
4. Repeat Steps 1 and 2 until you have tested all three combinations.



Baking soda + cornstarch	Baking soda + cream of tartar	Cornstarch + cream of tartar

4. Your teacher did a demonstration comparing the way vinegar and cream of tartar react with indicator solution. Based on your observations, why do you think the baking soda and cream of tartar reaction is similar to the baking soda and vinegar reaction?

Testing Chart

Test solutions	Baking Soda	Baking Powder	Cream of tartar	Cornstarch	Unknown
Water					
Vinegar					
Iodine					
Indicator					

Results Table

Test solutions	Baking Soda	Baking Powder	Cream of tartar	Cornstarch	Unknown
Water					
Vinegar					
Iodine					
Indicator					

Chapter 6, Lesson 7: Energy Changes in Chemical Reactions

Key Concepts

- If two substances react and the temperature of the mixture decreases, the reaction is endothermic.
- If two substances react and the temperature of the mixture increases, the reaction is exothermic.
- A chemical reaction involves the breaking of bonds in the reactants and the forming of bonds in the products.
- It takes energy to break bonds.
- Energy is released when bonds are formed.
- If a reaction is endothermic, it takes more energy to break the bonds of the reactants than is released when the bonds of the products are formed.
- If a reaction is exothermic, more energy is released when the bonds of the products are formed than it takes to break the bonds of the reactants.

Summary

Students will conduct two chemical reactions. In the first, the temperature will go down (endothermic) and in the second, the temperature will go up (exothermic). Students will see an animation to review a concept that was introduced in Chapter 5— that it takes energy to break bonds and that energy is released when new bonds are formed. Students will use this idea to explain why a reaction is either endothermic or exothermic.

Objective

Students will be able to define an endothermic and exothermic reaction. Students will be able to use the concept of energy in bond breaking and bond making to explain why one reaction can be endothermic and another reaction can be exothermic.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles.

Materials for the Each Group

- Vinegar
- Baking soda
- Calcium chloride

- Water
- Thermometer
- 4 small cups
- Disposable self-heating hand warmer
- Self-inflating balloon

Additional Materials if You Choose to do the Extra Extend

- Magnesium sulfate
- Sodium carbonate
- Citric acid
- Universal indicator

About the Materials

Calcium chloride is available from Sargent Welch, Product #WLC94075-06, or Flinn Scientific, Product #C0016, or other suppliers. Calcium chloride is also available in hardware stores for absorbing moisture and for melting ice in the winter.

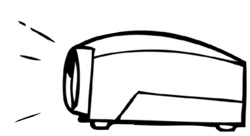
Hand warmers may be purchased from Flinn Scientific, catalog #AP1931 or from camping, sporting goods, or discount stores. Look for hand warmers that are disposable and sealed in a package and will only warm up when the package is opened. Self-inflating mylar balloons may be purchased from Joissu, product number #43-712 or Educational Innovations, product #AS-800.

ENGAGE

1. Discuss the temperature changes in chemical reactions students have conducted so far.

Remind students that the decomposition reaction of hydrogen peroxide and the reaction with copper II sulfate and aluminum both caused the temperature of the solution to increase. Tell students that you will show them three chemical reactions where the temperature increases dramatically.

Project the video *Thermite Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#thermite
After adding one or more catalysts, iron oxide (rust) and aluminum react to produce elemental iron and aluminum oxide. So much heat is produced in this reaction that the iron becomes a liquid. The heat is so intense that the molten iron can be used to weld railroad tracks together.



Project the video *Nitrogen Triiodide Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#nitrogen_triiodide
This is a decomposition reaction where nitrogen triiodide decomposes into nitrogen gas and purple iodine vapor. Nitrogen triiodide crystals are so unstable that just a light touch will cause them to rapidly decompose generating a great deal of heat.

Project the video *White Phosphorous Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#white_phosphorous
White phosphorous is dissolved in a solvent and spread on a piece of paper. When the solvent evaporates, the phosphorous reacts with oxygen in the air in a combustion reaction.

Ask students to make a prediction:

- **Do you think substances can react and cause the temperature of the mixture to decrease?**

Tell students that this lesson is going to explore temperature changes in chemical reactions.

Give Each Student an Activity Sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

EXPLORE

2. Have students measure the change in temperature of the reaction between baking soda and vinegar.

Question to Investigate
Does the temperature increase, decrease, or stay the same in the reaction between baking soda and vinegar?

Materials

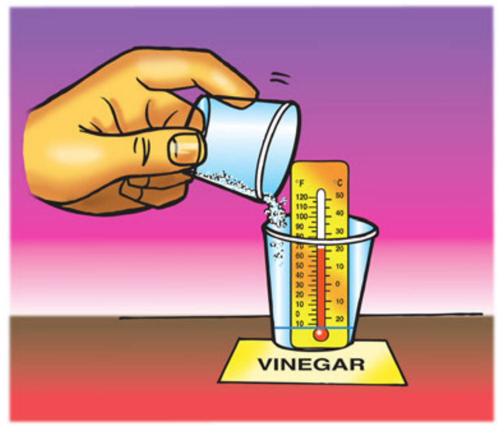
- Vinegar in a cup
- Baking soda in a cup
- Thermometer

Materials Note: The amount of the solutions must be enough to cover the bulb of the thermometer. If they aren't, use a smaller cup or clip the end of a plastic-backed thermometer so that the backing is flush with the bottom of the bulb.

Teacher Preparation

- Place about 10 mL of vinegar in a small plastic cup for each group.
- Place about ½ teaspoon of baking soda in a small cup for each group.

Procedure



1. Place a thermometer in the vinegar. Read the thermometer and record the temperature on the activity sheet.
2. While the thermometer is in the cup, add all of the baking soda from your cup.
3. Watch the thermometer to observe any change in temperature. Record the temperature after it has stopped changing.

Expected Results

If you begin with room-temperature vinegar, the temperature will decrease by about 7 °C. The amount of temperature decrease will vary. Carbon dioxide gas is also produced.

3. Discuss student observations.

Ask students:

- **Did the temperature increase, decrease, or stay the same when you combined baking soda and vinegar?**
  The temperature decreased.
- **What is the lowest temperature reached during your group's reaction?**
  There will likely be some variation.

Tell students that when the temperature of a chemical reaction decreases, the reaction is called an *endothermic* reaction. The first part of the word, *endo,* means in or into and *thermic* has to do with heat or energy. So an endothermic reaction means that more energy goes into making the reaction happen than is released by the reaction. This leaves the reaction mixture at a lower temperature.

3. Have students measure the change in temperature of the reaction between baking soda solution and calcium chloride.

Question to Investigate
Does the temperature increase, decrease, or stay the same in the reaction between baking soda solution and calcium chloride?

Materials
- Baking soda solution in a cup
- Calcium chloride in a cup
- Thermometer

Teacher Preparation
- Make a baking soda solution by dissolving about 2 tablespoons of baking soda in 1 cup of water. Stir until no more baking soda will dissolve.
- Place about 10 mL of baking soda solution in a small plastic cup for each group.
- Place about ½ teaspoon of calcium chloride in a small cup for each group.

Procedure
1. Place a thermometer in the baking soda solution. Read the thermometer and record the temperature on the activity sheet.
2. While the thermometer is in the cup, add all of the calcium chloride from the cup.
3. Watch the thermometer to observe any change in temperature. Record the temperature when it stops changing.

Expected Results
The temperature of the solution should increase by about 15–20 °C. The temperature increase will vary. Carbon dioxide gas is produced, and a white cloudy precipitate, calcium carbonate, is formed.

***Note**: Some of the temperature increase in this reaction may be due to the chemical reaction between baking soda and calcium chloride, but some is also due to the exothermic way calcium chloride dissolves in water. Chapter 5 Lesson 9 addresses temperature changes as bonds between a solute are broken and the bonds between the solute and water are formed during the physical change of dissolving.*

Read more about exothermic and endothermic chemical reactions in the additonal teacher background section at the end of the lesson.

5. **Discuss student observations.**

Ask students:

- **Did the temperature increase, decrease, or stay the same when you combined baking soda solution and calcium chloride?**
  The temperature increased.
- **What is the highest temperature reached during your group's reaction?**
  There will likely be some variation.

Tell students that when the temperature of a chemical reaction increases, the reaction is called an *exothermic* reaction. The first part of the word, *exo,* means out or out of, and *thermic* has to do with heat or energy. So an exothermic reaction means that more energy goes out or is released by the reaction than goes into it. This leaves the reaction mixture at a higher temperature.

EXPLAIN

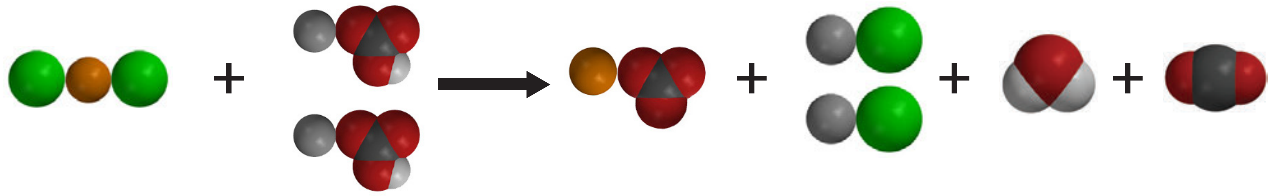
6. **Explain how differences in the energy required to break bonds and make bonds cause temperature changes during chemical reactions.**

Tell students that an example of a very exothermic reaction is the combustion or burning of fuel like the gas in a kitchen stove. Even if students have seen the animation of the combustion of methane from Chapter 6, Lesson 1, remind them that methane (CH_4) reacts with oxygen (O_2) from the air to produce carbon dioxide gas (CO_2) and water vapor (H_2O) and a lot of energy.

Project the animation *Methane Combustion Energy*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#methane_combustion_energy

Click on the methane and the oxygen to show that it takes energy to break the bonds of the reactants. This is shown by "energy arrows" going *into* the molecules of the reactants. Then click on the carbon dioxide and the water to show that energy is released when the atoms bond to make the products. This is shown by the energy arrows coming *out* of the molecules in the products. Show students that more energy was released when the bonds in the products were formed than was used to break the bonds of the reactants. This is shown by larger energy arrows coming out of the products and smaller energy arrows going into the reactants. Since more energy was released than was used, this reaction gets warmer and is exothermic.

Project the image *Baking Soda and Calcium Chloride Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#baking_soda_calcium_chloride

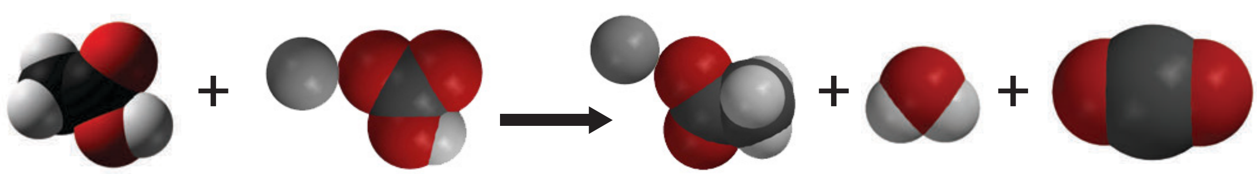


$CaCl_2$ calcium chloride + $2NaHCO_3$ sodium bicarbonate → $CaCO_3$ calcium carbonate + $2NaCl$ sodium chloride + H_2O water + CO_2 carbon dioxide

Ask students:

- **Is this an endothermic or exothermic reaction?**
  Exothermic
- **What do you know about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when bonds in the products are formed?**
  More energy was released when bonds in the products were formed than was required to break the bonds in the reactants.
- **If we were using energy arrows, where would the bigger and smaller arrow go?**
  A smaller arrow going in would be on the reactant side and a bigger arrow coming out would be on the product side.

Project the image *Baking Soda and Vinegar Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#baking_soda_and_vinegar



$C_2H_4O_2$ acetic acid + $NaHCO_3$ sodium bicarbonate → $NaC_2H_3O_2$ sodium acetate + H_2O water + CO_2 carbon dioxide

Ask students:

- **Is this an endothermic or exothermic reaction?**
  Endothermic.
- **What do you know about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the products are formed?**
  It took more energy to break the bonds of the reactants than was released when the bonds in the products were formed.

- **If we were using energy arrows, where would the bigger and smaller arrows go?**
  A bigger arrow going in would be on the reactant side and a smaller arrow coming out would be on the product side.

Project the animation *Endothermic Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#endothermic_reaction
Remind students that a chemical reaction involves the breaking of bonds in the reactants and the making of bonds in the products. Also remind them that it takes energy to break bonds and that energy is released when bonds are formed.

In an endothermic reaction, it takes more energy to break the bonds of the reactants than is released when the bonds in the products are formed. In an endothermic reaction, the temperature goes down.

Project the animation *Exothermic Reaction*.
www.middleschoolchemistry.com/multimedia/chapter6/lesson7#exothermic_reaction
Explain that in an exothermic reaction it takes less energy to break the bonds of the reactants than is released when the bonds in the products are formed. In an exothermic reaction, the temperature goes up.

EXTEND

7. Have students explain how changes in energy during chemical reactions cause them to be either endothermic or exothermic.

Tell students that they will use their knowledge of endothermic and exothermic reactions to describe the energy changes that occur when hand warmers and self-inflating balloons are activated. These two different products use chemical reactions to make them work.

Materials for Each Group
- Disposable self-heating hand warmer
- Self-inflating balloon

Hand Warmer
Tell students that the outer packaging on the hand warmer keeps air away from it and prevents the chemical reaction from happening, until the moment when a consumer wants it to start producing heat. Oxygen in the air is one of the reactants in the chemical reaction. So once the package is opened, the iron powder in the hand warmer reacts with the oxygen in the air.

Self-Inflating Balloon
Tell students that the chemical reaction that causes the self-inflating balloon to inflate is very similar to a chemical reaction students have explored already. Have students gently feel the self-inflating balloon to guess what the reactants are. They should notice a tablet and a sealed packet of liquid inside the balloon. Explain that the tablet is baking soda and the liquid in the packet is citric acid, which reacts with baking soda in a way similar to vinegar. The sealed packet prevents the citric acid from reacting with the baking soda.

Procedure

1. Open the package the hand warmer is in to begin the chemical reaction.
2. Shake the hand warmer and feel for any temperature change.
3. Activate the self-inflating balloon by either pressing down or stepping on the packet of citric acid to rupture it.
4. Shake the balloon and feel the area on the balloon where the liquid is.
5. Be sure everyone in your group has a chance to feel both the hand-warmer and the self-inflating balloon.

Expected Results
The hand warmer will become warmer, and the liquid in the self-inflating balloon will become colder. The balloon will inflate as carbon dioxide gas is produced.

Ask students:

- **Which is an example of an endothermic reaction? An exothermic reaction?**
  The self-inflating balloon is an example of an endothermic reaction, and the hand warmer is an example of an exothermic reaction.
- **What can you say about the amount of energy required to break bonds in the reactants compared to the amount of energy that is released when bonds are formed in the products in the self-inflating balloon?**
  In the self-inflating balloon, more energy is required to break the bonds in the reactants than is released when the new bonds in the products are formed. Therefore, the reaction is endothermic.
- **What can you say about the amount of energy required to break bonds in the reactants compared to the amount of energy that is released when bonds are formed in the products in the hand warmer?**
  In the hand warmer, more energy is released when the new bonds in the products are formed than is used to break the bonds in the reactants. Therefore, the reaction is exothermic.
- **What do you think is the gas inside the self-inflating balloon?**
  Carbon dioxide gas is produced when citric acid and baking soda react.

If you do not have access to a self-inflating balloon, you may choose to have students make their own.

Materials for Each Group

- Alka-Seltzer tablet
- Water
- Graduated cylinder
- Snack size zip-closing plastic bag

Procedure

1. Place 10 mL of water in a zip-closing plastic bag.
2. Tilt the open bag at an angle so that the water flows into one corner. Hold the bag while a partner places the Alka-Seltzer tablet in the opposite corner. Remove as much air as possible and seal the bag.
3. Shake the bag to help water and tablet react. Place the bag in a bowl or other container in case it pops.
4. Feel the liquid near the tablet to see if there is any temperature change.

Expected Results

The liquid will get colder and the bag will inflate and may pop.

EXTRA EXTEND

8. Have students identify clues of chemical change in the following reactions.

Remind students that in this chapter, they have seen different clues of chemical change. Ask students to identify all of the clues they observe in this pair of chemical reactions.

Question to Investigate

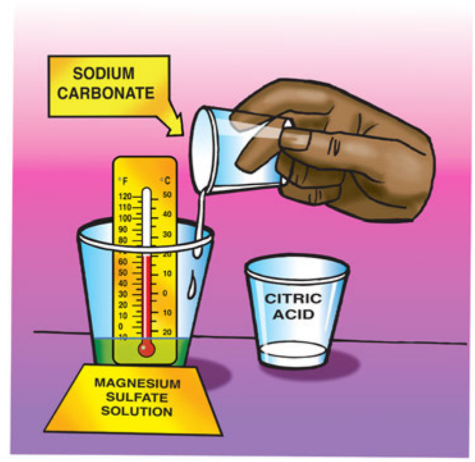
What clues do you observe that a chemical reaction is taking place?

Materials for Each Group

- Magnesium sulfate solution in cup
- Sodium carbonate solution in cup
- Citric acid solution in cup
- Universal indicator
- Thermometer
- Dropper

Teacher Preparation

- Label 3 small cups Magnesium Sulfate, Sodium Carbonate, and Citric Acid for each group.
- Make each solution by adding:
  - 1 tablespoon of magnesium sulfate to 250 mL of water.
  - 1 teaspoon of sodium carbonate to 125 mL of water.
  - 1 teaspoon of citric acid to 125 mL water.
- Pour 30 mL of magnesium sulfate, 10 mL of sodium carbonate, and 10 mL of citric acid solution into their labeled cups for each group.



Procedure

1. Add 5 drops of universal indicator to the magnesium sulfate solution.
2. Place a thermometer in the cup and record the temperature of the solution.
3. Add 10 mL of sodium carbonate solution.
4. Add 10 mL of citric acid.

Expected Results

The magnesium sulfate, universal indicator, and sodium carbonate will turn purple and form a precipitate. With the addition of citric acid, the mixture will turn yellow or pink and bubble as the precipitate disappears. There is no noticeable temperature change.

Ask Students:

- **What clues do you observe that let you know that a chemical reaction is taking place?**
  There is a color change, formation of a precipitate, another color change, and bubbling.
- **How can it be that in this chemical reaction, you did not notice a temperature change?**
  Maybe the amount of energy required to break bonds was about the same as the amount of energy released when bonds are formed. Or the temperature change was so small that it was not noticeable with student thermometers.

Activity Sheet
Chapter 6, Lesson 7
Energy Changes in Chemical Reactions

Name ________________________

Date ________________________

ACTIVITY

Question to Investigate

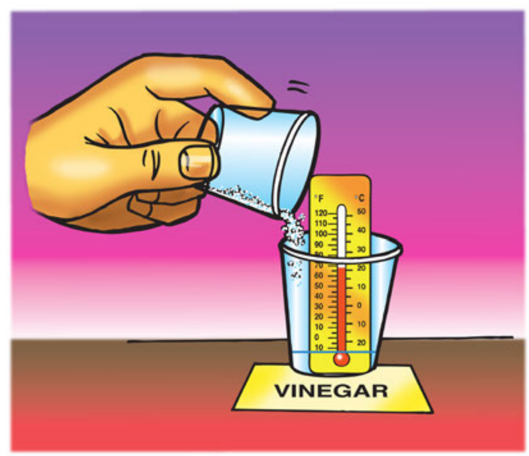
Does the temperature increase, decrease, or stay the same in the reaction between baking soda and vinegar?

Materials

- Vinegar in a cup
- Baking soda in a cup
- Thermometer

Procedure

1. Place a thermometer in the vinegar. Read the thermometer and record the temperature on the activity sheet.
2. While the thermometer is in the cup, add all of the baking soda from your cup.
3. Watch the thermometer to observe any change in temperature. Record the temperature after it has stopped changing.



1. Did the temperature increase, decrease, or stay the same when you combined baking soda and vinegar?

2. What is the lowest temperature reached during your group's reaction?

Question to Investigate

Does the temperature increase, decrease, or stay the same in the reaction between baking soda solution and calcium chloride?

Materials

- Baking soda solution in a cup
- Calcium chloride in a cup
- Thermometer

Procedure

1. Place a thermometer in the baking soda solution. Read the thermometer and record the temperature on the activity sheet.
2. While the thermometer is in the cup, add all of the calcium chloride from the cup.
3. Watch the thermometer to observe any change in temperature. Record the temperature when it stops changing.

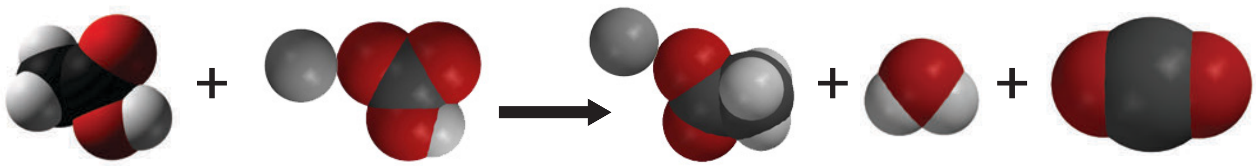
3. Did the temperature increase, decrease, or stay the same when you combined baking soda solution and calcium chloride?

3. What is the highest temperature reached during your group's reaction?

EXPLAIN IT WITH ATOMS & MOLECULES

When the temperature of a chemical reaction decreases, the reaction is called an *endothermic* reaction. When the temperature of a chemical reaction increases, the reaction is called an *exothermic* reaction.

Vinegar and baking soda reaction



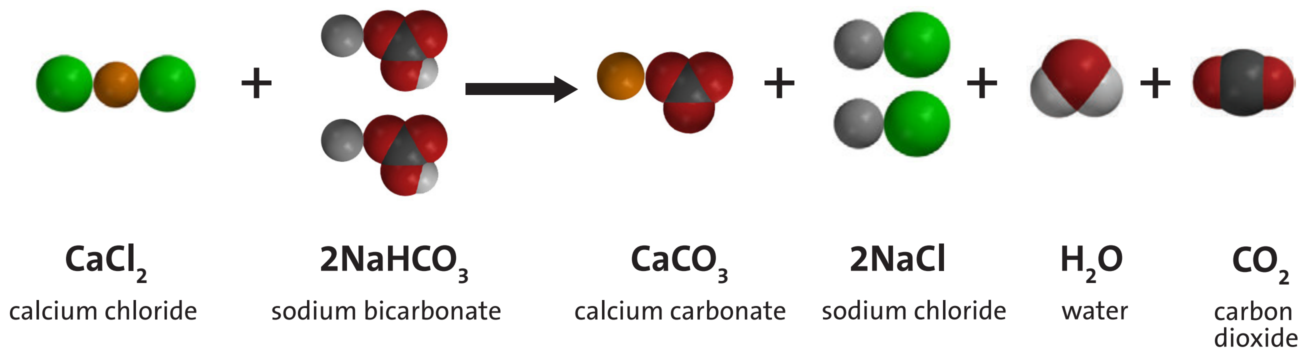
$C_2H_4O_2$		$NaHCO_3$		$NaC_2H_3O_2$		H_2O		CO_2
acetic acid	+	sodium bicarbonate	→	sodium acetate	+	water	+	carbon dioxide

4. Is this an endothermic or exothermic reaction?

5. Draw an energy arrow on the reactant side and another on the product side to compare the amount of energy used and released during the reaction.

6. What do the arrows show about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the products are formed?

Baking soda solution and calcium chloride reaction



7. Is this an endothermic or exothermic reaction?

8. Draw an energy arrow on the reactant side and another on the product side to compare the amount of energy used and released during the reaction.

9. What do the arrows show about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the products were formed?

TAKE IT FURTHER

Disposable hand warmers and self-inflating balloons use different chemical reactions to make them work. Both are packaged so that the reactants are kept separate. Once the consumer causes the reactants to combine, the chemical reactions begin.

Question to Investigate
How can endothermic and exothermic chemical reactions be useful?

Materials for Each Group
- Disposable self-heating hand warmer
- Self-inflating balloon

Procedure
1. Open the package the hand warmer is in to begin the chemical reaction.
2. Shake the hand warmer and feel for any temperature change.
3. Activate the self-inflating balloon by either pressing down or stepping on the packet of citric acid to rupture it.
4. Shake the balloon and feel the area on the balloon where the liquid is.
5. Be sure everyone in your group has a chance to feel both the hand-warmer and the self-inflating balloon.

11. Which is an example of an endothermic reaction?

    Which is an example of an exothermic reaction?

12. For the hand warmer, what can you say about the amount of energy required to break bonds in the reactants compared to the amount of energy that is released when bonds are formed in the products?

13. For the self-inflating balloon, what can you say about the amount of energy required to break bonds in the reactants compared to the amount of energy that is released when bonds are formed in the products?

EXTRA EXTEND

Question to investigate

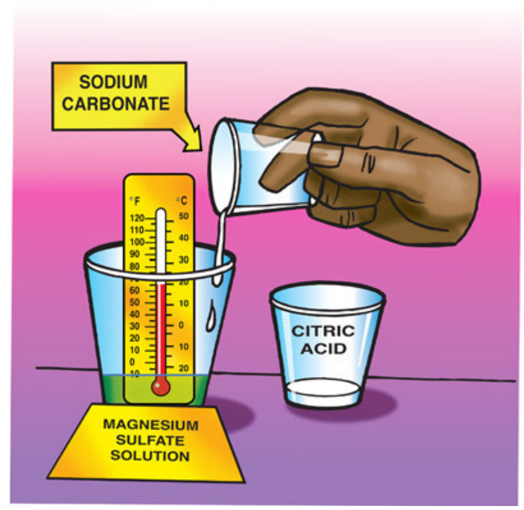
What clues do you observe that a chemical reaction is taking place?

Materials for each group

- Magnesium sulfate solution in cup
- Sodium carbonate solution in cup
- Citric acid solution in cup
- Universal indicator
- Thermometer
- Dropper

Procedure

1. Add 5 drops of universal indicator to the magnesium sulfate solution.
2. Place a thermometer in the cup and record the temperature of the solution.
3. Add 10 mL of sodium carbonate solution.
4. Add 10 mL of citric acid.



14. What clues do you observe that let you know that a chemical reaction is taking place?

15. In this chemical reaction, you may not have noticed a temperature change. Use what you know about energy and the breaking and making of bonds to explain how this can be.

Additional Teacher Background
Chapter 6, Lesson 7, p. 609

Chemical Reactions can be Exothermic or Endothermic

Previous Extra Teacher Background sections in Chapters 2 and 5 discuss the energy changes in the process of evaporation/condensation and dissolving. The processes in both contexts involve the breaking and making of bonds. In both cases the point was made that:

It takes energy to break bonds, and **energy is released when bonds are formed**

These same principles apply in the context of chemical reactions which can be either exothermic or endothermic. If it takes more energy to break the bonds of the reactants than is released when the bonds of the products are formed, then the reaction is endothermic and the temperature decreases.

If more energy is released when the bonds in the products form than it took to break the bonds of the reactants, then the reaction is exothermic and the temperature increases.

"Using" energy in bond-breaking and "releasing" energy in bond-making are really energy conversions between kinetic and potential energy. It takes a certain amount of kinetic energy to break the bonds holding atoms together in the molecules of the reactants. When the bonds are broken, this kinetic energy is converted to the potential energy of attraction between the atoms. When the atoms rebond to form the products, this potential energy is converted to kinetic energy. Depending on the combinations of bonds broken and made, a reaction is either endothermic or exothermic.

Chapter 6, Lesson 8: pH and Color Change

Key Concepts

- Whether a solution is acidic or basic can be measured on the pH scale.
- When universal indicator is added to a solution, the color change can indicate the approximate pH of the solution.
- Acids cause universal indicator solution to change from green toward red.
- Bases cause universal indicator to change from green toward purple.
- Water molecules (H_2O) can interact with one another to form H_3O^+ ions and OH^- ions.
- At a pH of 7, there are equal numbers of H_3O^+ ions and OH^- ions in water, and this is called a neutral solution.
- Acidic solutions have a pH below 7 on the pH scale.
- Basic solutions have a pH above 7 on the pH scale.

Summary

Students will see a demonstration of a color change using universal pH indicator. Students will change the concentrations of an acid and a base and use universal indicator to test the pH of the resulting solutions. Students will see an animation showing that water molecules interact and separate into the H_3O^+ ion and the OH^- ion. Students will see that the pH of a solution is related to the concentration of these ions in water.

Objective

Students will be able to explain, on the molecular level, that pH is a measure of the concentration of the H_3O^+ ions in water and that adding an acid or a base to water affects the concentration of these ions.

Evaluation

Download the student activity sheet, and distribute one per student when specified in the activity. The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan.

Safety

Be sure you and the students wear properly fitting goggles during the activity and wash hands afterwards. Sodium carbonate may irritate skin. Citric acid is an eye irritant. Universal indicator is alcohol-based and flammable. Read and follow all safety warnings on the label. At the end of the lesson, have students pour their used solutions in a waste container. Dispose of this waste down the drain or according to local regulations. The leftover citric acid and sodium carbonate powders can be disposed of with the classroom trash.

Materials for the Demonstration

- 3 clear plastic cups
- Citric acid
- Sodium carbonate
- Universal indicator solution
- Water

Materials for Each Group

- 3 clear plastic cups
- Masking tape and pen or permanent marker
- Universal indicator solution
- pH color chart
- Water
- Citric acid
- Sodium carbonate
- Graduated cylinder
- At least 12 flat toothpicks
- 2 6-well spot plates or 1 12-well spot plate
- 3 droppers

About the Materials

For this lesson, each group will need a Universal Indicator pH Color Chart. Print enough pages of these charts on a color printer so that each group can have its own chart, or purchase them from Flinn Scientific, Product #AP8765.

Each group will also need Universal Indicator Solution, Flinn Product #U0002, citric acid (anhydrous), Product #C0136 (500 grams) and sodium carbonate (anhydrous – Laboratory grade), Product #S0052. Each group will need either two 6-well spot plates or one 12-well spot plate. A porcelain 6-well spot plate is available from NASCO, Product #SB40727M. A polystyrene 12-well spot plate is available from Flinn Scientific, Product #AP6399.

About this Lesson

Because of their chemical properties, reactions involving acids and bases are different from the chemical reactions students have seen so far in Chapter 6. In the previous lessons, it was always the electrons that were being shared or transferred when atoms interacted. In the next three lessons about acids and bases, things are a little different. With acids and bases, it is a proton from a hydrogen atom that is transferred from one substance to another.

The main aspect of acids and bases that students will explore in the next three lessons deals with the influence of acids and bases on water. The reactions of acids and bases with water are measured using the pH scale. Understanding pH on the molecular level will give students a better appreciation for some of the environmental issues involving acids and bases. The meaning of pH and the way it is affected by acids and bases can be a little tricky, but by using animations, drawings, and some simplifications, students should be able to understand the main ideas.

ENGAGE

1. Add universal indicator solution to an acid and a base hidden in "empty" cups to demonstrate how an acid and a base can change the color of a pH indicator.

Materials for the Demonstration

- 3 clear plastic cups
- Citric acid
- Sodium carbonate
- Universal indicator solution
- Water

Note: *Your local tap water is likely fine for the demonstration and activities in this lesson. If the indicator solution you make is not green, this means that your water is either acidic or basic. If this happens, use distilled water, which is available in supermarkets and pharmacies.*

Teacher Preparation

Make indicator solution for student groups

- Make a dilute universal indicator solution for this demonstration and for each student group by combining 250 mL water with 10 mL universal indicator solution.
- Pour about 25 mL of this dilute universal indicator solution into a clean cup for each student group.

Note: *In the activity, students will fill 12 wells with universal indicator solution. Check to make sure that 25 mL of solution is enough. You will need about 50 mL of indicator solution for your demonstration. If 250 mL of solution is not enough, make more using the same proportions.*

Prepare for the Demonstration

- Pour about 50 mL indicator solution into a clear plastic cup for you to use in the demonstration.
- Using two empty clear plastic cups, add about ⅛ teaspoon of citric acid to one cup and ⅛ teaspoon of sodium carbonate to the other. Do not tell students that you have added anything to the cups.

Procedure

1. Pour about ⅓ of the indicator solution into the citric acid cup and ⅓ into the sodium carbonate cup. Leave ⅓ in the indicator cup.

Expected Results
The citric acid turns the indicator from green to reddish. The sodium carbonate turns the indicator from green to purple.

Reveal to students that you put something in the cups beforehand.

Ask students:

- **Do you think this was a chemical reaction? Why or why not?**
  A color change is often a clue that a chemical reaction has taken place. So the color change in each cup is likely the result of a chemical reaction. (This point is made in Chapter 6, Lesson 6.)
- **Would you say that the substances that were in the cups before the liquid was added were the same or different? Why?**
  The liquid in each cup turned a different color during the reaction. Because substances react chemically in characteristic ways and the substances reacted differently, the substances in each cup must be different.

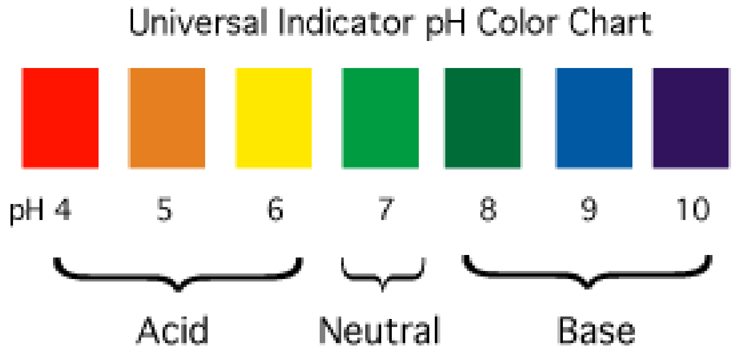
Tell students that the green solution was made by adding a substance called *universal indicator* to water. Explain that you put a small amount of a substance, one an acid and one a base, in each cup. Don't tell students which cup contained the acid or base.

Tell students that when you poured universal indicator solution into the cups, the acid and base each reacted with the indicator and changed its color. Usually, when two substances are mixed and a color change results, that is a clue that a chemical reaction has taken place. The cause of this color change will be discussed later in this lesson when students do their own activity.

Tell students that they will use an acid, a base, and universal indicator solution to learn about how acids and bases affect water. They will also learn how to measure the effect with colors and numbers on the pH scale.

2. Have students compare the color of the solutions made in the demonstration to the colors on the Universal Indicator pH Color Chart.

Distribute one Universal Indicator pH Color Chart to each group. The charts can be found right before the student activity sheets. Explain that the chart shows the range of color changes for universal indicator when acidic or basic solutions are added to the indicator. Point out that each color has a number associated with it and that students will learn more about these numbers later in the lesson. As the solution becomes more acidic, the color changes from green toward red. As the solution becomes more basic, the color changes from green toward purple.



Hold up the cups from the demonstration and ask the following questions:

- **What does the color of the liquid in each cup tell you about the substance that was already in the cup when the indicator was added?**
  The cup that turned reddish initially contained an acid, and the cup that turned purple initially contained a base.
- **What does the green color of the indicator tell you about the water in that cup? Is it acidic, basic, or neither?**
  The green indicator left in the cup is neither acidic nor basic, so it must be neutral.

3. Introduce the acid and base used in the demonstration and discuss how the color of universal indicator may change with other common acids and bases.

Explain that before class, you placed a small amount of citric acid in the cup that turned red and a small amount of sodium carbonate in the cup that turned purple. So citric acid is an acid and sodium carbonate is a base.

Acids and Universal Indicator Solution
Explain that citric acid is in citrus fruits such as lemons, limes, and oranges.

Ask students:

- **What are some other common examples of acids?**
  Students might say that vinegar is an acid. You could point out that there are also stronger acids, like sulfuric acid used in car batteries.
- **What colors would you expect to see if you placed any of these substances in universal indicator?**
  The color may change to yellow, orange, or red for these acids.

Bases and Universal Indicator Solution
Explain that sodium carbonate is one of the chemicals commonly used in detergents made for dishwashing machines.

Ask students:

- **What are some other common examples of bases?**
  Students may not know any examples of bases but you can tell them that soaps, ammonia, and other cleaners are often bases.
- **What colors would you expect to see if you placed any of these substances in universal indicator?**
  The color may change to dark green, blue, and purple for any of these bases. (For universal indicator, the changes in color for bases are not as different as they are for acids.)

Tell students that next they will explore the color changes of universal indicator with small amounts of citric acid and sodium carbonate.

Give each student an activity sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. To find the answers to the activity sheet, go to the downloads area within the online version of this lesson.

EXPLORE

4. Have students prepare the solutions for the activity.

Explain to students that they will first make their solutions for the activity. Either go through each step with them or have them follow the procedure described on their activity sheet.

Teacher Preparation
Students will need small amounts of sodium carbonate and citric acid for the activity.

- Label two small plastic cups *citric acid* and *sodium carbonate* for each group.
- Place about ¼ teaspoon of **citric acid** and **sodium carbonate** in the labeled cups.
- Distribute the cups with universal indicator solution to each student group.

Materials for Each Group

- 2 clear plastic cups
- 3 droppers
- Masking tape and pen or permanent marker
- Universal indicator in cup
- Water

- Graduated cylinder
- Sodium carbonate
- Citric acid
- 2 flat toothpicks

Procedure

Label your equipment

1. Use masking tape and a pen to label one cup **citric acid solution** and another cup **sodium carbonate solution**.
2. Use a small piece of masking tape and a pen to label one dropper **citric acid solution** and the other dropper **sodium carbonate solution**.

Make a citric acid solution

3. Use your graduated cylinder to add 5 mL of water to the cup labeled citric acid.
4. Use a flat toothpick to pick up as much citric acid as you can on the end of the toothpick as shown.
5. Add this citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.

Make a sodium carbonate solution

6. Use your graduated cylinder to add 5 mL of water to the cup labeled sodium carbonate.
7. Use a flat toothpick to pick up as much sodium carbonate as you can on the end of a toothpick.
8. Add this sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.

5. Explain what students will do in the next activity and discuss the purpose of having a control.

Explain to students that in this activity they will fill the wells in each spot plate with universal indicator solution. Then in the first spot plate, they will test how different concentrations of citric acid affect the color of universal indicator solution. In the other spot plate, they will test how different concentrations of sodium carbonate affect the color of universal indicator solution.

Tell students that in each spot plate, they will add nothing to the indicator solution in the first well. This is because the first well will serve as the control.

Ask students:

- **Why is it important to have a control?**
  The control is left alone and not changed so that any color changes in the other wells can be compared to the original color in the control.

6. Have students test increasing concentrations of citric acid solution.

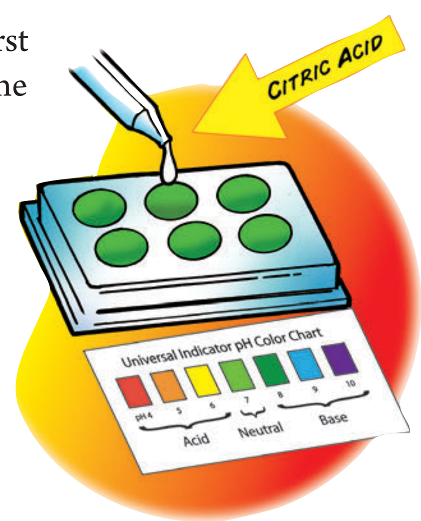
Question to Investigate
How does the concentration of citric acid affect the color of universal indicator solution?

Materials for Each Group

- Universal indicator solution
- pH color chart
- Citric acid solution
- At least 6 toothpicks
- Spot plate
- 2 droppers

Procedure
Test your citric acid solution

1. Use one of your droppers to nearly fill 6 wells in your first spot plate with the universal indicator solution. Place the Universal Indicator pH Color Chart in front of the spot plate.
2. Use your dropper to add 1 drop of citric acid solution to the second well. Gently mix the liquid with a clean toothpick.
3. Compare the color of the liquid to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of citric acid, and the pH number in the chart on the activity sheet for well 2.



Expected Results

The color of the indicator should turn yellow-green or yellow. If there is no obvious color change after adding a toothpick of citric acid, have students add a little more citric acid to the solution. Tell them to be sure to pick up as much citric acid as they can on the end of a toothpick.

Record Observations

Help students fill out the chart on their activity sheet. Students may say that the color of the solution in well 2 is yellow or yellow-green. Then have students assign a number for pH. Tell students that if the color in the well seems to be between two colors on the chart, they should assign a pH value between the two.

Tell students that in the next part of the activity they will add a little more citric acid to the citric acid solution. This will make the citric acid solution more **concentrated.** Just as they did before, they will add one drop of citric acid solution, but this time the citric acid solution will be more concentrated.

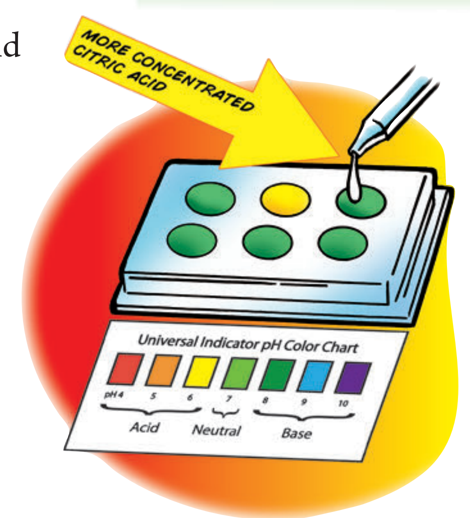
Ask students to make a prediction:

- **How do you think the color will change if you add one drop of a more concentrated citric acid solution to the universal indicator in the next well?**

Procedure

Test a more concentrated citric acid solution

4. Add another toothpick scoop of citric acid to the citric acid cup. Gently swirl until the citric acid dissolves.
5. Add 1 drop of this more concentrated citric acid solution to the *third* well. Gently mix the solution with a clean toothpick.
6. Compare the color of the solution to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpick scoops of citric acid added, and the pH number in the chart for well 3.
7. Continue adding toothpicks of citric acid and testing the solution in the last three wells to see how many different colors you can get.



Expected Results

As the citric acid solution becomes more concentrated, the color should change to variations of yellow-green, yellow, yellow-orange, orange, orange-red, and red. The colors obtained will vary from group to group because of the different amounts of citric acid students can pick up on the end of a toothpick. Students may be able to get 4 or 5 different colors. The answers and colors included in the chart below will vary.

The color and pH of different concentrations of citric acid			
Well number	**Number of toothpicks of citric acid used in 5 mL of water**	**Color**	**pH**
1	0	Green	7
2	1	Yellow-green	6.5
3	2	Yellow	6
4	3	Light orange	5.5
5	4	Peach	5
6	5	Pink	4

Ask students:

- **How does the color of the indicator solution change as the citric acid solution becomes more concentrated?**
  As the citric acid solution becomes more concentrated, the color moves from green toward red on the pH color chart.
- **How does the number on the pH scale change as the concentration of citric acid solution increases?**
  As the citric acid solution becomes more concentrated (more acidic), the number on the pH scale decreases.

7. Have students test increasing concentrations of sodium carbonate solution.

***Note**: The differences in color on the base side of the pH scale for universal indicator are not as obvious as those on the acid side. Students will have to look harder to see the difference between green-blue, blue, blue-purple, and purple.*

Question to Investigate

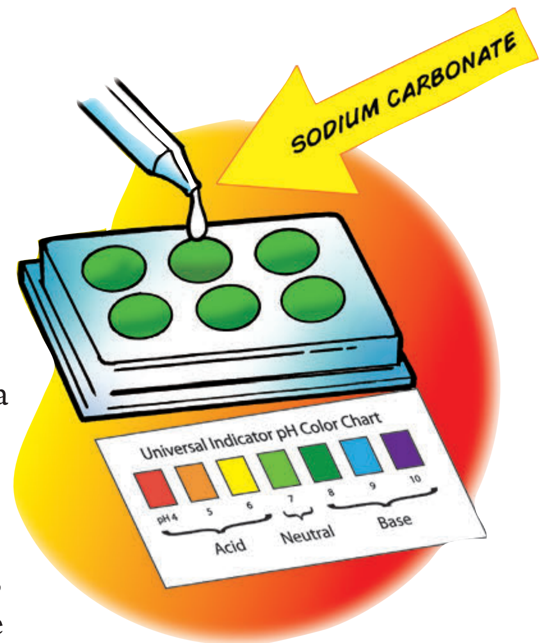
How does the concentration of sodium carbonate affect the color of universal indicator solution?

Materials for Each Group

- Universal indicator solution
- pH color chart
- Sodium carbonate solution
- At least 6 toothpicks
- Spot plate
- 2 droppers

Procedure

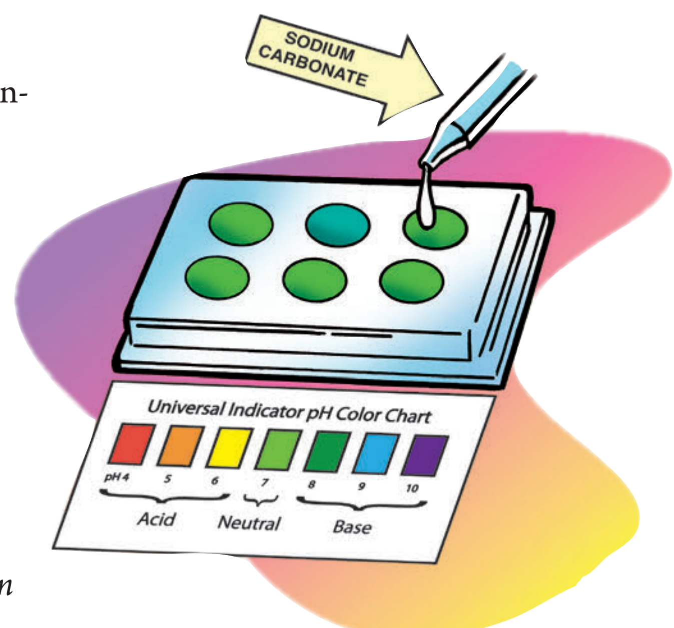
Test your sodium carbonate solution



1. Use a dropper to nearly fill the 6 wells in your other spot plate with universal indicator solution. You will not add anything else to the first well.
2. Add 1 drop of sodium carbonate solution to the second well. Gently mix the solution with a clean toothpick.
3. Compare the color of the solution to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of sodium carbonate used to make the solution, and the pH number in the chart for well 2.

Expected Results

The color of the indicator should turn green-blue or blue.



Ask students to make a prediction:

- **How do you think the color will change if you add one drop of a more concentrated sodium carbonate solution to the universal indicator in the next well?**

Tell students that if you add more base to the same amount of water, the *concentration* of the base increases.

Procedure

Test a more concentrated sodium carbonate solution

4. Add another toothpick of sodium carbonate to the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.
5. Add 1 drop of sodium carbonate solution to the next well. Gently mix the liquid with a clean toothpick.
6. Compare the color of the liquid to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of sodium carbonate used, and the pH number in the chart for well 3.
7. Continue adding toothpicks of sodium carbonate and testing the solution in the last three wells to see how many different colors or shades you can make.

Expected Results

The more concentrated sodium carbonate solution should cause the color to change to a darker blue moving toward purple. Answers and colors in the chart below will vary.

The color and pH of different concentrations of sodium carbonate			
Well number	**Number of toothpicks of sodium carbonate used in 5 mL of water**	**Color**	**pH**
1	0	Green	7
2	1	Green-blue	8
3	2	Blue	8.5
4	3	Blue-purple	9
5	4	Purple	9.5
6	5	Purple	10

Ask students:

- **How does the color of the indicator solution change as the sodium carbonate solution becomes more concentrated?**
  As the sodium carbonate solution becomes more concentrated, the color moves from green toward purple on the pH color chart
- **How does the number on the pH scale change as the concentration of base increases?**
  As the sodium carbonate solution becomes more concentrated (more basic), the number on the pH scale increases.

EXPLAIN

5. Explain how water molecules interact with each other to form ions.

Tell students that pH has to do with the way acids and bases interact with water. Explain that first you will show students how water molecules interact with each other before an acid or a base is added.

Project the animation *Proton Transfer in Water*
Play the first part of the animation.
Remind students that each hydrogen atom in a water molecule has both a proton and an electron. The hydrogen atoms share their electrons with the oxygen atom.

Click "next" to show how the water molecules become ions.
Water molecules continuously move and bump into one another. Sometimes when two water molecules come together, a proton from one hydrogen atom leaves its water molecule and becomes part of another water molecule. Only the positively charged proton moves; the negatively charged electron stays behind. So, these two H_2O molecules become the ions H_3O^+ and OH^-.

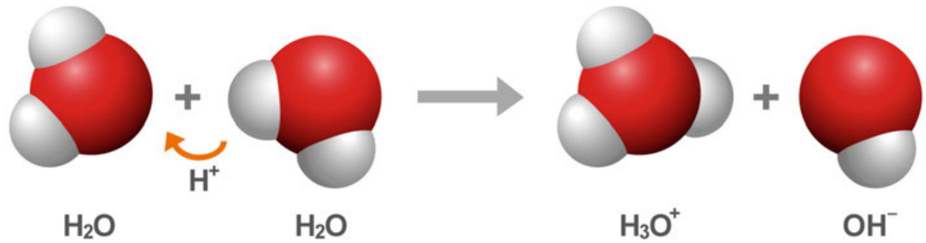
Click "next" again to show how the ions become water molecules again
Explain that when these ions bump into each other, the proton from the H_3O^+ can move over to the OH^- ion, forming two regular water molecules again. Because protons go back and forth between the water molecules or between ions continuously, there is always the same amount of H_3O^+ and OH^- ions in water.

Project the illustration *Water Molecules Trade Protons.*
This illustration shows the chemical equations that explain how water molecules can become ions and how ions can become water molecules again.

Explain to students that the first chemical equation shows two water molecules coming together. Point out the chemical formula for each water molecule, H_2O.

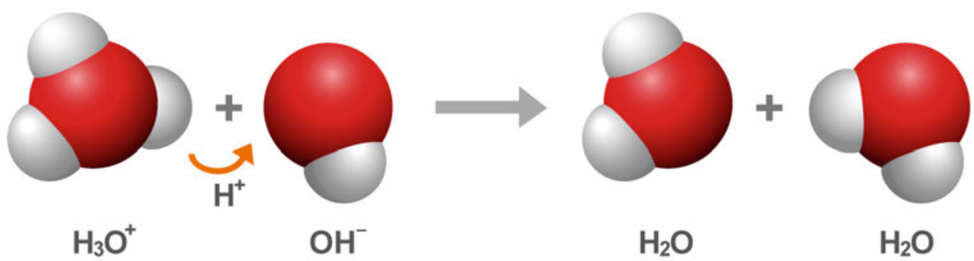
- *Explain the formation of the H_3O^+ ion.*
  After the proton is transferred, the water molecule that now has the extra proton is called an H_3O^+ ion. The reason why the number of hydrogen atoms changed from two (the subscript in H_2) to three (the subscript in H_3) is because having an extra proton is like having an extra hydrogen atom, even though the electron did not come over with it. Because one proton was added, there is one more proton than electrons, making this a positive ion.

- *Explain the formation of the OH^- ion.*
  The water molecule that lost a proton now has an extra electron, so it is called the OH^- ion. The reason why the number of hydrogen atoms changed from two (the subscript in H_2) to one (no subscript after the H means 1 hydrogen) is because losing a proton is like losing a hydrogen atom. Because only the proton was transferred, there is one more electron than proton, making this a negative ion.



Tell students that the second chemical equation shows an H_3O^+ ion and OH^- ion coming together to become water molecules again.

- *Explain the reformation of two H_2O molecules.*
  Explain to students that water molecules and ions are always colliding. When an H_3O^+ ion and an OH^- ion bump into each other, the proton can be transferred from the H_3O^+ ion over to the OH^- ion so that each ion becomes an H_2O molecule again.



At any given time in an ordinary sample of water, a small percentage of water molecules are transferring protons and becoming ions. Also, the H_3O^+ and OH^- ions are transferring protons and becoming water molecules again.

6. Explain how acids and bases cause the indicator to change color.

Project the animation *Acids Donate Protons.*
Tell students that when an acid is added to an indicator solution, the acid donates protons to the water molecules. This increases the concentration of H_3O^+ ions in the solution. The H_3O^+ ions donate protons to the indicator molecules causing the indicator to change color toward red.

Project the animation *Bases Accept Protons.*
When a base is added to an indicator solution, it accepts protons from the water molecules, creating OH^- ions. The H_3O^+ ions and indicator molecules donate protons to the OH^- ions, causing the indicator to change color toward purple.

Read more about strength vs. concentration in acids and bases in the additonal teacher background section at the end of the lesson.

EXTEND

7. Have students slowly pour their remaining acidic and basic solutions into the indicator solution to introduce the idea that acids and bases can neutralize each other.

Ask students to make a prediction:

- **How do you think the color will change if you pour a small amount of each left-over solution into your universal indicator solution?**

Materials for Each Group

- Universal indicator solution
- pH color chart
- Citric acid solution
- Sodium carbonate solution

Procedure

1. Pour a small amount of either your citric acid solution or sodium carbonate solution into your indicator solution. Swirl and compare the color to your Universal Indicator pH Color Chart.
2. Pour a small amount of the other solution into your indicator solution. Swirl and compare the color to your color chart.
3. Continue pouring small amounts of the acid and base solutions into your indicator until the solutions are used up.

Expected Results
The colors of the indicator solution will vary, but students should see that acids and bases mixed together cause the color of the indicator to change toward neutral.

Have students describe what they did and their observations. Then explain that in Chapter 6, Lesson 9, they will combine acids and bases in an indicator solution with the goal of making the pH of the final solution neutral.

Activity Sheet
Chapter 6, Lesson 8
pH and Color Change

Name ______________________

Date ______________________

DEMONSTRATION

1. Your teacher poured green universal indicator into each of two cups. What does the change in color of the indicator solution tell you about the substance your teacher placed in each cup?

PREPARE FOR THE ACTIVITY

Materials for Each Group

- 2 clear plastic cups
- 3 droppers
- Masking tape and pen or permanent marker
- Universal indicator in cup
- Water
- Graduated cylinder
- Sodium carbonate
- Citric acid
- 2 flat toothpicks

Procedure

Label your equipment

1. Use masking tape and a pen to label one cup **citric acid solution** and another cup **sodium carbonate solution.**
2. Use a small piece of masking tape and a pen to label one dropper **citric acid solution** and the other dropper **sodium carbonate solution.**

Make a citric acid solution

3. Use your graduated cylinder to add 5 mL of water to the cup labeled **citric acid**.
4. Use a flat toothpick to pick up as much citric acid as you can on the end of the toothpick as shown.
5. Add this citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.

Make a sodium carbonate solution

6. Use your graduated cylinder to add 5 mL of water to the cup labeled **sodium carbonate**.
7. Use a flat toothpick to pick up as much sodium carbonate as you can on the end of a toothpick.
8. Add this sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.

ACTIVITY

Question to Investigate

How does the concentration of citric acid affect the color of universal indicator solution?

Materials for Each Group

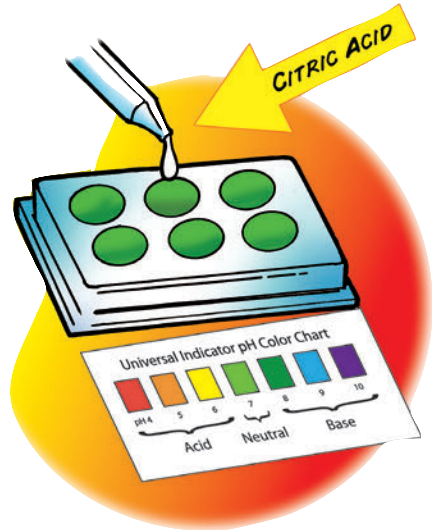
- Universal indicator solution
- pH color chart
- Citric acid solution
- At least 6 toothpicks
- Spot plate
- 2 droppers

Procedure

Test your citric acid solution

1. Use one of your droppers to nearly fill 6 small wells in your first spot plate with the universal indicator solution. Place the Universal Indicator pH Color Chart in front of the spot plate.

2. Use your dropper to add 1 drop of citric acid solution to the second well. Gently mix the liquid with a clean toothpick.
3. Compare the color of the liquid to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of citric acid, and the pH number in the chart for well 2.



Test a more concentrated citric acid solution

4. Add another toothpick scoop of citric acid to the citric acid cup. Gently swirl until the citric acid dissolves.
5. Add 1 drop of this more concentrated citric acid solution to the *third* well. Gently mix the solution with a clean toothpick.
6. Compare the color of the solution to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpick scoops of citric acid added, and the pH number in the chart for well 3.
7. Continue adding toothpicks of citric acid and testing the solution in the last three wells to see how many different colors you can get.

The color and pH of different concentrations of citric acid			
Well number	Number of tiny scoops of citric acid used in 5 mL of water	Color	pH
1	0		7
2	1		
3	2		
4	3		
5	4		
6	5		

2. How does the color of the indicator solution change as the citric acid solution becomes more concentrated?

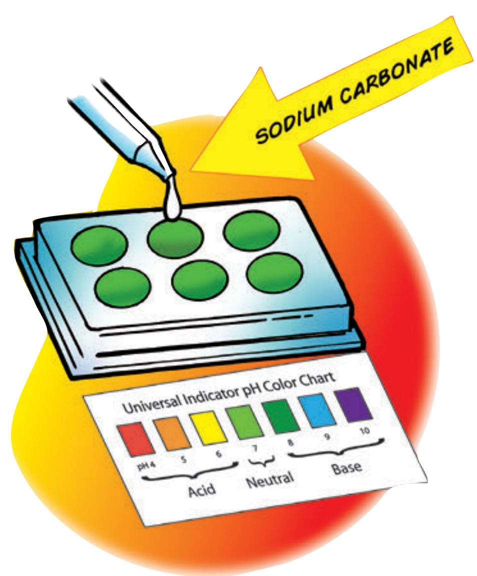
3. How does the number on the pH scale change as the concentration of citric acid solution increases?

Question to Investigate

How does the concentration of sodium carbonate affect the color of universal indicator solution?

Materials for Each Group

- Universal indicator solution
- pH color chart
- Sodium carbonate solution
- At least 6 toothpicks
- Spot plate
- 2 droppers



Procedure

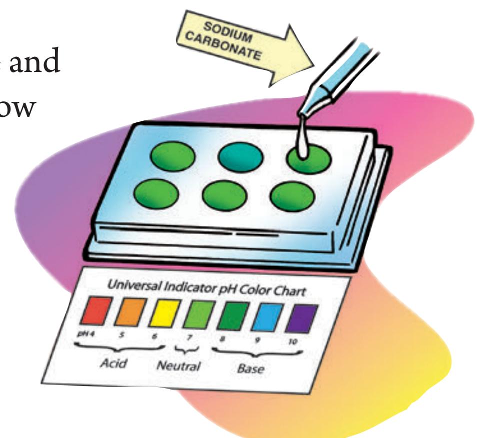
Test your sodium carbonate solution

1. Use a dropper to nearly fill the 6 wells in your other spot plate with universal indicator solution. You will not add anything else to the first well.
2. Add 1 drop of sodium carbonate solution to the second well. Gently mix the solution with a clean toothpick.

3. Compare the color of the solution to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of sodium carbonate used to make the solution, and the pH number in the chart for well 2.

Test a more concentrated sodium carbonate solution

4. Add another toothpick of sodium carbonate to the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.
5. Add 1 drop of sodium carbonate solution to the next well. Gently mix the liquid with a clean toothpick.
6. Compare the color of the liquid to the control and to the Universal Indicator pH Color Chart. Record the color of the indicator, the number of toothpicks of sodium carbonate used, and the pH number in the chart for well 3.
7. Continue adding toothpicks of sodium carbonate and testing the solution in the last three wells to see how many different colors or shades you can make.



The color and pH of different concentrations of sodium carbonate			
Well number	Number of tiny scoops of sodium carbonate used in 5 mL of water	Color	pH
1	0		7
2	1		
3	2		
4	3		
5	4		
6	5		

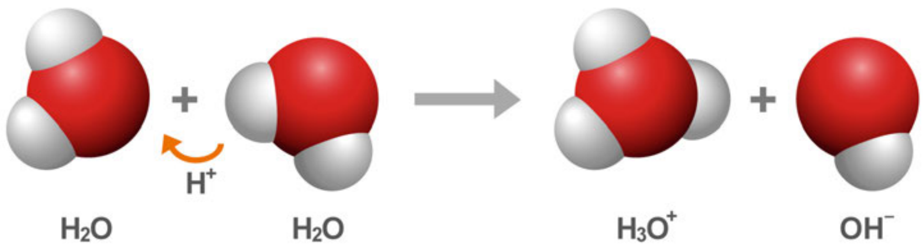
4. How does the color of the indicator solution change as the sodium carbonate solution becomes more concentrated?

5. How does the number on the pH scale change as the concentration of base increases?

6. In this activity, you did not add any citric acid solution or sodium carbonate solution to the first well in each spot plate. What is the purpose of leaving the first well green?

EXPLAIN IT WITH ATOMS & MOLECULES

7. The chemical formula for water is H_2O. Sometimes two water molecules can bump into each other and form the ions H_3O^+ and OH^-.



What is happening in the chemical equation above?

Why is one ion positive and the other ion negative?

2. The pH scale is a measure of the concentration of H_3O^+ ions in a solution. Use the words *increases*, *decreases*, or *stays the same* to describe how the concentration of H_3O^+ ions changes as different substances are added to water.

How does the concentration of H_3O^+ ions change as each substance is added to water?	
Type of substance	Concentration of H_3O^+ ions
Acid	
Base	
Neutral	

TAKE IT FURTHER

Question to Investigate

How will the color change as you slowly pour your acid and base solutions into the indicator?

Materials for Each Group

- Universal indicator solution
- pH color chart
- Citric acid solution
- Sodium carbonate solution

Procedure

1. Pour a small amount of either your citric acid solution or sodium carbonate solution into your indicator solution. Swirl and compare the color to your Universal Indicator pH Color Chart.
2. Pour a small amount of the other solution into your indicator solution. Swirl and compare the color to your color chart.
3. Continue to pour small amounts of the acid and base solutions into your indicator until the solutions are used up.

9. What did you observe as you slowly poured your acid and base solutions into the indicator solution?

Chapter 6, Lesson 9: Neutralizing Acids and Bases

Key Concepts

- pH is a measure of the concentration of H_3O^+ ions in a solution.
- Adding an acid increases the concentration of H_3O^+ ions in the solution.
- Adding a base decreases the concentration of H_3O^+ ions in the solution.
- An acid and a base are like chemical opposites.
- If a base is added to an acidic solution, the solution becomes less acidic and moves toward the middle of the pH scale. This is called *neutralizing* the acid.
- If an acid is added to a basic solution, the solution becomes less basic and moves toward the middle of the pH scale. This is called *neutralizing* the base.

Summary

Students will use citric acid and sodium carbonate solutions to see that adding a base to an acidic solution makes the solution less acidic. Students will then use a base to help them identify which of two acidic solutions is more concentrated.

Objective

Students will be able to explain, on the molecular level, that pH is affected by the concentration of the H_3O^+ ions in water. They will also be able to explain why adding a base to an acid or an acid to a base can make the pH of the solution closer to 7.

Evaluation

Download the student activity sheet, and distribute one per student when specified in the activity. The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan.

Safety

Be sure you and the students wear properly fitting goggles during the activity and wash hands afterwards. Sodium carbonate may irritate skin. Citric acid is an eye irritant. Universal indicator is alcohol-based and flammable. Read and follow all safety warnings on the label. At the end of the lesson, have students pour their used solutions in a waste container. Dispose of this waste down the drain or according to local regulations. The leftover citric acid and sodium carbonate powders can be disposed of with the classroom trash.

Materials for the Demonstration

- 4 clear plastic cups
- Graduated cylinder
- Universal indicator
- Water
- Sodium carbonate
- Citric acid
- Flat toothpicks
- 2 droppers
- Masking tape and pen or permanent marker

Materials for Each Group

- Universal indicator solution in cup
- Citric acid in cup
- Sodium carbonate in cup
- Water
- Solution A, sodium carbonate solution
- Solution B, more concentrated sodium carbonate solution
- At least 8 flat toothpicks
- Graduated cylinder
- Spot plate
- 4 droppers
- 3 clear plastic cups
- Masking tape and pen or permanent marker

About the Materials

Each group will need Universal Indicator Solution, Flinn Product #U0002, citric acid (anhydrous), product # C0136 (500 grams) and sodium carbonate (anhydrous—Laboratory grade), Product #S0052. Each group will also need a spot plate. A porcelain 6-well spot plate is available from NASCO, Product #SB40727M. A polystyrene 12-well spot plate is available from Flinn Scientific, Product #AP6399.

ENGAGE

1. Do a demonstration to show students that an acidic solution becomes less acidic when drops of a base are added.

Materials for the Demonstration

- 4 clear plastic cups
- Graduated cylinder
- Universal indicator
- Water
- Sodium carbonate
- Citric acid
- Flat toothpicks
- 2 droppers
- Masking tape and pen or permanent marker

Teacher Preparation

Make indicator solution for student groups

- Make a dilute universal indicator solution for this demonstration and for each student group by combining 125 mL water with 5 mL universal indicator solution.
- Pour about 15 mL of this dilute universal indicator solution into a clean cup for each student group.

Note*: Your local tap water is likely fine for the demonstration and activities in this lesson. If the indicator solution you make is not green, this means that your water is either acidic or basic. If this happens, use distilled water, which is available in supermarkets and pharmacies.*

Note*: In the engage and extend activities, students will fill 6 wells with universal indicator solution. Check to make sure that 15 mL of solution is enough. You will need about 25 mL of indicator solution for your demonstration. If 125 mL of solution is not enough, make more using the same proportions.*

Prepare for the Demonstration

- Divide the remaining indicator solution into two clear plastic cups for you to use in the demonstration.
- Use masking tape and a pen to label two empty cups **citric acid** and **sodium carbonate**.
- Use your graduated cylinder to add 5 mL of water to each labeled cup.
- Use a flat toothpick to pick up as much citric acid as you can on the end of the toothpick as shown. Add this citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.
- Use a flat toothpick to pick up as much sodium carbonate as you can on the end of a toothpick. Add this sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.

Procedure

1. Hold up the two cups of universal indicator solution, which are both green.
2. Also show students that you have a citric acid solution and a sodium carbonate solution.

Ask students:

- **What color will the green indicator solution turn if I add a few drops of citric acid solution?**
  The indicator solution will change color toward red.

Procedure

3. Add 3–5 drops of citric acid solution to one of the cups.

Expected Results

The color of the solution should change from green to reddish.

Ask students:

- **What do you think you could add to the reddish indicator to make it less acidic and go back toward green?**
  Students should suggest adding sodium carbonate (a base) to the acidic (red) solution.

Procedure

4. While holding up the cup of reddish indicator solution, add 1 drop of sodium carbonate solution, swirl, and compare the color of the solution to the color of the control.
5. Add another drop if necessary to get closer to the green color of the control. Continue adding drops until the color gets close to green. If you add a drop and the color goes past green to blue, ask students what the blue color tells you about the solution. The blue indicates that the solution has gone from being acidic to basic.

Explain that acids and bases are like chemical opposites. Tell students that they will experiment to figure out how many drops of a basic solution it takes to cause an acidic solution to move to the middle of the pH scale. This is called *neutralizing* the acid.

Give each student an activity sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. To find the answers to the activity sheet, go to the downloads area within the online version of this lesson.

EXPLORE

2. Have students prepare the solutions for the activity.

Teacher Preparation

Students will need small amounts of sodium carbonate and citric acid for the activity.

- Label two small plastic cups **citric acid solution** and **sodium carbonate solution** for each group.
- Place about ¼ teaspoon of citric acid and sodium carbonate in the labeled cups.
- Distribute the cups with universal indicator solution to each student group.

Materials for Each Group

- Sodium carbonate in cup
- Citric acid in cup
- Universal indicator in cup
- Water
- 3 clear plastic cups
- Graduated cylinder
- Flat toothpicks
- 2 droppers
- Spot plate
- Masking tape and pen or permanent marker

Procedure

Label your equipment

1. Use masking tape and a pen to label one cup **citric acid solution** and another cup **sodium carbonate solution.**
2. Use a small piece of masking tape and a pen to label one dropper **citric acid solution** and the other dropper **sodium carbonate solution.**

Make a citric acid solution

3. Use your graduated cylinder to add 5 mL of water to the cup labeled citric acid.
4. Use a flat toothpick to pick up as much citric acid as you can on the end of the toothpick as shown.
5. Add this citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.

Make a sodium carbonate solution

6. Use your graduated cylinder to add 5 mL of water to the cup labeled sodium carbonate.
7. Use a flat toothpick to pick up as much sodium carbonate as you can on the end of a toothpick.
8. Add this sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.

3. Have students neutralize an acidic solution.

Question to Investigate
How many drops of sodium carbonate solution will it take to neutralize your citric acid solution?

Materials for Each Group

- Universal indicator solution
- Citric acid solution
- Sodium carbonate solution
- At least 6 flat toothpicks
- Spot plate
- 3 droppers

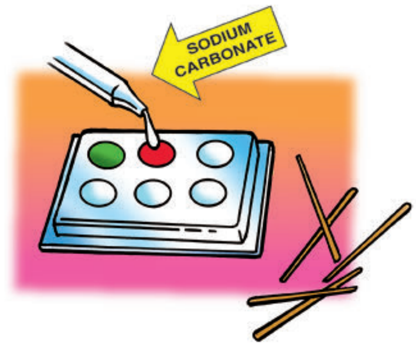
Procedure

1. Use a dropper to nearly fill two small wells in your spot plate with universal indicator solution. Do not add anything else to the first well. This will be your control.
2. Add 3 drops of citric acid solution to the indicator in one of the wells. Use a clean toothpick to mix the solution. If it is not reddish, add more drops, but be sure to count the total number of drops added.

Ask students:

- **What could you then add in order to make the indicator solution less acidic?**
  Adding a base, like the sodium carbonate solution, will make the solution less acidic.
- **Should you add one drop of sodium carbonate solution at a time or a few drops at once?**
  You should add one drop at a time to better monitor how many more drops of the sodium carbonate solution should be added.
- **How will you know when the solution is neutralized?**
  The color of the solution will be similar to the color of the control. Tell students that if the solution turns blue, it has gone from an acid, past neutral, and is now a base. If this happens, try adding one or more drops of citric acid until the color is close to

neutral. Be sure to keep track of the total number of drops of acid and base you add.



3. Add single drops of sodium carbonate to the same well in which you added the acid. Be sure to count the drops you use and stir with a toothpick after adding each drop.

Expected Results
With each drop of sodium carbonate, the citric acid solution will move toward neutral, eventually becoming green.

Note: *The solution may get close to the green color of the control, but will probably not be exact. This is because the citric acid and sodium carbonate solutions are not exactly equal in the way they act as acid and base. Also, to be very exact, students would need to be able to use half-drops or even quarter-drops, which is not possible with the droppers the students are using. As long as students see a trend toward the green control color, that is good enough.*

How many drops of sodium carbonate does it take to neutralize your citric acid solution?		
Acidic solution	**Number of drops of citric acid solution added to the indicator**	**Number of drops of sodium carbonate solution needed to neutralize the citric acid solution**
First citric acid solution	3 drops	
More concentrated citric acid solution		

2. **Discuss student observations.**

- **How many drops of sodium carbonate did it take to bring the color back to the color of the control?**
  Results will vary but it should take fewer drops of sodium carbonate than drops of citric acid to neutralize the solution.
- **Does the solution become more acidic or less acidic as each drop of sodium carbonate is added to the indicator?**
  The solution becomes less acidic.
- **How do you use the color of the control to help you neutralize an acid?**
  When the color of the universal indicator solution becomes near green, the acidic solution has been neutralized.

EXPLAIN

3. **Explain how adding a base to an acidic solution affects the concentration of H_3O^+ ions.**

Project the animation *Neutralizing an Acidic Solution.*
Explain to students that adding drops of citric acid to the indicator solution increased the concentration H_3O^+ ions. When you add a base to this acidic solution, the base accepts protons from the water molecules creating OH^- ions. The H_3O^+ ions and indicator molecule transfer protons to the OH^- ions. When enough base is added so that the concentration of H_3O^+ and OH^- ions becomes equal, the solution is neutralized.

EXPLORE

4. **Have students compare how many more drops of a base it takes to neutralize a more concentrated acidic solution.**

Question to Investigate
How many more drops of sodium carbonate solution will it take to neutralize a more concentrated citric acid solution?

Materials for Each Group
- Citric acid
- Citric acid solution
- Sodium carbonate solution
- Universal indicator solution
- 2 flat toothpicks
- 3 droppers
- Spot plate

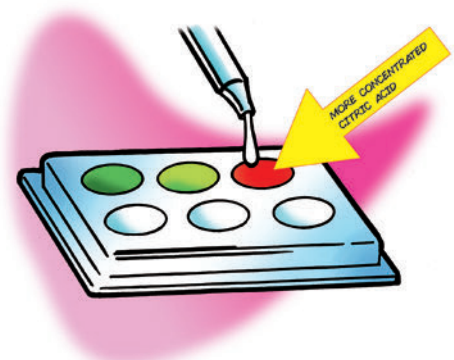
Procedure

Neutralize a citric acid solution

1. Use a flat toothpick to add two scoops of citric acid to your citric acid solution to make it even more acidic. Gently swirl until the citric acid dissolves.
2. Add universal indicator solution to a clean well in the spot plate.
3. Add 3 drops of the more concentrated citric acid solution to the indicator and stir with a clean toothpick.

Ask students:

- **Do you think it will take more, less, or the same amount of sodium carbonate solution to neutralize this more concentrated citric acid solution?**
  It will take more drops of the base to neutralize the more concentrated citric acid solution.
- **Thinking about the animation, why will you need more drops of sodium carbonate solution?**
  Since the solution is more acidic, there are more H_3O^+ ions. So it takes more molecules of the base to accept the extra protons toward neutral.



Procedure

Neutralize a more concentrated citric acid solution

4. Add single drops of sodium carbonate solution to the same well in which you added the acid. Be sure to count the drops you use and stir with a toothpick after adding each drop. Record this number in the chart.

EXTEND

7. Have students neutralize two basic solutions to determine which is most concentrated.

Materials for each group

- Universal indicator solution
- Citric acid solution
- Solution A
- Solution B
- At least 6 toothpicks

- Spot plate
- 3 droppers

Teacher Preparation

Make two mystery solutions using different amounts of sodium carbonate.

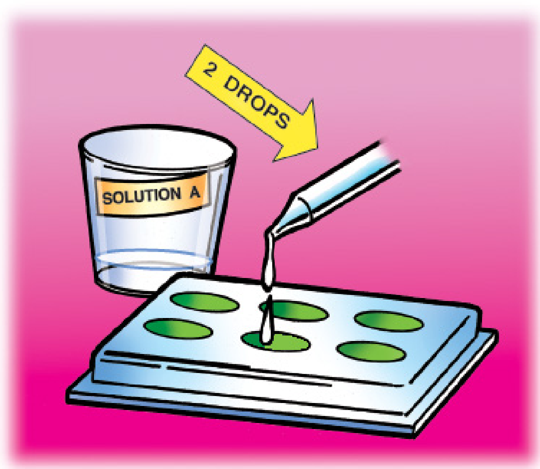
- Label two cups *Solution A* and *Solution B* for each group.
- Make a class set of solutions A and B.
    - Solution A: 50 mL of water and 5 toothpicks of sodium carbonate
    - Solution B: 50 mL of water and 10 toothpicks of sodium carbonate
- Place about 5 mL of each solution in their labeled cups.

Ask students:

- **Solutions A and B are both basic solutions made with sodium carbonate and water. One of these solutions has more sodium carbonate than the other. How can you figure out which solution is more concentrated?**
  Students should describe a procedure very similar to the one they used to neutralize the two citric acid solutions. They should suggest that they neutralize each sodium carbonate solution with drops of citric acid and count how many drops it takes to neutralize each solution. When the color of the solution is close to the color of the control, the solution is neutralized.
- **How will you know which solution is the most concentrated?**
  The solution that requires the greatest number of drops of citric acid to become neutral is the most basic.

Discuss what students will do:

- For best results, have students place 2 drops of Solution A in one well filled with indicator solution and 2 drops of Solution B in another well filled with indicator solution.
- Then they should add single drops of citric acid solution, stir, and compare the color to the color of the control.
- Students should keep track of the number of drops of citric acid it takes to neutralize each solution.



Procedure

1. Add universal indicator solution to three wells in a clean spot plate.
2. Leave the first well alone so that it can be used as a control. Add 2 drops of Solution A to the second well.
3. Add 2 drops of Solution B to the third well.

Which solution is the most concentrated?		
Solution	**Number of drops of solution added to the indicator**	**Number of drops of citric acid solution needed to neutralize the sodium carbonate solution**
Solution A	2 drops	
Solution B	2 drops	

Ask students:

- **Which solution is the most concentrated? How do you know?**
  Students should discover that it takes more drops of citric acid to neutralize Solution B. Therefore, Solution B must be more concentrated than Solution A.
- **Antacids are medicines people take when the acid in their stomach is causing them discomfort. One advertisement says that the medicine provides relief for acid indigestion and sour stomach. What type of chemical do you think is in the medicine?**
  Bases neutralize acids, so the chemical is probably a base.

EXTRA EXTEND

8. Place an Alka-Seltzer® tablet in indicator solution and have students interpret what the color changes say about the pH of the solution.

Explain that Alka-Seltzer® contains powdered acids and a base. The acids are citric acid, which tastes a little sour, and acetylsalicylic acid, which is aspirin. The base is baking soda, which is also known by its chemical name sodium bicarbonate.

Tell students that they will observe an Alka-Seltzer tablet in a universal indicator solution. Then they will use what they know about universal indicator and its color changes to describe whether the solution is acidic or basic as the substances in the tablet react.

Question to Investigate
How does the pH of the solution change during a chemical reaction between the ingredients in an Alka-Seltzer tablet in water?

Materials for Each Group

- Universal indicator solution in cup
- Water
- Alka-Seltzer tablet
- Graduated cylinder
- Snack-sized zip-closing plastic bag

Procedure

1. Add 20 mL of universal indicator solution to a snack-sized zip-closing plastic bag.
2. Seal the bag.

***Note**: So that students do not handle the Alka-Seltzer, which is a medicine, you should place an Alka-Seltzer tablet in each group's bag.*

Procedure for the Teacher

1. Add an Alka-Seltzer tablet to each group's bag by opening the corner of the bag just enough so that the tablet can fit through.
2. Remove as much air as possible and drop the Alka-Seltzer tablet through the small opening.
3. Seal the bag and hand it to one of the students. Instruct this student to shake the bag and pass it around so that each group member has an opportunity to hold the bag.

Expected Results

As soon as the Alka-Seltzer tablet is placed in the bag, the color of the indicator solution changes to red. Bubbles appear in the solution and the bag inflates. The solution also becomes cold. Over time the solution becomes orange, yellow, and finally returns to green.

9. Discuss student observations.

As the colors are changing and the bags are inflating, ask students:

- **What do the color changes tell you about the pH of the solution at the beginning, middle, and end of the chemical reaction?**
  Beginning: The solution is acidic.
  Middle: The solution is becoming less acidic.
  End: The solution is neutralized.

Students should conclude that the acid and base ingredients in the tablet neutralized one another.

Activity Sheet
Chapter 6, Lesson 9
Neutralizing Acids and Bases

Name ______________________

Date ______________________

DEMONSTRATION

1. Your teacher added drops of an acid to a universal indicator solution and then neutralized the solution by adding drops of a base. How did you know when the solution became close to neutral?

PREPARE FOR THE ACTIVITY

Materials for Each Group

- Sodium carbonate in cup
- Citric acid in cup
- Universal indicator in cup
- Water
- 3 clear plastic cups
- Graduated cylinder
- Flat toothpicks
- 2 droppers
- Masking tape and pen or permanent marker

Procedure

Label your equipment

1. Use masking tape and a pen to label one cup **citric acid solution** and another cup **sodium carbonate solution.**
2. Use a small piece of masking tape and a pen to label one dropper **citric acid solution** and the other dropper **sodium carbonate solution.**

Make a citric acid solution

3. Use your graduated cylinder to add 5 mL of water to the cup labeled citric acid.
4. Use a flat toothpick to pick up as much citric acid as you can on the end of the toothpick as shown.
5. Add this citric acid to the water in the citric acid cup. Gently swirl until the citric acid dissolves.

Make a sodium carbonate solution

6. Use your graduated cylinder to add 5 mL of water to the cup labeled sodium carbonate.
7. Use a flat toothpick to pick up as much sodium carbonate as you can on the end of a toothpick.
8. Add this sodium carbonate to the water in the sodium carbonate cup. Gently swirl until the sodium carbonate dissolves.

ACTIVITY

Question to Investigate

How many drops of sodium carbonate solution will it take to neutralize your citric acid solution?

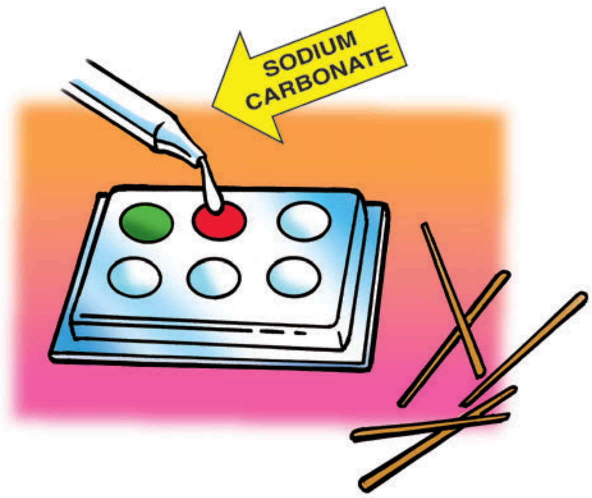
Materials for Each Group

- Universal indicator solution
- Citric acid solution
- Sodium carbonate solution
- At least 6 flat toothpicks
- Spot plate
- 3 droppers

Procedure

1. Use a dropper to nearly fill two small wells in your spot plate with universal indicator solution. Do not add anything else to the first well. This will be your control.
2. Add 3 drops of citric acid solution to the indicator in one of the wells. Use a clean toothpick to mix the solution. If it is not reddish, add more drops, but be sure to count the total number of drops added.

3. Add single drops of sodium carbonate to the same well in which you added the acid. Be sure to count the drops you use and stir with a toothpick after adding each drop.



How many drops of sodium carbonate does it take to neutralize your citric acid solution?		
Acidic solution	**Number of drops of citric acid solution added to the indicator**	**Number of drops of sodium carbonate solution needed to neutralize the citric acid solution**
First citric acid solution	3 drops	
More concentrated citric acid solution		

2. Does the solution become more acidic or less acidic as each drop of sodium carbonate is added to the indicator?

EXPLAIN IT WITH ATOMS & MOLECULES

3. What happens to the protons from the H_3O^+ ions when a base is used to neutralize an acid?

4. What do you know about the concentration of H_3O^+ ions and OH^- ions when a solution is neutralized?

ACTIVITY

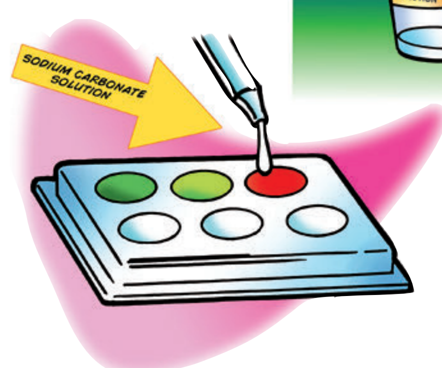
Question to Investigate
How many more drops of sodium carbonate solution will it take to neutralize a more concentrated citric acid solution?

Materials for Each Group

- Citric acid
- Citric acid solution
- Sodium carbonate solution
- Universal indicator solution
- 2 flat toothpicks
- 3 droppers
- Spot plate

Procedure

1. Use a flat toothpick to add two scoops of citric acid to your citric acid solution to make it even more acidic. Gently swirl until the citric acid dissolves.
2. Add universal indicator solution to a clean well in the spot plate.
3. Add 3 drops of the more concentrated citric acid solution to the indicator and stir with a clean toothpick.
4. Add single drops of sodium carbonate to the same well in which you added the acid. Be sure to count the drops you use and stir with a toothpick after adding each drop. Record this number in the chart.



2. Did it take *more*, *less*, or *the same* amount of sodium carbonate solution to neutralize this more concentrated citric acid solution?

3. Thinking about the animation, why will you need more drops of sodium carbonate solution?

TAKE IT FURTHER

Question to Investigate

Is Solution A or Solution B a more concentrated basic solution?

Materials for Each Group

- Universal indicator solution
- Citric acid solution
- Solution A
- Solution B
- At least 6 toothpicks
- Spot plate
- 3 droppers

Procedure

1. Add universal indicator solution to three wells in a clean spot plate.
2. Leave the first well alone so that it can be used as a control. Add 2 drops of Solution A to the second well.
3. Add 2 drops of Solution B to the third well.
4. Neutralize Solution A. Record the number of drops used in the chart.
5. Neutralize Solution B. Record the number of drops used in the chart.

Which solution is the most concentrated?		
Solution	**Number of drops of solution added to the indicator**	**Number of drops of citric acid solution needed to neutralize the sodium carbonate solution**
Solution A	2 drops	
Solution B	2 drops	

7. Which solution is the most concentrated? How do you know?

8. Antacids are medicines people take when the acid in their stomach is causing them discomfort. One advertisement says that the medicine provides relief for acid indigestion and sour stomach. What type of chemical do you think is in the medicine?

Chapter 6, Lesson 10: Carbon Dioxide Can Make a Solution Acidic

Key Concepts

- Carbon dioxide (CO_2) gas dissolved in water can cause water to become acidic.
- The acidity of water from dissolved CO_2 can be reduced by a base such as baking soda (sodium bicarbonate).

Summary

The teacher blows into a universal indicator solution until it changes color. Students interpret this color change and explain that the solution becomes acidic. Students explore whether carbon dioxide from other sources, namely carbonated water and a chemical reaction between baking soda and vinegar, can also make a solution acidic. Students then apply their observations to the environmental problem of ocean acidification by doing research on this issue.

Objective

Students will be able to explain that carbon dioxide from any source reacts chemically with water to form carbonic acid. They will also be able to use the color changes of universal indicator to monitor the changing pH of a solution during a chemical reaction.

Evaluation

Download the student activity sheet, and distribute one per student when specified in the activity. The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan.

Safety

Be sure you and the students wear properly fitting goggles during the activity and wash hands afterwards. Universal indicator is alcohol-based and flammable. Use vinegar in a well-ventilated room. Read and follow all safety warnings on the label. Dispose of all liquid waste down the drain or according to local regulations.

Materials for the Demonstration

- Universal indicator solution
- Water
- 2 clear plastic cups
- Straw

Materials for Each Group

- Water
- Universal indicator solution in cup
- Universal indicator pH color chart
- Carbonated water (club soda or seltzer water) in wide, clear, plastic cup

- Baking soda in wide, clear, plastic cup
- Vinegar
- Alka-Seltzer tablet
- 2 small clear plastic cups
- 4 wide clear plastic cups
- 4 taller, clear, plastic cups
- Graduated cylinder
- Snack-sized zip-closing plastic bag

About the Materials

For this lesson, each group will need a Universal Indicator pH color chart. Print enough pages of these charts on a color printer so that each group can have their own chart. You may also choose to purchase them from Flinn Scientific, Product number AP8765.

Each group will also need universal indicator solution, Flinn Product #U0002, Flinn Product #C0136 (500 grams), and sodium bicarbonate (baking soda).

ENGAGE

1. Do a demonstration to show that adding CO_2 gas to water can make the water become acidic.

Materials for the Demonstration

- Universal indicator solution
- Water
- 2 clear plastic cups
- Straw

Teacher Preparation

Make indicator solution for student groups

- Make a dilute universal indicator solution for this demonstration and for each student group by combining 625 mL water with 25 mL universal indicator solution.
- Pour at least 80 mL of this dilute universal indicator solution into a clean plastic cup for each student group.

***Note**: Your local tap water is likely fine for the demonstration and activities in this lesson. If the indicator solution you make is not green, this means that your water is either acidic or basic. If this happens, use distilled water, which is available in supermarkets and pharmacies.*
***Note**: In the activities, each group will need 80 mL of indicator solution. Check to make sure that you prepare enough solution. You will need about 50–60 mL of indicator solution for your demonstration. If 650 mL of solution is not enough, make more using the same proportions.*

Prepare for the Demonstration
Pour about 25–30 mL of indicator solution into each of two clear plastic cups for you to use in the demonstration.

Procedure

1. Show students both samples of universal indicator solution. Place a straw in one of the samples so that the straw goes all the way to the bottom of the cup.
2. Hold the cup so that students can clearly see the liquid. Blow into the straw until the indicator solution changes from green to yellow.

Ask students:

- **Does blowing into the indicator solution change its pH?**
  Yes, the color changes, so there must be a change in pH, too.
- **Does the solution become a little more acidic or a little more basic?**
  The color change shows that the solution is a little more acidic.

Tell students that a chemical reaction occurs between the molecules of CO_2 and the molecules of H_2O to create a very small amount of an acid called *carbonic* acid (H_2CO_3).

Give each student an activity sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. To find the answers to the activity sheet, go to the downloads area within the online version of this lesson.

EXPLORE

2. Have students use club soda as a source of CO_2 to see if the gas will change the pH of an indicator solution.

Question to Investigate
Will carbon dioxide from carbonated water change the pH of an indicator solution?

Materials for Each Group
- Universal indicator solution in a plastic cup
- Water
- Carbonated water (club soda or seltzer water) in a wide clear plastic cup
- 1 wide, clear, plastic cup
- 2 taller, clear, plastic cups
- Graduated cylinder
- Universal Indicator pH Color Chart

Teacher Preparation
Pour 25 mL of carbonated water into a wide, clear, plastic cup for each group.

Procedure
1. Measure 30 mL of universal indicator solution and divide it evenly into two small, clear, plastic cups.
2. Add 25 mL of water to a wide plastic cup and 25 mL of carbonated water to another wide cup.
3. Stand the small cups with indicator solution in the liquid in the wider cups as shown.
4. Turn the two tall cups upside down and place them over the two wider cups.
5. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
6. Compare the color of the indicator to the pH Color Chart to find out whether the solution is acidic, neutral, or basic.

Expected Results
The indicator inside the cups with water remained green, while the indicator with the carbonated water turned yellow.

3. Discuss student observations and what will happen in the following activity.

Ask students:

- **Did either indicator change color?**
  Only the indicator with the carbonated water changed color.
- **What does the color change tell you about the pH of the indicator solution? Is it acidic or basic?**
  The indicator solution is now acidic.
- **The carbonated water should not have splashed into the indicator. Why did the indicator solution change color in one set of cups?**
  The carbon dioxide from the carbonated water dissolved in the indicator solution. The molecules of carbon dioxide reacted with the water, forming carbonic acid, and changed the color of the indicator.

Tell students that they have seen carbon dioxide gas from your breath and carbon dioxide gas from carbonated water turn an indicator solution acidic.

Ask students:

- **Do you think carbon dioxide gas produced during a chemical reaction will also turn an indicator solution acidic?**
  Carbon dioxide from any source should cause the indicator solution to become acidic. The amount of carbon dioxide gas produced and dissolved in the indicator solution may cause the color of the indicator to vary, but on the acidic side.
- **What chemical reaction do you know of that can produce carbon dioxide gas?**
  Students should remember that vinegar and baking soda react, producing carbon dioxide gas. Tell students that they will combine baking soda and vinegar in the next activity.

4. Use a chemical reaction to produce CO_2 to see if it changes the pH of an indicator solution.

Question to Investigate
Will carbon dioxide gas produced in the baking soda and vinegar reaction change the pH of an indicator solution?

Materials for Each Group

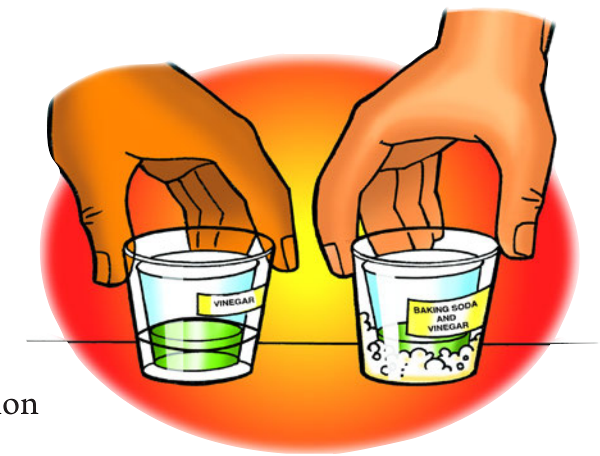
- Universal indicator solution in cup
- Universal indicator pH color chart
- Water
- Baking soda in wide clear plastic cup
- Vinegar in cup
- 2 small clear plastic cups
- 1 wide clear plastic cups
- 2 taller clear plastic cups
- Graduated cylinder

Teacher Preparation

- Pour about 50 mL of vinegar in a wide plastic cup for each group.
- Place about ½ teaspoon of baking soda into a small clear plastic cup for each group.

Procedure

1. Measure and pour 25ml of vinegar into two wide plastic cups.
2. Pour 15ml of universal indicator into two clean small plastic cups.
3. Pour all the baking soda into one of the cups of vinegar. Do not pour anything into the other.
4. Stand the small cups with indicator solution in both of the wider cups as shown.
5. Turn the two tall cups upside down and place them over the two wider cups.
6. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
7. Compare the color of the indicator to the pH Color Chart to find out whether the solution is acidic, neutral, or basic.



Expected Results

The indicator inside the cup with only vinegar remained green while the indicator inside the cup with the vinegar and baking soda reaction turned yellow.

5. Discuss student observations.

Ask students:

- **Did either indicator change color?**
  Only the indicator with the chemical reaction changed color.
- **Why did one set of cups only have vinegar in the bottom?**
  It is possible that vinegar by itself causes the indicator to change color. Since this indicator did not change color, it must be the carbon dioxide gas produced by the chemical reaction, and not just the vinegar that caused the color change. The indicator solution in the set of cups with only vinegar in the bottom serves as a control.
- **What does the color of the indicator solution tell you about the pH of each solution? Is it acidic, neutral, or basic?**
  The color change shows that the indicator solution is slightly acidic.
- **What could you add to the acidic indicator solution to neutralize it?**
  Because the indicator solution is acidic, students should suggest adding a base. Tell students that baking soda is a base.

EXPLAIN

6. Explain that carbon dioxide from any source can make water acidic.

Ask students:

- **What did carbon dioxide from breath, carbonated water, and the baking soda and vinegar reaction all do to water?**
  The CO_2 from each source reacted with the water and made it acidic.

Project the illustration *CO_2 Reacting with Water.*

Tell students that carbon dioxide reacts with water to produce carbonic acid. Students may count up the number of atoms on each side of the equation to show that it is balanced. Point out that the double arrow in this equation means that carbonic acid breaks down readily to form carbon dioxide and water again.

Explain to students that too much CO2 in the atmosphere causes Earth and its atmosphere to become warmer. But excess CO2 can do something else which they have seen in the chemical equation and in their experiments. Carbon dioxide can make water more acidic which is causing a big problem in the oceans. The excess acid in ocean water, called ocean acidification, makes it difficult for some organisms to form shells and is especially damaging to coral.

EXTEND

7. Explain how ocean acidification is bad for shell-making organisms and show a video about ocean acidification.

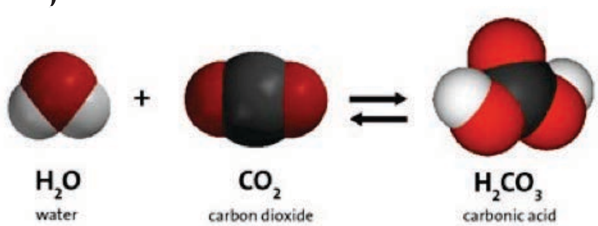
Explain that the ocean is actually basic. The pH of the ocean is about 8.2. The term "ocean acidification" means that the ocean is tending to become more acidic or less basic. It has moved from about 8.2 to 8.1. This may not seem like a big change but it is a very big change to organisms in the ocean which are very sensitive to changes in pH. When ocean water becomes more acidic it causes two main problems for shell-making organisms like clams, oysters, and coral:

1. It becomes harder for these organisms to make their shells
2. If the water becomes too acidic, normal shells can react with the more acidic water causing the shell to break down

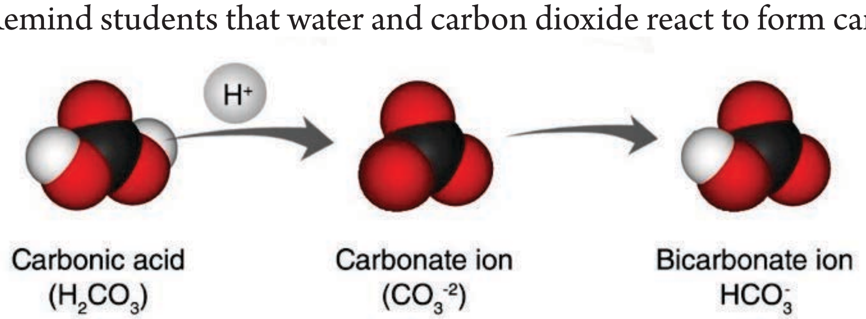
Clams, oysters, coral and other shell-making organisms make their shells out of two ions: the calcium ion (Ca^{+2}) and the carbonate ion (CO_3^{-2}). When these two ions join together, they make calcium carbonate ($CaCO_3$) which is the main substance for the structure of the shell. Ocean acidification affects the carbonate ion. Here's how:

The site also offers a wealth of resources on ocean acidification and climate change.

Project the illustration Carbonic acid and Carbonate ion.



Remind students that water and carbon dioxide react to form carbonic acid.



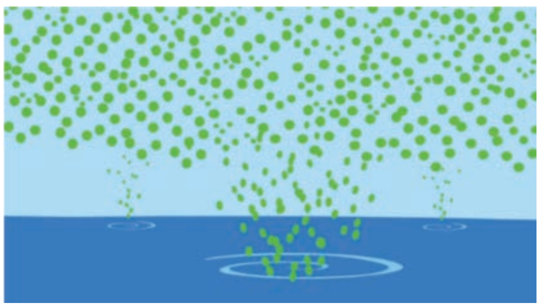
A hydrogen atom from the carbonic acid gets into the water as a hydrogen ion (H^+). This hydrogen ion bonds to the carbonate ion in ocean water and creates bicarbonate ion

(HCO_3^-) which the shell-making organisms can't use. This means there are fewer carbonate ions for the creatures to attach a calcium ion to, making it harder for them to make the calcium carbonate they need to make their shells.

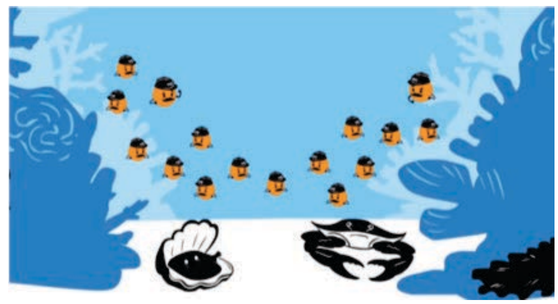
Extra hydrogen ions in the water also makes the water more acidic. If the water eventually gets too acidic it might react with the calcium carbonate in the shells causing them to break down.

Show the video Ocean Acidification.

Note: The narration and action of the video go by pretty quickly so you might want to stop the video in a few places to help students understand what is being presented.



The green dots represent excess carbon dioxide in the atmosphere due to the burning of fossil fuels. The ocean absorbs a large amount of this carbon dioxide.



The little orange characters represent carbonate ions which the shell-making organisms need. They use carbonate ions and calcium ions to make calcium carbonate to build their shells.

Carbon dioxide reacts with water and produces carbonic acid (green irregular blob) which produces hydrogen ions. These ions bond to the carbonate ions and create a substance (bicarbonate ion not shown) that the organisms can't use.

With shells difficult to make, clams and other shell-making organisms will be smaller and not reproduce as much so the creatures that eat them may not get enough food. This could affect the whole food chain.

The extra hydrogen ions don't just bond to the carbonate ion, they also make the water more acidic.

The oceans could become so acidic in the future that the calcium carbonate shells could react with the water and break down.

8. Have students do research on ways to reduce the amount of carbon dioxide released into the atmosphere.

The vast majority of the excess carbon dioxide in Earth's atmosphere is from burning fossil fuels such as petroleum, natural gas, and coal. Most of this fuel is used for cars, trucks and other forms of transportation, for running power plants that produce electricity, and for heating homes and businesses.

Have students research alternative sources of energy that could help in burning less fossil fuel. Students could present their research in a short paper with illustrations, power point, tri-fold board, or in any way you feel will work. Students should describe how the renewable energy source works and the advantages and challenges of the technology.

Some possible topics could be:

Renewable energy sources
Wind
Solar
Geothermal
Biofuels
Hydroelectric

New transportation technology
Electric cars
Hydrogen fuel cells

Activity Sheet
Chapter 6, Lesson 10
Carbon Dioxide Can Make a Solution Acidic

Name ______________________

Date ______________________

DEMONSTRATION

1. Your teacher blew through a straw into a universal indicator solution until it changed color. Did the indicator solution become acidic or basic?

2. What chemical from your teacher's breath caused the indicator to change color?

ACTIVITY

Question to Investigate
Will carbon dioxide from carbonated water change the pH of an indicator solution?

Materials for Each Group

- Universal indicator solution in a plastic cup
- Water
- Carbonated water in a wide clear plastic cup
- 1 wide, clear, plastic cup
- 2 taller, clear, plastic cups
- Graduated cylinder
- Universal Indicator pH Color Chart

Procedure

1. Measure 30 mL of universal indicator solution and divide it evenly into two small clear plastic cups.
2. Add 25 mL of water to a wide plastic cup and 25 mL of carbonated water to another wide cup.
3. Stand the small cups with indicator solution in the liquid in the wider cups as shown.
4. Turn the two tall cups upside down and place them over the two wider cups.
5. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
6. Compare the color of the indicator to the pH Color Chart to find out whether the solution is acidic, neutral, or basic.

Describe the color of the indicator solution in each set of cups	
Carbonated Water	**Water**

3. What does the color of the indicator solution tell you about the pH of each solution? Is it acidic, neutral, or basic?

4. The carbonated water and water should not have splashed into the indicator solutions. Why did the indicator solution change color in one set of cups?

ACTIVITY

Question to Investigate
Will carbon dioxide gas produced in the baking soda and vinegar reaction change the pH of an indicator solution?

Materials for Each Group

- Universal indicator solution in cup
- pH color chart
- Water
- Baking soda in wide clear plastic cup
- Vinegar in cup
- 2 small, clear, plastic cups
- 1 wide, clear, plastic cups
- 2 taller, clear, plastic cups
- Graduated cylinder

Procedure

1. Measure 30 mL of universal indicator solution and pour it into a clean, small, plastic cup.
2. Pour half the indicator solution into another small cup so that you have two equal samples.
3. Pour the vinegar on top of the baking soda in one of the wide, clear, plastic cups. The other wide, clear, plastic cup should be empty.
4. Stand the small cups with indicator solution in both of the wider cups as shown.

5. Turn the two tall cups upside down and place them over the two wider cups.
6. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
7. Compare the color of the indicator to the pH Color Chart to find out whether the solution is acidic, neutral, or basic.

Describe the color of the indicator solution in each set of cups	
Reacting baking soda and vinegar	**Just Vinegar**

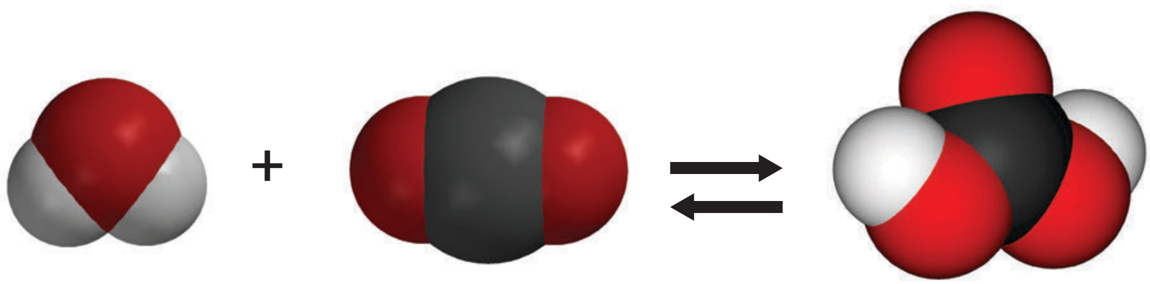
5. What does the color of the indicator solution tell you about the pH of each solution? Is it acidic, neutral, or basic?

6. Why did one set of cups only have vinegar in the bottom, while the other had vinegar and baking soda?

7. The baking soda and vinegar should not have splashed into their indicator solutions. Why did the indicator solution change color in one set of cups?

EXPLAIN IT WITH ATOMS & MOLECULES

8. Water and carbon dioxide gas react to produce carbonic acid. As more carbon dioxide is released into the atmosphere, why is that a problem for our oceans?



H_2O — water

CO_2 — carbon dioxide

H_2CO_3 — carbonic acid

TAKE IT FURTHER

Question to Investigate

How does the pH of the solution change during a chemical reaction between the ingredients in an Alka-Seltzer tablet in water?

Materials for Each Group

- Universal indicator solution in cup
- Water
- Alka-Seltzer tablet
- Graduated cylinder
- Snack-sized zip-closing plastic bag

Procedure

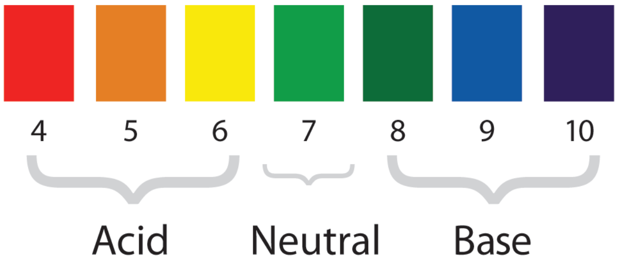
1. Add 20 mL of universal indicator solution to a snack-sized zip-closing plastic bag.
2. Seal the bag.

9. What do you think caused the bag to inflate?

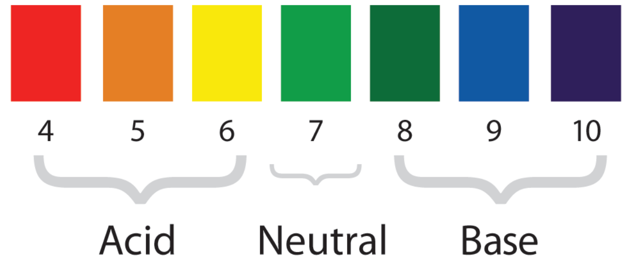
What do the color changes tell you about the pH of the indicator solution during the chemical reaction?	
Beginning	
Middle	
End	

10. Why do you think the indicator solution turned green at the end of the reaction?

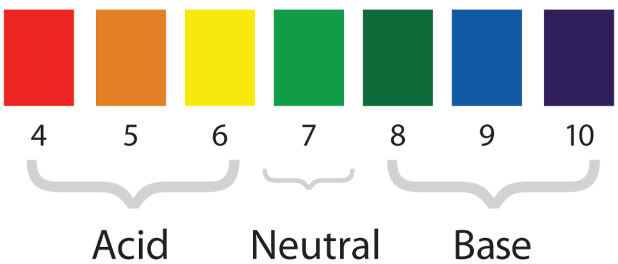
Universal Indicator pH Color Chart



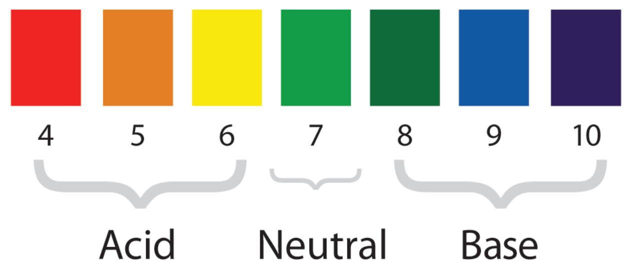
Universal Indicator pH Color Chart



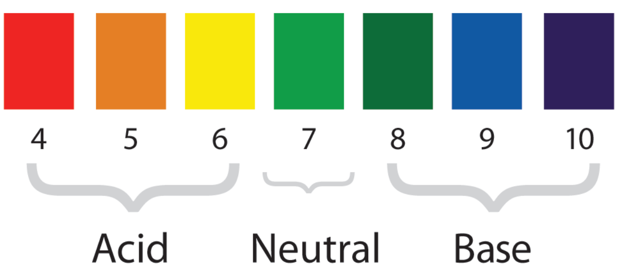
Universal Indicator pH Color Chart



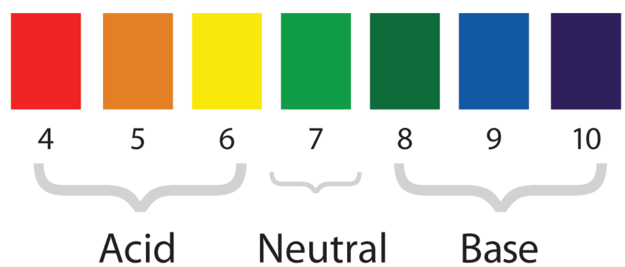
Universal Indicator pH Color Chart



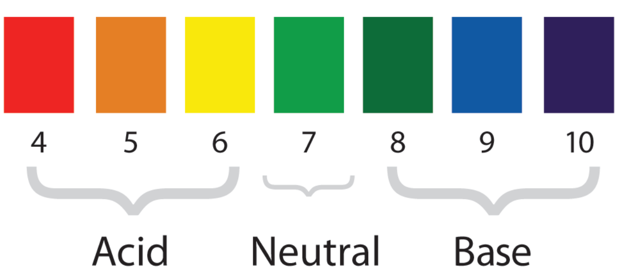
Universal Indicator pH Color Chart



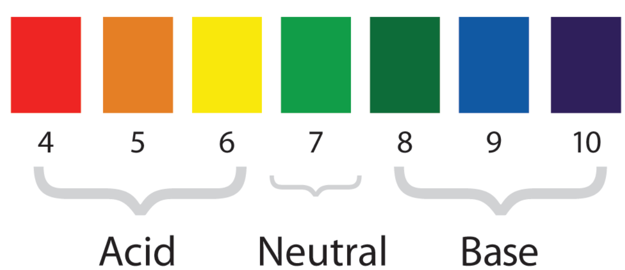
Universal Indicator pH Color Chart



Universal Indicator pH Color Chart



Universal Indicator pH Color Chart



Chapter 6, Lesson 11: Chemical Reactions & Engineering Design

NGSS Standard: MS-PS1-6

Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Introduction

In Chapter 5, students learned how the process of dissolving different substances can result in an increase or decrease in temperature. In Chapter 6, students saw that different chemical reactions can also be exothermic or endothermic. This engineering design lesson gives students an opportunity to apply these temperature-changing chemical processes to the problem of making a device to achieve and maintain a particular temperature range for a very specific purpose. This lesson is expected to take approximately two class periods plus additional time for students to imagine, draw, and describe their temporary portable reptile egg incubator.

Key Concepts

- The goal of engineering is to design an object or process to solve a problem.
- To design a solution to a problem, engineers need to define the features that will make the object or process successful (criteria) and those that may interfere with the success (constraints).
- Engineering involves designing and testing a model/prototype and modifying, improving, and optimizing the prototype based on testing.
- Designing a device that uses a chemical reaction to reach a certain temperature range requires testing, measuring, and refining the quantities of substances and modifying the materials for an optimal design.

Summary

This lesson begins with a story about rescuing reptile eggs from a new construction site. Using the story as motivation, students are presented with an engineering design challenge: Build a portable device which can warm, support, and protect one reptile egg as it is moved from a construction site to a nearby reptile conservation center. After observing different heat packs, students discuss the criteria and constraints related to designing a heat pack as the basis for their device. Students investigate calcium chloride as an exothermic dissolver, and then move on to calcium chloride and baking soda as the exothermic chemical reaction which will serve as the heat source for their device.

Students adjust the amounts of the reactants (water, calcium chloride and baking soda) to achieve the right temperature range and then test a prototype in a sealed zip-closing plastic bag. Students use their findings and ideas about insulation and heat transfer to draw an optimized design that 1) Keeps an egg at the ideal temperature, 2) Holds an egg in the proper orientation, and 3) Protects the egg from impact. Each student or student group draws this device and explains how the device meets each of the three criteria.

Engineering Design Process

This lesson follows the engineering design process described below.

Define the Problem

In the story, the eggs need to be moved while they are protected and kept at a specific temperature range. Students observe heat packs that use different chemical processes as possible heat sources for their device. As a class, students identify the features the device should have to be successful (criteria) as well as the factors that might limit or impede the development of a successful design (constraints).

Develop Possible Solutions

After determining the target temperature range, students use water and different amounts of calcium chloride and baking soda to achieve the right temperature and produce enough gas to support the egg and cushion against impact.

Optimize the Design

Students discuss and draw a model of their device and describe how certain features heat and support the egg. These features include the container, how the heat pack is incorporated to support the egg, and materials used to insulate the container.

Objective

Students will design, test, modify, and optimize a device that uses a chemical reaction to reach a specific temperature range for a portable reptile egg incubator.

Note: *Students will not be expected to build every element of the heat pack such as incorporating a pouch of water into the pack. Their main goal is to achieve the target temperature range and to design, on paper, the final device.*

Evaluation

The activity sheet will serve as the Evaluate component of this lesson. The activity sheets are formative assessments of student progress and understanding.

DEFINE THE PROBLEM

1. Help students identify the problem that their engineering design process will try to solve.

The following story is included on the Student Activity Sheet. This story introduces the design challenge and serves as motivation for the lesson. Either read it aloud or have students read it silently.

Imagine that you are a volunteer with a reptile conservation center. One important project is to rescue reptiles (turtles, snakes, and lizards) that are in the unlucky position of living in the path of new construction. Typically in these cases, animals move. They search for new homes and food sources nearby. However, eggs cannot crawl, slither, or swim to another location. And construction projects will not wait for eggs to hatch.

You have talked with construction workers at a site who agreed to notify you if they find reptile eggs. The center is able to incubate the eggs until the babies hatch and then return them to the wild. Your role is to design a reptile egg incubation device that keeps an egg warm and safe as it is transported from the worksite to the reptile conservation center.

Reptile eggs are leathery and soft. While they are not prone to crack easily, they need to remain in the same orientation they were originally laid—whatever is facing up, must stay facing up. They cannot be flipped, turned, or jostled. Very importantly, the eggs must be kept warm, but not too warm, to properly develop and hatch.

You have a job to do before the first batch of eggs is found—build a temporary portable reptile egg incubator device that will keep one egg warm and properly positioned while you take it to the reptile conservation center. Let's give these young lizards, turtles, and snakes their best chance at life!

Tell students that in this lesson, they will conduct activities to develop a portable reptile egg incubator device. The device will need to warm, support, and protect one egg.

2. Show the video of different heat packs to serve as a starting point for the design of a portable reptile egg incubator.

Tell students that there are a variety of heat packs that use different chemical processes to heat up. One of these processes could be used to begin development of their egg incubator device.

One type of heat pack contains a fine iron powder, salt, and water in a pouch that is permeable to air. When it is exposed to air, the iron begins to rust. This rusting process produces heat.

Another type of hand warmer contains a solution of the chemical sodium acetate and a small metal disc. When the disc is bent, crystals of sodium acetate begin to form. This process of changing from a liquid to a solid produces heat.

Another type of heat pack contains a solid, such as magnesium sulfate, and a pouch of water. When the pouch of water is broken, the magnesium sulfate begins to dissolve. Dissolving this type of magnesium sulfate produces heat.
Let students know that they will begin the development of their egg incubator device by using a dissolving process.

3. Discuss the criteria and constraints for a successful design.

Explain to students that the features the device must have are called the *criteria*.

Ask students

- **If you think about a heat pack as the basis for an egg incubator, what basic features does your device need to have?**
  - Small and light-weight
  - Uses small amounts of chemicals

- Gets to the right temperature and stays there long enough
- Can help support and protect the egg

Explain to students that possible problems that might prevent the design from successfully meeting all the criteria are called constraints.

Ask students

- **What are some factors that might prevent the design from successfully meeting all these criteria?**
  - The chemicals might not produce the right temperature
  - Might need a large amount of chemicals to make it work (too expensive and wasteful)
  - The temperature might not stay in the right range long enough

DEVELOP POSSIBLE SOLUTIONS

4. Continue the story about rescuing reptile eggs and determine the incubation temperature requirement.

The student activity sheet returns to the story about transporting reptile eggs from a construction site to a reptile conservation center. Have students look at the text message as well as the reptile egg identification page on their activity sheet to identify whether these eggs belong to a snake, turtle, or lizard. Each type of reptile egg has a different incubation temperature requirement.

Ask students

- **Do these eggs belong to a snake, turtle, or lizard?**
  Snake
- **How do you know?**
  Both lizard and snake eggs are laid on top of the ground, but snake eggs are larger.
- **What temperature range should you aim for when you develop your heat pack?**
  28-32 °C

5. Have students begin developing their device by dissolving different amounts of calcium chloride in water.

Ask students

- **Do you know of a chemical that gets hot when dissolved in water?**
  If students have done the activities in Chapter 5, they may remember that dissolving

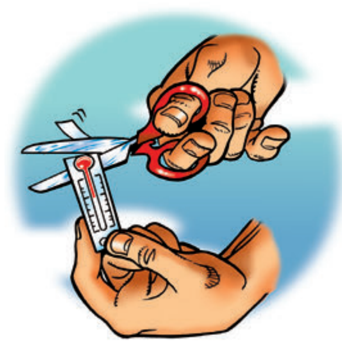
calcium chloride in water causes an increase in temperature.

- **How can you design a test to see if the amount of calcium chloride dissolved in water affects the temperature change?**
  Use the same amount of water but add different amounts of calcium chloride to see which causes the greater increase in temperature.

Question to investigate
Does the amount of calcium chloride dissolved in water affect the temperature change?

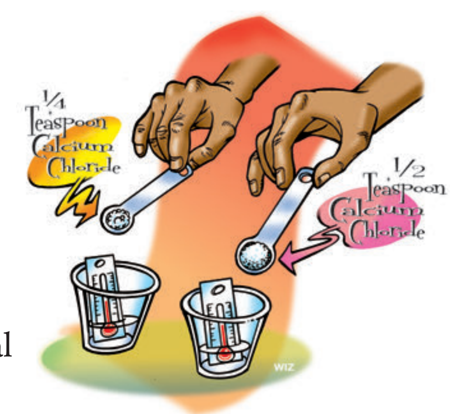
You will need

- Goggles
- 2 small thermometers
- Calcium chloride
- Baking soda (used in the second part of the procedure)
- Water
- 2 small clear plastic cups
- 1 graduated cylinder, medicine cup, or Tablespoon
- Measuring spoons (⅛ tsp., ¼ tsp. and ½ tsp.)

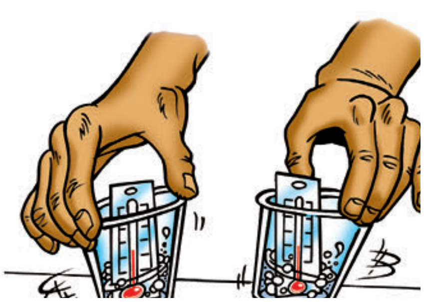


Note: *The bulb of each thermometer must be completely submerged in order to accurately measure the temperature of the liquid. If using thermometers with a thin plastic backing, use scissors to clip the bottom off so that the bottom of the bulb aligns with the bottom of the backing. This allows you to use less liquid which allows for more dramatic changes in temperature.*

Note: *Complete steps 5 and 6 as soon as possible after step 4.*



Procedure
Dissolve calcium chloride
1. Pour 15 mL of water into each of two small clear plastic cups.
2. Place a small thermometer in each cup and record the initial temperature.



3. With the help of a partner and at the same time, add ¼ tsp. of calcium chloride to one cup and ½ tsp. of calcium chloride to the other cup.
4. With the thermometers still in the cups, gently swirl both cups and check the temperature of both. Record the highest final temperature each reaches in the chart on the student activity sheet.

Expected results

The solution with more calcium chloride increases to a higher temperature.

Note: *Complete steps 5 and 6, found on the next page, as soon as possible after step 4. If students have worked with calcium chloride and baking soda before, ask the following questions before continuing the procedure.*

Ask students

- **Calcium chloride seems like it might be a good chemical for the heating part of the heat pack design, but what about the need to cushion and protect the egg? Is there something we could do to make the heat pack puffy?**
  Yes. Another substance could be added so the reaction also produces a gas. Production of the right amount of gas could make the heat pack into a little pillow which could cushion and protect the egg. But if too much gas is produced, the pack could pop or be too big to work well.
- **What do you think you could add to the calcium chloride solution to produce a gas?**
  Baking soda. In Chapter 6, Lesson 7, students added calcium chloride to a baking soda solution and saw it bubble. They could reasonably think that adding baking soda to a calcium chloride solution will do the same thing.

Add baking soda

5. Add about ⅛ teaspoon of baking soda to the solution that reached the highest temperature. Watch the solution and the thermometer.

6. With the thermometer still in the cup, gently swirl and check the temperature. Record the lowest final temperature reached.

Expected results

The solution bubbles and the temperature decreases.

Ask students

- **Since adding baking soda makes the temperature go down, does this mean that it should not be used in the design of the device?**
  Not necessarily. Maybe it can be used so that gas is produced but with enough calcium chloride to make the temperature high enough. There would need to be some kind of balance between the amount of calcium chloride and baking soda so that the right temperature is reached and enough gas is produced to hold the egg in position and protect the egg.

Give students time to complete this page of their student activity sheet.

This may be a good stopping point for the first portion of this lesson.

6. Have students test a combination of calcium chloride, baking soda, and water.

Tell students that they will combine calcium chloride, baking soda and water to try to get within the right range for snake eggs. First they will mix the calcium chloride and baking soda together and then add this mixture to water.

Ask students

- **If the temperature is too high what can you do? What if it is too low?**
  If the temperature is too high, either decrease the amount of calcium chloride, add more baking soda, or a combination of both. If the temperature is too low, either increase the amount of calcium chloride, add less baking soda, or a combination of both.

Question to investigate

About how much calcium chloride, baking soda, and water should be mixed to reach the right temperature to incubate snake eggs?

You will need

- Calcium chloride
- Baking soda
- Measuring spoons (⅛ tsp. and ½ tsp.)
- 2 small clear plastic cups
- Water
- Thermometer

Procedure

1. Place ½ tsp. of calcium chloride in a cup.
2. To the same cup, add ⅛ tsp. of baking soda.
3. Swirl the cup to mix these dry ingredients as well as you can.
4. In a separate cup, add 15 milliliters of water, place a thermometer in the cup, and record the temperature.
5. With the thermometer in the cup, add all of the calcium chloride and baking soda mixture and gently swirl to mix.
6. Record the final temperature in the chart on the student activity sheet.
7. Adjust the amount of calcium chloride and/or baking soda and try the reaction two more times to achieve the target temperature.

Expected results
There should be bubbling as the gas is produced. The temperature should increase and students should be able to get within the target range of 28-32 °C.

Ask students

- **About how much calcium chloride, baking soda, and water should be mixed to reach the right temperature range to incubate snake eggs?**
  Results will vary depending on the particular calcium chloride and baking soda you are using, accuracy of measuring tools and student measuring technique.

7. Have students conduct their chemical reaction in a sealed bag as a prototype heat pack.

Remind students that their challenge is to make a heat pack to warm and safely transport snake eggs. Explain that next they will conduct the chemical reaction in a sealed bag to see if the temperature and amount of gas produced will do the job. Would the chemical reaction you tested in this lesson work if it were sealed in a plastic bag? Sealing the chemicals in a plastic bag would mean that you would be able to bring just the portable reptile egg incubator with you rather than carry all the supplies needed for each of your tests. In this activity, students combine calcium chloride and baking soda in a zip-closing plastic bag to see if this design will keep reptile eggs warm.

Question to investigate
Does enough heat transfer through the bag to reach the right temperature range?

You will need

- Calcium chloride
- Baking soda
- Measuring spoons (⅛ tsp. and ½ tsp.)
- Graduated cylinder
- 2 small clear plastic cups
- Small zip-closing plastic bag
- Water
- Thermometer

Note: *The bag will not inflate fully. By only partially inflating, the bag will serve as a better cushion and support for the egg.*

Procedure
Combine chemicals in a cup

1. Place the amount of calcium chloride and baking soda, which

resulted in the best temperature from the previous procedure, in a cup.

2. Swirl the cup to mix these two dry ingredients.

Prepare the bag

3. Pour the combined powders into one corner of a small zip-closing plastic bag. Tilt the bag so that all the calcium chloride and baking soda stays in one corner.
4. Use your fingers to seal off that part of the bag.
5. Have your partner pour 15 milliliters water into the other corner of the bag so that the water does not touch the dry powders.
6. While keeping the water and powders separated, try to get the air out of the bag as you close it and make sure that it is tightly sealed.

Start the chemical reaction

7. Let go of the corner and tilt the bag so that the water and the powders mix and react.
8. Position a thermometer under the bag so that the bulb is beneath the solution where the chemical reaction is taking place. Be sure you can read the temperature without having to remove the thermometer. Record the highest temperature reached in the chart on the activity sheet.

Expected results

There should be bubbling as the gas is produced and the bag inflates a bit. The bag should feel warm on the surface where the reaction is taking place and should get up to about 28-32 °C. If the outside of the bag does not get hot enough, students can do the reaction again with more calcium chloride.

Ask students

- **Since the plastic bag will be part of the portable egg incubator, enough heat needs to transfer through the bag to the egg. Does enough heat transfer through the bag to warm a snake egg enough?**

Yes.

- **The bag inflates slightly. How could this feature be useful in the design of the portable egg incubator?**
If we place the bag under, around, or on top of the egg, it may be able to hold the egg in place so that it is not flipped, turned, or jostled when it is being transported.

OPTIMIZE THE DESIGN

8. Discuss features of a portable snake egg incubator that could maintain the temperature for as long as possible and keep eggs properly positioned.

The lesson, so far, has focused on a chemical reaction which would reach a temperature to keep one snake egg warm, but not too warm. Students will need to think of a way or ways they could keep the heat generated in the chemical reaction around the egg during the time it is transported. Once the chemical reaction is over, it will no longer generate heat. So students will need to consider using some sort of insulation in their device. Because reptile eggs must remain in the position they are found, the device should ensure that the egg is not turned or jostled too much. Perhaps the partially inflated bag students experimented with could be used to hold the eggs in position. Help students think about how they might build their snake egg protection device.

Ask students

- **How will you incorporate the partially inflated bag so that the egg is supported?**
The bag could be placed in a paper, plastic, or Styrofoam cup so that the bottom of the bag would be insulated and the egg could be placed on top of the bag in the cup.
- **What are some ways you could keep the egg and the inflated bag warm for as long as possible?**
The container that the bag and egg are placed in will insulate to a certain extent. Perhaps torn paper, paper towels, or a lid could keep the egg warm for a longer time.

Have each student or group design a model snake egg protection device. Students will draw their device and answer the following questions:

- How does your device keep an egg at the ideal temperature for as long as possible?
- How does your device hold an egg in the proper orientation?
- How does your device protect an egg from impact?

The story below concludes the lesson. Students will find the same story on the last page of their student activity sheet.

Reptiles rescued!
Congratulations, your device works! It was used to take the snake eggs from the construction site safely to the reptile conservation center. The eggs were carefully placed in incubators and both the temperature and humidity were ideal for the growth of healthy snakes.

Because most reptiles are able to feed and take care of themselves as soon as they hatch, the baby snakes will be taken to a new location and released into the wild. There they will make their new home as they strive to survive and thrive.

Name ______________________

Date ______________________

DEFINE THE PROBLEM

Imagine that you volunteered to rescue reptiles (turtles, snakes, and lizards) that are in the unlucky position of living in the path of new construction. Typically in these cases, animals move. They search for new homes and food sources nearby. However, eggs cannot crawl, slither, or swim to another location. And construction projects will not wait for eggs to hatch.

You have talked with the construction workers and with a nearby reptile conservation center. The workers are willing to notify you when they come across reptile eggs. The center is able to incubate the eggs until the babies hatch and then return them to the wild. Your role is to design a reptile egg incubation device that keeps an egg warm and safe as it is transported from the worksite to the reptile conservation center.

Reptile eggs are leathery and soft. While they are not prone to crack easily, they need to remain in the same orientation they were originally laid—whatever is facing up, must stay facing up. They cannot be flipped, turned, or jostled. Very importantly, the eggs must be kept warm, but not too warm, to properly develop and hatch.

You have a job to do before the first batch of eggs is found—build a temporary portable reptile egg incubator device that will keep one egg warm and properly positioned while you take it to the reptile conservation center. Let's give these young lizards, turtles, and snakes their best chance at life!

1. Inspiration for an invention can come from just about anywhere. Sometimes it can come from products that already exist.

What features of the three hot packs shown in the video keep them from getting hot before you want them to?

2. The features that the device must have are called the *criteria*. As you begin to think about a temporary portable reptile egg incubator, what features might be useful to borrow from the design of the hot packs?

3. Possible problems that might prevent the design from successfully meeting all the criteria are called *constraints*. What are possible constraints, or challenges, which would prevent you from getting the features you listed above?

DEVELOP POSSIBLE SOLUTIONS

Think back to the story about transporting reptile eggs from a construction site to a reptile conservation center. Read the text message from one of the construction workers in the illustration to the left.

4. Take a look at the Reptile Egg Identification chart on the next page to answer the following questions:

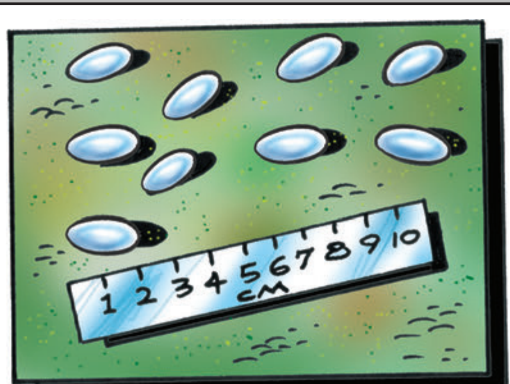
a. Do these eggs belong to a snake, turtle, or lizard?

b. What characteristics helped you identify these eggs?

c. As you design your temporary portable reptile egg incubator, you will need to consider the ideal temperature the reptile eggs need. What temperature range should you aim for when you mix calcium chloride, baking soda, and water?

Reptile Egg Identification Chart

Reptile eggs have a leathery shell and are found on or just under the ground. Care must be used when handling them, because they can be quite fragile. Also, the eggs should never be turned over: Whichever part is facing up must always face up until the reptile has hatched. Turning the eggs over could harm the developing embryo!

<table>
<tr><td colspan="3">Snake</td></tr>
<tr><td rowspan="2">
</td><td>Location
Snake eggs are found in a hidden location on top of soil, dried leaves, or mulch.</td><td>Length
4-10 cm</td></tr>
<tr><td>Shape
Snake eggs are oblong and irregularly shaped.</td><td>Incubation temperature
28-32°C</td></tr>
<tr><td colspan="3">Turtle</td></tr>
<tr><td rowspan="2">
</td><td>Location
Turtle eggs are buried in loose soil. A spoon and paint brush can be used to carefully remove these.</td><td>Length
2-5 cm</td></tr>
<tr><td>Shape
Turtle eggs are about the size and shape of ping pong balls.</td><td>Incubation temperature
24-28°C</td></tr>
<tr><td colspan="3">Lizard</td></tr>
<tr><td rowspan="2">
</td><td>Location
Lizard eggs are laid on soil, mulch, or dried leaves.</td><td>Length
1-3 cm</td></tr>
<tr><td>Shape
Lizard eggs are oblong and irregularly shaped.</td><td>Incubation temperature
26-30°C</td></tr>
</table>

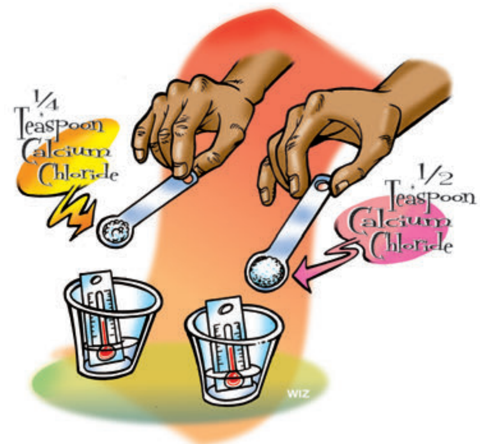
Question to investigate

Does the amount of calcium chloride dissolved in water affect the temperature change?

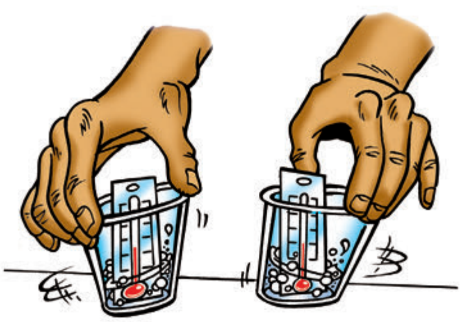
You will need

- Goggles
- 2 small thermometers
- Calcium chloride
- Baking soda
- Water
- 2 small clear plastic cups
- 1 graduated cylinder
- Measuring spoons (⅛ tsp., ¼ tsp., and ½ tsp.)

Procedure



1. Pour 15 mL of water into each of two small clear plastic cups.
2. Place a small thermometer in each cup and record the initial temperature in the chart below.
3. With the help of a partner and at the same time, add ¼ tsp. calcium chloride to one cup and ½ tsp. of calcium chloride to the other cup.



4. With the thermometers still in the cups, gently swirl both cups and check the temperature of both. Record the highest final temperature each reaches.

How much does the temperature increase?		
	¼ tsp. calcium chloride	½ tsp. calcium chloride
Initial temperature Just water	°C	°C
Final temperature Water plus calcium chloride	°C	°C
Change in temperature Final temp.– Initial temp.	°C	°C

Procedure, continued

5. Add about ⅛ teaspoon of baking soda to the solution that reached the highest temperature. Watch the solution and the thermometer.

6. With the thermometer still in the cup, gently swirl and check the temperature. Record the lowest final temperature reached.

How does baking soda affect the temperature of the calcium chloride solution?	
Temperature of the calcium chloride solution from Step 4	°C
Calcium chloride solution plus ⅛ teaspoon baking soda	°C
Change in temperature	°C

Should we use baking soda in the design of a portable reptile egg incubator?	
Disadvantages	Advantages

Question to investigate

About how much calcium chloride, baking soda, and water should be mixed to reach the right temperature range to incubate snake eggs?

You will need

- Calcium chloride
- Baking soda
- Measuring spoons (⅛ tsp., ¼ tsp., and ½ tsp.)
- 2 small clear plastic cups
- Water
- Thermometer

Procedure

1. Place ½ tsp. of calcium chloride in a cup.
2. To the same cup, add ⅛ tsp. of baking soda.
3. Swirl the cup to mix these dry ingredients.
4. In a separate cup, add 15 milliliters of water, place a thermometer in the cup, and record the temperature.

5. With the thermometer in the cup, add all of the mixture of calcium chloride and baking soda and gently swirl to mix.
6. Record the final temperature.
7. Adjust the amount of calcium chloride or baking soda and try the reaction two more times to achieve the target temperature.

About how much calcium chloride, baking soda, and water should be mixed to reach the right temperature range to incubate snake eggs?			
Calcium chloride	½ tsp.		
Baking soda	⅛ tsp.		
Water	15 mL	15 mL	15 mL
Initial temperature Just water	°C	°C	°C
Final temperature Highest temperature reached	°C	°C	°C

DEVELOP POSSIBLE SOLUTIONS

Would the chemical reaction you tested in this lesson work if it were sealed in a plastic bag? Sealing the chemicals in a plastic bag would mean that you would be able to bring just the portable reptile egg incubator with you rather than carry all the supplies needed for each of your tests. In this lesson, you will combine calcium chloride and baking soda in a zip-closing plastic bag to see if this design will keep reptile eggs warm enough.

Question to investigate

Does enough heat transfer through the plastic bag to reach the right temperature range?

You will need

- Calcium chloride
- Baking soda
- Measuring spoons (⅛ tsp., ¼ tsp., and ½ tsp.)
- Graduated cylinder
- 2 small clear plastic cups
- Small zip-closing plastic bag
- Water
- Thermometer

Procedure

Combine chemicals in a cup

1. Place the amount of calcium chloride and baking soda, which resulted in the best temperature in the previous procedure, in a cup.
2. Swirl the cup to mix these dry ingredients as well as you can.

Prepare the bag

3. Pour the combined powders into one corner of a small zip-closing plastic bag. Tilt the bag so that all the calcium chloride and baking soda stays in one corner.

4. Use your fingers to seal off that part of the bag.
5. Have your partner pour 15 milliliters water into the

other corner of the bag so that the water does not touch the dry powders.

6. While keeping the water and powders separated, try to get the air out of the bag as you close it and make sure that it is tightly sealed.

Start the chemical reaction

7. Let go of the corner and tilt the bag so that the water and the powders mix and react.
8. Position a thermometer under the bag so that the bulb is beneath the solution where the chemical reaction is taking place. Be sure you can read the temperature without having to remove the thermometer. Record the highest temperature reached.

What temperature does the thermometer reach when it is placed beneath the solution where the chemical reaction is taking place?	
Final temperature Highest temperature reached	°C

5. Since the plastic bag will be part of the portable egg incubator, enough heat needs to transfer through the bag to the egg. Does enough heat transfer through the bag to warm a snake egg enough?

6. The bag inflates slightly. How could this feature be useful in the design of the portable snake egg incubator?

OPTIMIZE THE DESIGN

7. Draw your design for a temporary portable snake egg incubator in the large space below. In your drawing use captions to point out how your device meets the following requirements:

    - Keep the egg at the ideal temperature for as long as possible
    - Hold the egg in the proper orientation
    - Protect the egg from impact

Reptiles rescued!

Congratulations, your device works! It was used to take the snake eggs from the construction site safely to the reptile conservation center. The eggs were carefully placed in incubators and both the temperature and humidity were ideal for the growth of healthy snakes.

Because most reptiles are able to feed and take care of themselves as soon as they hatch, the baby snakes will be taken to a new location and released into the wild. There they will make their new home as they strive to survive and thrive.

Chapter 6, Lesson 12 - Natural Resources & Synthetic Materials

NGSS Standard: MS-PS1-3

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Key Concepts

- Synthetic materials are made from natural resources.
- Synthetic materials are made by chemically changing the starting substances to create a material with different characteristics.
- Some examples of synthetic materials are plastics, medicines, and new fuels.
- A synthetic substance may be chemically identical to a naturally-occurring substance or may be different.
- Making and using synthetic materials have both positive and negative impacts on society.

Summary

The teacher models and describes the kinds of information students will be looking for in their research project on a synthetic product. This is done by using an example of a synthetic product that students make in the classroom: a gel worm (not for eating.) Students make it by combining a sodium alginate solution with a calcium chloride solution. The teacher uses this product to model answers to the three questions students need to answer in their research:

1. What natural resources are used to make the synthetic product?
2. What chemical processes are used to make the synthetic product?
3. What are the negative and positive impacts to society of making and using the synthetic product, compared to making and using a more natural product with a similar function?

Students choose or are assigned a synthetic product to research. They use library and internet resources to investigate the product to answer the three questions. Students apply their learning to make an advertisement, poster, short video, or article about their synthetic product.

Objective

Students will be able to find and analyze information to describe that chemical processes are used to convert natural resources into synthetic materials and products. They will also be able to give examples of how the production of synthetic products has impacts, both positive and negative, for society.

Evaluation

The activity sheet will serve as the "Evaluate" component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. Download the student activity sheet, and distribute one per student when specified in the activity.

Safety

Be sure you and the students wear properly fitting goggles during the activity and wash hands afterwards. Students should not eat anything in the laboratory, despite the reactants being common food additives.

Materials for each group

- Calcium chloride solution in a small cup
- Sodium alginate solution in a small wide cup
- Plastic droppers
- Paper towels
- Food coloring (optional)

Notes about the materials

For this lesson, you will need sodium alginate and calcium chloride. While these are both used in a variety of prepared foods, students should not consume the solutions or the gummy worm which is synthesized in the activity. Flinn Scientific sells calcium chloride, anyhdrous, product #C0016 and sodium alginate, product S0445.

Make sure the small wide plastic cups are wide yet short enough for students to "pinch" with their index finger and thumb all the way down to the bottom of the cup. This is how students will extract the gel worm. Portion cups will work well for this purpose.

ENGAGE

1. Have a class discussion to introduce the terms "synthetic" and "natural."

Explain that in science a "synthetic" material is one in which the starting substances are changed chemically to produce a material with different characteristics. A common example is plastic. To make it, petroleum is processed and chemically changed to eventually become plastic. The series of chemical reactions that are used to change natural resources into synthetic products is called chemical synthesis.

To make a "natural" product, the natural resource is not chemically changed as much. One example is a wooden chair. It is more natural than synthetic, because its shape has been changed, but the material is still wood. Glass is a little harder to classify, but could be considered a natural material. It comes from sand, which has been melted and then cooled. The molecules which make up the glass are still the same as they were in sand.

Tell students that all products are made from natural resources. "Natural" products are made from natural resources, like wood and sand. "Synthetic" products are also made from natural resources. For example, the synthetic material plastic is made from petroleum, which is pumped out of the earth. Petroleum is a natural resource.

Ask students

- **Both natural and synthetic products come from natural resources. Explain why this statement is true.**
  If you trace what something is made of far back enough, you will find that all of the substances used to make that product come from our world. They may originally come from plants, animals, or the earth.
- **How can you tell when something should be classified as synthetic?**
  Both synthetic and natural products are made from natural resources that can be changed by people from the form they were in when found in nature. But synthetic products are processed and changed *chemically* by people to produce a new substance with different characteristics.

Note: The meaning of "synthesis" in "photosynthesis"

Students may be familiar with the term synthesis from the word photosynthesis. You may have broken the word up into photo and synthesis to explain the process by which plants use energy from the sun to synthesize sugar from carbon dioxide and water. Used in this way, synthesis is a natural process that happens in green plants and other organisms with chlorophyll. But, for the purpose of this lesson, the term synthesis and synthetic material is used to mean that humans use chemical processes to create or synthesize a new material.

Introduce the idea that scientists may synthesize a compound that can also be found in nature.
Show the Professor Dave video, Will Synthetic Vitamins Make Me Explode? https://www.youtube.com/watch?v=wioqhkDpI_I.

Ask students:

- **Is the Vitamin D that our skin makes when exposed to the sun's rays natural or synthetic?**
  When we are out in the sun and our bodies make Vitamin D, the vitamin is considered to be natural. But the exact same compound made in factories that you can purchase as a vitamin pill is considered to be synthetic.
- **Why might it be useful for scientists to synthesize a compound that can be found in nature?**
  If there is some reason you cannot get the compound from a natural source, it may be helpful to use a synthetic, yet identical, version. If harvesting the item from nature is too expensive or over-harvesting could damage the environment or destroy habitat, it might be better to synthesize the compound.

Explain to students that even though Vitamin D can be found in nature, the fact that scientists create it through chemical processes makes it synthetic. So it is possible to make a synthetic substance that is identical to one found in nature. This idea is especially important for students who will work on the topic of synthetic medicines for the research portion of this lesson.

EXPLORE

2. Introduce the research project that students will do and assign or have students select a synthetic product to explore.

Explain to students that they will do a research project to learn about a synthetic product. They will read various online articles, watch informational videos, and use library resources. Students will try to find answers to the following three guiding questions:

1. What natural resources are used to make the synthetic product?
2. What chemical processes are used to make the synthetic product?
3. What are the negative and positive impacts to society of making and using the synthetic product, compared to making and using a more natural product with a similar function?

Either assign or have students select the synthetic product they will research and report on from the list below. Decide whether or not you will have students work in groups or individually.

Synthetic Products

- Plastic bag
- Plastic bottle
- Disposable diaper
- Synthetic fiber/cloth (polyester, nylon, or rayon)
- Kevlar
- Artificial sweetener
- Synthetic fuel (Synfuel)
- Synthetic rubber
- Chloroquine (Malaria drug)
- Taxol(Cancer drug)
- Physostigmine(Glaucoma drug)
- Aspirin

Note: *Links have been provided to online resources for each synthetic product. This list is provided at the end of this lesson. You may choose to give one or more of these links to students as a way to help start* *their research. Students may also use other resources, online or not, that they find. If you have students use resources they find on their own, remind them to consider the author and author's purpose in provided the information.*

3. Explain that the in-class lesson will model the research students will conduct on a synthetic product.

Tell students that before having them begin their research project, they will learn about and make their own synthetic product—a gel worm. Explain that if this was a real gel worm for eating, sweeteners, vitamins, and fruit flavoring would be added. However, the purpose of this lesson is to learn about chemical synthesis so students will focus on the chemicals which are involved in the chemical reaction, rather than the flavoring. Also, since this is a science lab, students should not taste or eat the gel worm.

Explain that you will provide information about the synthetic gel worm organized around the three guiding questions. The types of information you provide in class will serve as a model of what students will look for when researching their synthetic product.

Remind students that the questions are:

1. **What natural resources are used to make the synthetic product?**
2. **What chemical processes are used to make the synthetic product?**
3. **What are some negative and positive impacts to society of making and using the synthetic product, compared to making and using a more natural product with a similar function?**

4. Introduce the substances used to make the gel worm and explain that they come from natural resources.

Question 1: What natural resources are used to make the synthetic product?

Tell students that they will combine two solutions in a particular way to make a single gel worm. The ingredients in the solution which react chemically are sodium alginate and calcium chloride. Both of these are commonly used in food to improve its texture.

Sodium alginate

Show illustration Brown Seaweed

What natural resource does sodium alginate come from?

Sodium alginate is made from a type of brown seaweed called kelp which grows wild in the ocean. It is harvested and processed to make sodium alginate.

What is done to the seaweed to get the sodium alginate?
The seaweed is cut up and mixed with water to make a thick gel. Then it is diluted with more water and filtered. The mixture is evaporated and further processed to make sodium alginate powder.

Calcium chloride

Show illustration Limestone
What natural resource does calcium chloride come from?
Calcium chloride is made from limestone which is a common rock that is mined.

What is done to the limestone to make calcium chloride?
The limestone is reacted with hydrochloric acid or sodium chloride to make the calcium chloride.

5. **Have students make a synthetic gel worm by mixing solutions of sodium alginate and calcium chloride.**

Give each student a student activity sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The Explain It with Atoms & Molecules and Take It Further sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. Look at the teacher version of the activity sheet to find the answers.

Question 2: What chemical processes are used to make the synthetic product?

As a class, students will conduct the following hands-on activity to answer the question about chemical synthesis. When researching their synthetic product, students will not conduct a chemical synthesis. Instead they should find out generally how the product is made. The purpose of the gel worm activity is to give students an example of chemical synthesis.

Note: *Remind students that they cannot taste or eat the synthetic gel worm. Be sure students wash their hands after conducting this activity.*

Question to Investigate
Why is a gel worm made from calcium chloride and sodium alginate solutions considered a synthetic product?

Materials for each group

- Calcium chloride solution in a small cup
- Sodium alginate solution in a small wide cup
- One dropper
- Paper towels

Teacher preparation for all groups

1. Place ½ teaspoon calcium chloride in a cup. Add 25 mL of water and stir until the calcium chloride dissolves. Place about ½ teaspoon of calcium chloride solution into a small cup for each group.
2. Place ¼ teaspoon sodium alginate powder in a plastic bottle. An empty disposable 8-oz plastic water bottle with a tight-fitting cap will work well.
3. Carefully add 50 mL water to the bottle containing sodium alginate. Cap the bottle tightly and shake vigorously for about 30 seconds.
4. Add another 50 mL of water to the bottle containing the sodium alginate solution. Optional: Add one drop of food coloring. Cap the bottle tightly and shake again.
5. Pour one tablespoon (15 mL) of sodium alginate solution from the bottle into a portion cup or wide plastic cup for each group.

Procedure for students

1. Using a plastic dropper, add about 10 drops of calcium chloride solution to the center of the cup containing the sodium alginate solution.

2. Reach into the center of the solution(where you put the calcium chloride) and gently and slowly pull out the gel "worm."
3. Place the "worm" on a paper towel.

Expected Results

Students will be able to pull a long gelatinous string (worm) or blob from the cup.

Note: *Remind students not to taste or eat the gel worm. Tell students that they have made a synthetic gel worm but that actual gel worms are manufactured using a different process and different ingredients.*

Ask students

- **What were the calcium chloride and sodium alginate solutions like when your teacher first gave them to you?**
  The calcium chloride solution was clear and colorless. It looked pretty much like water. The sodium alginate solution was also clear and colorless but it seemed thicker.

- **After you added the calcium chloride solution to the sodium alginate solution and began pulling from the center, how did the solutions change?**
  Instead of flowing like a liquid, the chemical reaction made it come out of the cup like a gel.
- **Would you consider the gel worm to be a synthetic product? Why or why not?**
  The gel worm is a synthetic product because it was changed chemically and now has very different properties than the sodium alginate and calcium chloride solutions that were used to make it.

Clean-up
At the end of the lesson, have students pour their calcium chloride solutions down the drain with plenty of water or according to local regulations. Any extra sodium alginate solution and gel worms should be disposed of with the classroom trash. Have students wash their hands after cleaning up.

EXPLAIN

6. Explain the chemical process of crosslinking which is used to make the synthetic gel worm.

Question 2 Continued: What chemical processes are used to make the synthetic product?

Tell students that in their research, they should look for the following clues about the chemical process(es) used to make their synthetic product:

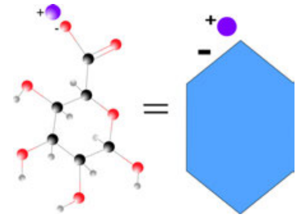
- Can you identify one or more molecules involved in making the product?
- Do one or more chemical reactions take place?
- Are substances heated?
- Are substances put under pressure?
- Is special machinery used?
- Has the method changed over the years?

Explain that you will continue to use the gel worm as an example to guide the class about the kinds of information they should look for to answer the second question when researching their own synthetic product.

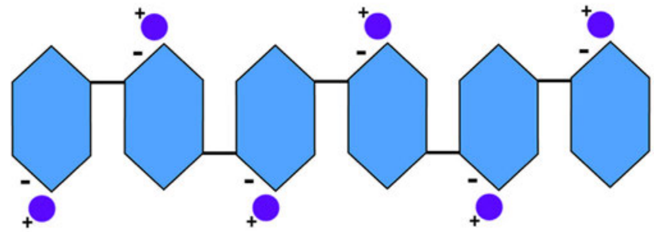
This explanation addresses the following:

- Can you identify one or more molecules involved in making the product?
- Do one or more chemical reactions take place?

Project the illustration Sodium alginate polymer.

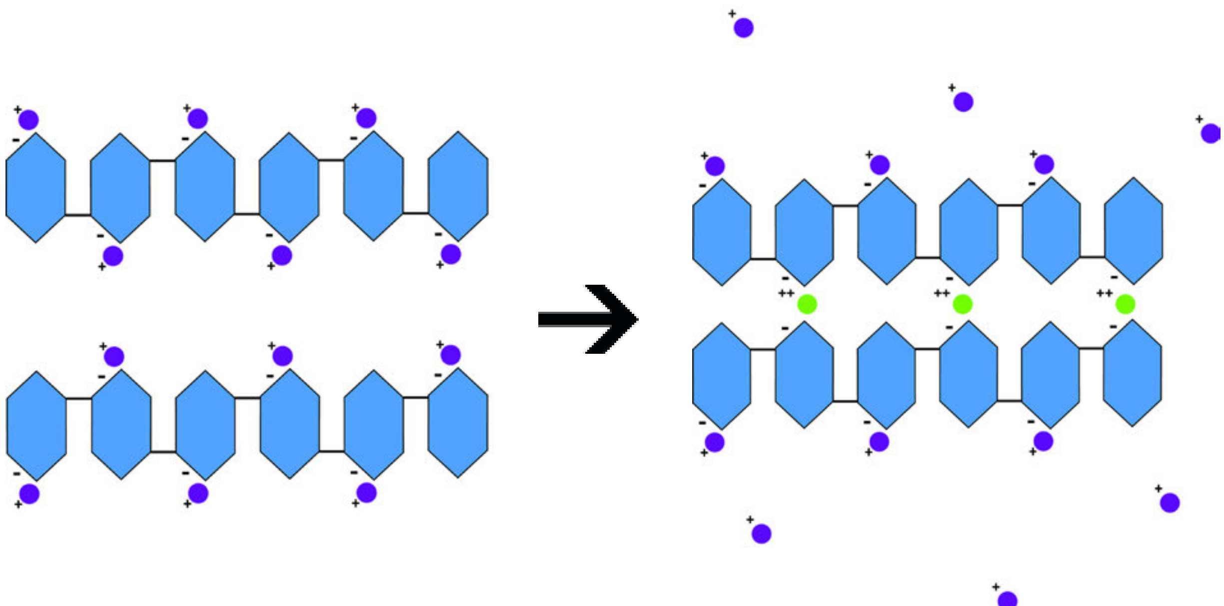


Here are two models of a sodium alginate molecule. One is a ball-and-stick model showing all the atoms: 6 carbon atoms (black), 7 oxygen atoms (red), and 9 hydrogen atoms (white) and 1 positive sodium ion (purple). The other is a much simpler model using a hexagon shape for almost the whole molecule and a little circle for the positive sodium ion. Notice that on both models the sodium ion has a positive charge and the place where it's bonded to the molecule has a negative charge. Many sodium alginate molecules are bonded together to make a long molecule called a polymer. Point out to students that each molecule is upside down compared to the one next to it.



Project the illustration Crosslinking sodium alginate.

To see what happens when calcium chloride is added, we need to use at least two sodium alginate polymer chains.



Two sodium alginate polymer chains

After adding calcium chloride

When the sodium alginate solution and the calcium chloride solution are mixed, the positive calcium ions replace the positive sodium ions. Since the calcium ions have two positive charges, the calcium ions bond with the negative area on two sodium alginate molecules and create a "crosslink" between the two chains. Many crosslinking chemical reactions cause the sodium alginate to thicken and become a gel.

Explain that since the final product is chemically different from the starting substances, a chemical synthesis occurred and the gel worm is a synthetic material.

Let students know that they may not be able to find this level of detail about the chemical process used to make their synthetic product. However, they should try to find something about the molecules or the characteristics of the materials before and after the process that synthesizes their product.

7. Explain the impacts to society of making and using the synthetic product compared to making and using a more natural product with a similar function.

Question 3: What are some negative and positive impacts to society of making and using the synthetic product compared to making and using a more natural product with a similar function?

Have students imagine that the gel worms could be mass-produced with fruit flavoring, vitamins, and minerals to make a synthetic fruit snack. Explain that you will use the idea of a mass-produced gel worm as an example to guide the class about the kinds of information they should look for when researching the impacts of their synthetic product.

Tell students that in their research, they should look for the following kinds of environmental, social, and economic impacts that result from producing and using their synthetic product. They should also compare these impacts to the impacts of producing and using a less synthetic/more natural alternative with a similar function. Students should consider these questions:

- Are the natural resources used renewable or nonrenewable?
- What are the negative impacts of:
  - Harvesting, mining, or collecting the natural resources?
  - Processing the natural resources before using them to make the final product?
  - Producing the final product?
- What are the positive impacts to society of using the final product?

Renewable and Nonrenewable Natural Resources Used to Make Each Snack			
	Main ingredient(s)	**Natural resources used to make each**	**Renewable? Why or why not?**
Gel worm	Sodium alginate	Brown Seaweed	Renewable, because seaweed reproduces within a few years.
	Calcium chloride	Limestone	Not renewable, because limestone is a rock that took millions of years to form.
Fresh fruit slices	Fruit	Fruit tree, water, and soil nutrients	Renewable, because new trees can be planted, rain provides water, and good farming practices can replenish soil nutrients.

Consider the impacts of producing the synthetic gel worm snack compared to producing pieces of real fruit

Renewable or Nonrenewable?

Both sodium alginate and calcium chloride are natural resources. When considering our resources, it's important to consider whether these are renewable or non-renewable resources. If students are not familiar with these terms, introduce them now. Explain that renewable resources are replenished through natural processes in enough time to meet the need. For example, trees are renewable resources, but petroleum is not. Usually using renewable resources has less negative impact because the resource can be replenished.

Impacts from making synthetic gel worm snack

- **Sodium alginate**
  Brown seaweed is harvested from the ocean in the wild. It is home and food for ocean creatures. Harvesting brown seaweed from the ocean could affect other organisms in the ecosystem. Processing seaweed into sodium alginate takes energy and produces waste which has to be controlled.
- **Calcium chloride**
  Have to mine limestone. This takes equipment which uses energy and pollutes.
- Processing limestone to make calcium chloride produces waste which has to be controlled.
- **Producing the gel worms**
  Mass-production of the gel worms in a factory takes equipment and uses energy.
- **Positive impacts**
  People (kids mostly) like eating them.

Impacts from making real fruit slices

- **Grow and maintain the fruit trees**
  Prepare the land using large equipment. This uses energy and adds to pollution. Fertilize and water the trees. Some fertilizers can be pollutants if they get into lakes and rivers. In some areas, water may be less available than in others. Use of pesticides can be a possible pollutant.
- **Harvesting and slicing the fruit**
  Harvesting by hand is not polluting but harvesting by machine uses energy and adds to pollution. Cutting up the fruit into snack-size pieces would probably be done by machine which uses energy and adds to pollution.
- **Positive impacts**
  People like eating sliced fruit. Fresh fruit contains vitamins and nutrients essential for good health.

Conclusion

- Real fruit is probably healthier and might have fewer negative impacts. But if synthetic fruit snacks could be made with vitamins, other nutrients, and not too much sugar, they might be a possible alternative to real fruit slices.

EXPLORE

8. Have students investigate their synthetic product using internet and library resources.

Guiding Student Research

Discuss with students the importance of keeping track of the information they find, judging the reliability of the sources they use, and citing sources properly. You may already have resources for students on proper citation and on judging the reliability of sources. We have collected some samples below.

- http://www.edutopia.org/blog/evaluating-quality-of-online-info-julie-coiro
- http://eduscapes.com/tap/topic32.htm
- http://www.scholastic.com/teachers/top-teaching/2010/11/reliable-sources-and-citations
- https://www.teachingchannel.org/videos/analyzing-websites-with-students
- https://www.cerias.purdue.edu/education/k-12/teaching_resources/lessons_presentations/SITECREDIBILITY2.pdf
- http://www.readwritethink.org/classroom-resources/lesson-plans/hoax-hoax-strategies-online-1135.html?tab=4
- http://www.easybib.com/reference/guide/mla/website

Note: *Depending on the synthetic product students select, the information they find to answer the questions may vary in detail and completeness.*

Researching aspects of synthetic materials, natural resources, how products are made, and the impact of production on society can be challenging for students. It can be difficult for students to find websites that are relevant, reliable, and understandable. Students may need substantial guidance to conduct research on the internet. We have provided some suggested websites as starting points for student research. Use your own expertise and that of the school library and media center to help students navigate to find useful material.

Main goals for student research

After students know the product they will research, remind them to look for the following information:

1. What natural resources are used to make the synthetic product?
2. What chemical processes are used to make the synthetic product?
3. What are the negative and positive impacts to society of making and using the synthetic product, compared to making and using a more natural product with a similar function?

Encourage students to use the findings from their research to conclude whether the positives outweigh the negatives. If they would need more information to make that decision, ask students to identify what they would need to know.

Note: *It may be challenging for students to find detailed and specific information on some aspects of the natural resources, production processes, and societal impacts for their synthetic materials and products. Encourage students to get as much information as they can to understand the basics of the resources* *that go into making the product, the general process for how it's made, and the positive and negative impacts the production and use of the product have on society.*

The following list is for students to compare the impact to society of their synthetic product to a more natural product with a similar function.

Products with similar functions (more synthetic / more natural)

- Plastic bag/ Paper bag
- Plastic container/ Glass container
- Disposable diaper/ Cloth diaper
- Synthetic fiber and cloth (polyester, nylon, or rayon) / Cotton, silk, or wool fiber and cloth
- Kevlar/ Steel
- Artificial sweetener/ Sugar
- Synthetic fuel (Synfuel)/ Petroleum
- Synthetic rubber/ Natural rubber
- Chloroquine (Malaria drug)/ Cinchona tree bark
- Taxol(Cancer drug)/ Yew tree bark
- Physostigmine(Glaucoma drug)/ Calabar beans
- Aspirin/ Willow tree bark

The following websites can help students begin their research on their synthetic product.

Plastic Bags

- Stopwaste.org, From Oil to Plastic
  https://www.youtube.com/watch?v=IwdUwffecsM&nohtml5=False
- The Atlantic, What is Crude Oil, Exactly?
  https://www.youtube.com/watch?v=62LvVYYqUFA
- How Stuff Works, Plastics
  http://science.howstuffworks.com/plastic.htm
- How Stuff Works, Which is more environmentally friendly: paper or plastic?
  http://science.howstuffworks.com/environmental/green-science/paper-plastic.htm
- Canadian Plastics Industry Association, All About Bags, Paper vs. Plastic Bags
  http://www.allaboutbags.ca/papervplastic.html
- Ecomyths Busted, Myth: Paper Bags Are Greener Than Plastic
  http://ecomyths.org/2014/05/27/myth-paper-bags-are-greener-than-plastic/

Plastic Bottles

- American Chemistry Council, The Basics: Polymer Definition and Properties
  https://plastics.americanchemistry.com/Education-Resources/Plastics-101/The-

Basics-Polymer-Definition-and-Properties.html
- Thomasnet.com, Plastic Bottle Manufacturing
http://www.thomasnet.com/articles/materials-handling/plastic-bottle-manufacturing
- Explain That Stuff!, Glass
http://www.explainthatstuff.com/glass.html
- Environmental Impact, Environmental Impact of Glass Production
http://envimpact.org/glass
- The Vermont Juice Co., Glass vs. Plastic
http://www.vtjuiceco.com/learn/plastic-vs-glass/
- Packaging of the World, Plastic vs. Glass—Why plastic containers are better
http://www.packagingoftheworld.com/2014/04/plastic-vs-glass-why-plastic-containers.html
- Washington Post, Why glass jars aren't necessarily better for the environment than plastic jars
https://www.washingtonpost.com/national/health-science/why-glass-jars-arent-necessarily-better-for-the-environment-than-plastic-ones/2014/06/23/2deecfd8-f56f-11e3-a606-946fd632f9f1_story.html
- Academy of Nutrition and Dietetics, Eat Right, Glass Versus Plastic Containers
http://www.eatright.org/resource/homefoodsafety/four-steps/refrigerate/glass-versus-plastic-containers
- Oregon Public Broadcasting, Which Is Greener? It's Not What You'd Expect
http://www.opb.org/news/blog/ecotrope/which-is-greener-its-not-what-youd-expect/

Disposable Diapers
- University of Minnesota, Diaper Choices
http://www.extension.umn.edu/environment/water/diaper-choices/
- Stanford Alumni, Don't Pooh- Pooh My Diaper Choice
https://alumni.stanford.edu/get/page/magazine/article/?article_id=56347
- National Geographic, How Disposable Diapers are Made
https://www.youtube.com/watch?v=kG-oWwI8L9M
- Appropedia, Cloth vs. Disposable Diapers
http://www.appropedia.org/Cloth_versus_disposable_diapers
- Healthline, The Diaper Wars: Cloth vs. Disposable
http://www.healthline.com/health/parenting/cloth-vs-disposable-diapers#1

Synthetic Fiber and Cloth (Polyester, Nylon, Rayon)
- ChemMatters, Nylon
https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-dec1990-nylon-kydd.pdf

- FiberSource, A Short History of Manufactured Fibers
  http://www.fibersource.com/f-tutor/history.htm
- Explain That Stuff, Nylon
  http://www.explainthatstuff.com/nylon.html
- Science360, Fabricating Fabric: Profile of Nylon
  https://science360.gov/obj/tkn-video/81d0ca7e-1741-4f03-ad99-aea708639e68
- Smithsonian, How 75 Years Ago, Nylon Stockings Changed the World
  http://www.smithsonianmag.com/smithsonian-institution/how-75-years-ago-nylon-stockings-changed-world-180955219/?no-ist
- How Products are Made, Rayon
  http://www.madehow.com/Volume-1/Rayon.html
- Textile Exchange, The Manufacturing Process of Rayon
  http://www.teonline.com/knowledge-centre/manufacturing-process-rayon.html
- Chemistry Explained, Fibers
  http://www.chemistryexplained.com/Fe-Ge/Fibers.html
- How Stuff Works, Why is Cotton More Absorbent than Nylon?
  http://home.howstuffworks.com/home-improvement/household-hints-tips/cleaning-organizing/question547.htm
- Quatr.us, What is Polyester?
  http://quatr.us/clothing/after1500/polyester.htm
- Sewing Parts Online, Cotton vs. Polyester
  http://www.sewingpartsonline.com/blog/411-cotton-vs-polyester-pros-cons/
- How Stuff Compares, Cotton vs. Polyester
  http://www.howstuffcompares.com/doc/c/cotton-vs-polyester.htm

Kevlar

- ChemMatters, Fabric of Steel
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-oct1990-kevlar-banks.pdf
- Explain That Stuff, Kevlar
  http://www.explainthatstuff.com/kevlar.html
- How Stuff Works, Stuff or Genius, Stephanie Kwolek
  http://shows.howstuffworks.com/stuff-of-genius/40371-the-stuff-of-genius-kevlar-video.htm
- Making the Modern World, Kevlar
  http://www.makingthemodernworld.org.uk/learning_modules/chemistry/03.TU.02/?section=10
- Science 360, Chance Discoveries, Kevlar
  http://science360.gov/obj/video/ff988118-72a9-404c-b3dd-b0a065239655

Artificial Sweetener

- ChemMatters, The Skinny on Sweeteners: How Do They Work?
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-oct2011-sweeteners-brownlee.pdf
- ChemMatters, Artificial Sweeteners
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-feb1988-sweeteners.pdf
- Scientific American, Sugar vs. Artificial Sweeteners
  http://www.scientificamerican.com/article/sugar-vs-artificial-sweeteners/
- CNN, Real or Fake Sugar: Does it Matter?
  http://www.cnn.com/2013/07/15/health/artificial-sweeteners-soda/
- Discovery Communications, Seeker, Artificial Sweetener Leaves Environmental Aftertaste
  http://news.discovery.com/earth/artificial-sweetener-not-removed-by-sewage-treatment-110623.htm
- American Chemical Society, Environmental Science and Technology, Artificial Sweetener Persists in the Environment
  http://pubs.acs.org/doi/pdf/10.1021/es087043g
- World Wildlife Fund, Sustainable Agriculture – Sugarcane
  http://www.worldwildlife.org/industries/sugarcane
- Discover, The Chemistry of Artificial Sweeteners
  http://discovermagazine.com/2005/aug/chemistry-of-artificial-sweeteners

Synthetic Rubber

- American Chemical Society, National Historic Chemical Landmarks, U.S. Synthetic Rubber Program
  http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/syntheticrubber.html
- Explain that Stuff, Rubber
  http://www.explainthatstuff.com/rubber.html
- Akron Global Polymer Academy, A Brief History of Rubber
  https://www.youtube.com/watch?v=rHhD6YhsGk0
- Discovery Communications, How It's Made - Natural Rubber
  https://www.youtube.com/watch?v=CKq42J7SaWw
- Discovery Communications, How It's Made - Synthetic Rubber
  https://www.youtube.com/watch?v=SedGDg2K_aI

Synthetic Fuel

- ChemMatters, Do You Want Biodiesel with That?
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-april2005-biodiesel-kirchhoff.pdf

- ChemMatters, Green Gasoline: Fuel from Plants
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-feb2010-greenfuel-schirber.pdf
- How Stuff Works, What is a Synfuel?
  http://auto.howstuffworks.com/fuel-efficiency/biofuels/synfuel.htm
- How Stuff Works, Top 8 Synthetic Fuels
  http://auto.howstuffworks.com/fuel-efficiency/biofuels/8-synthetic-fuels.htm
- Princeton University, Synthetic Fuels Could Eliminate U.S. Need for Crude Oil
  https://www.princeton.edu/main/news/archive/S35/39/49I49/index.xml?section=topstories

Taxol (Cancer drug)

- National Cancer Institute, Natural Compound Helps treat Breast and Ovarian Cancer
  http://www.cancer.gov/research/progress/discovery/taxol
- National Cancer Institute, Success Story – Taxol
  https://dtp.cancer.gov/timeline/flash/success_stories/S2_Taxol.htm
- American Chemical Society, National Historic Chemical Landmark – Discovery of Camptothecin and Taxol
  http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/camptothecintaxol.html
- American Chemical Society, Chemical and Engineering News - Taxol
  https://pubs.acs.org/cen/coverstory/83/8325/8325taxol.html

Physostigmine (Glaucoma drug)

- ChemMatters, Percy Julian: Rising above Racism
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-oct2007-percyjulian-brownlee.pdf
- Chemical Heritage Foundation, Science Alive, Physostigmine and Glaucoma
  http://www.chemheritage.org/percy-julian/history/5.html
- Chemical Heritage Foundation, Science Alive, Synthetic vs. Natural: What's the Difference?
  http://www.chemheritage.org/percy-julian/activities/5a.html
- American Chemical Society, National Historic Chemical Landmark, Percy L. Julian and the Synthesis of Physostigmine
  http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/julian.html
- Chemical Heritage Foundation, Science Alive, What is Synthesis?
  http://www.chemheritage.org/percy-julian/activities/3c.html

Chloroquine (Malaria drug)
Encyclopedia.com, Chemical Synthesis
http://www.encyclopedia.com/topic/Chemical_synthesis.aspx
Medicines for Malaria Venture, History of Antimalarials
http://www.mmv.org/malaria-medicines/history-antimalarials

Cortisone (Arthritis drug)

- Encyclopedia.com, Percy Lavon Julian
  http://www.encyclopedia.com/topic/Percy_Lavon_Julian.aspx
- PBS, NOVA, Percy Julian : Forgotten Genius – Making Cortisone from Plants
  http://www.pbslearningmedia.org/resource/drey07.sci.phys.matter.cortisone/making-cortisone-from-plants/

Aspirin

- ChemMatters, Aspirin
  https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/archive/chemmatters-feb1993-aspirin-marsella.pdf
- About.com, Inventors, History of Aspirin
  http://inventors.about.com/library/inventors/blaspirin.htm
- Chemical Heritage Foundation, Aspirin: Turn of the Century Miracle Drug
  http://www.chemheritage.org/discover/media/magazine/articles/27-2-aspirin.aspx
- The Conversation, Natural Medicine is Great but Chemists Can Make it Even Better
  http://theconversation.com/natural-medicine-is-great-but-chemists-can-make-it-even-better-28362

EXTEND

9. Have students make an advertisement, poster, short video, article, or other output about their synthetic product.

Student projects should address the following questions.

- What natural resources are used to make the synthetic product?
- What chemical processes are used to make the synthetic product?
- What are the negative and positive impacts to society of making and using the synthetic product, compared to making and using a more natural product with a similar function?

Encourage students to use the results of their research to conclude which product would be the best choice for society.

Activity Sheet
Chapter 6, Lesson 12
Natural Resources & Synthetic Materials

Name ________________

Date __________________

1. Both natural products and synthetic products come from natural resources. Explain why this statement is true.

2. What does it mean if a product is "synthetic"?

3. Some synthetic substances are exactly the same as substances found in nature. Why would scientists synthesize something that already exists?
   HINT: You Tube Video, "Professor Dave Explains: Will Synthetic Vitamins Make Me Explode?"

4. Which synthetic product will you do research on?

Use these questions to guide your research about your synthetic product.

1. What natural resources are used to make the synthetic product?
2. What chemical processes are used to make the synthetic product?
3. What are the impacts to society of making and using the synthetic product, compared to making a more natural product with a similar function?

Before starting your research, you will conduct a hands-on activity where you create a synthetic product—a gel worm. The three questions above will guide the activity and will model how to approach your research.

WHAT NATURAL RESOURCES ARE USED TO MAKE THE SYNTHETIC PRODUCT?

5. The reactants in the chemical synthesis you will do are sodium alginate and calcium chloride.

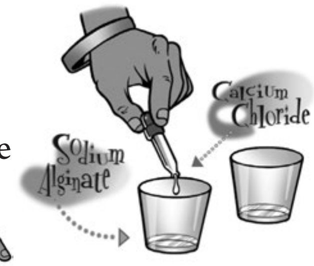
Natural resources used to make the gel worm		
	Sodium Alginate	**Calcium Chloride**
What natural resource is this chemical made from?	A brown seaweed called kelp	Calcium chloride is made from limestone which is a common rock that is mined.
How is the natural resource processed to make this chemical?	The seaweed is cut up, mixed with water and filtered. The water evaporates off and the sodium alginate powder is left	The limestone is reacted with hydrochloric acid or sodium chloride to make calcium chloride.

ACTIVITY

Question to investigate
Why is a gel worm made from calcium chloride and sodium alginate solutions considered a synthetic product?

Materials
- Calcium chloride solution in a small wide cup
- Sodium alginate solution in a small wide cup
- One dropper
- Paper towels

Procedure



1. Use a plastic dropper to add about 10 drops of calcium chloride solution to the center of a cup containing 15 mL of sodium alginate solution.

2. Reach into the center of the solution (where you put the calcium chloride) and gently and slowly pull out the gel "worm."

3. Set the "worm" on a paper towel.

6. What were the calcium chloride and sodium alginate solutions like before you added the calcium chloride solution to the sodium alginate solution?

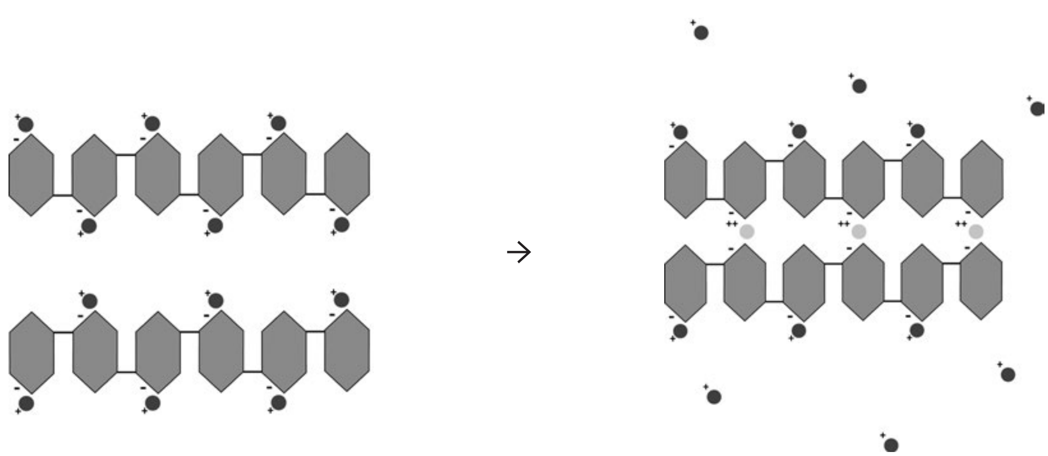
7. After you added the calcium chloride solution to the sodium alginate solution and began pulling from the center, how did the solutions change?

8. Why is the gel worm considered to be a synthetic product?

EXPLAIN IT WITH ATOMS & MOLECULES

What chemical processes are used to make the synthetic product?

Adding the calcium chloride solution to the sodium alginate solution caused the sodium alginate to become a stiffer gel.



9. Describe what the calcium ions from the calcium chloride do to help make the sodium alginate polymer become a gel.

TAKE IT FURTHER

What are the impacts to society of making and using the synthetic product, compared to making a more natural product with a similar function?

10. Are the natural resources used to make the synthetic gel worm renewable or nonrenewable?

    Fill out the chart below to answer the question.

Renewable and Nonrenewable Natural Resources Used to Make Each Snack			
	Main ingredients	**Natural resources used to make each**	**Renewable? Why or why not?**
Gel worm	Sodium alginate		
	Calcium chloride		
Fresh fruit slices	Fruit		

11. If gel worms were made and sold on a large scale as a synthetic snack item for kids, what are some of the impacts to society of producing and using them compared to producing and using fresh fruit slices?

Fill out the chart below to answer the question.

Impacts to society and the environment		
	Synthetic gel worm	**Fresh fruit slices**
Impact of harvesting, mining, or collecting the natural resources		
Processing the natural resources to make the final product?		
Usefulness of the product?		

12. Which do you think is better, the gel worm snack or fresh fruit slices?

Why do you think so?

Chapter 6—Student Reading

What is a chemical reaction?

There are many common examples of chemical reactions. For instance, chemical reactions happen when baking cookies and in your digestive system when you eat the cookies. Rusting iron and burning gasoline in a car engine are chemical reactions. Adding baking soda to vinegar also causes a chemical reaction. In a chemical reaction, the molecules in the reactants interact to form new substances. A chemical reaction causes a *chemical* change. Other processes, like dissolving or a change of state, cause a *physical* change in which no new substance is formed.

PHOTOS.COM

PHOTOS.COM

PHOTOS.COM

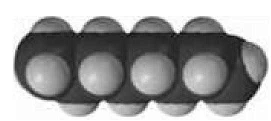
Another chemical reaction that you have seen many times is a burning candle.

PHOTOS.COM

When a candle burns, molecules in the wax react with oxygen in the air. This reaction, called combustion, releases energy in the form of the heat and light of the flame. The reaction also produces something else which is not as obvious – carbon dioxide and water vapor.

A closer look at a burning candle

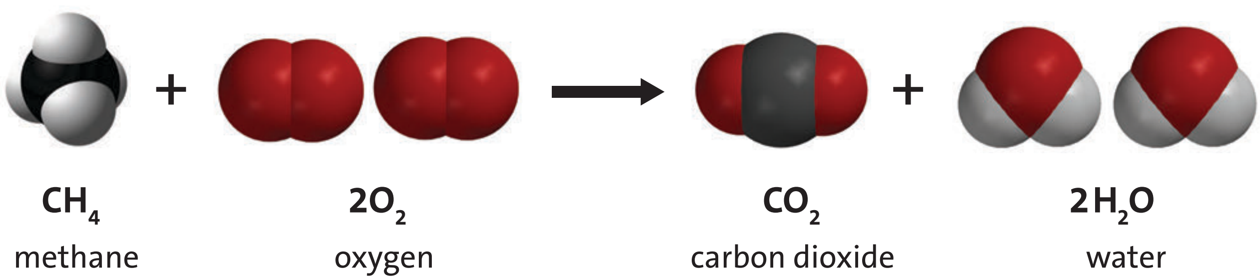
The wax in the candle is made of long molecules called *paraffin*. These paraffin molecules are made up of only carbon atoms and hydrogen atoms bonded together.



Molecules made of only carbon and hydrogen are called *hydrocarbons*. The simplest hydrocarbon (methane) can be used as a model to show how the wax or any other hydrocarbon burns.

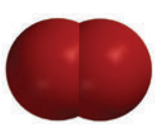
The chemical formula for methane is CH_4. This means that methane is made up of one carbon atom and 4 hydrogen atoms.

This is the chemical equation for the reaction of methane and oxygen.



The reactants

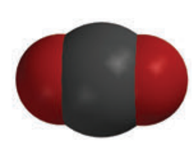
The methane and oxygen on the left side of the equation are called the *reactants*. Each molecule of oxygen gas is made up of two oxygen atoms bonded together.



It can be confusing that oxygen the atom, and oxygen the molecule, are both called "oxygen". When we talk about the oxygen in the air, it is always the molecule of oxygen which is two oxygen atoms bonded together, or O_2. The reason why there is a "2" in front of the O_2 shows that there are two molecules of O_2.

The products

The carbon dioxide and water on the right side of the equation are called the products. The chemical formula for carbon dioxide is CO_2. This means that carbon dioxide is made up of one carbon atom and 2 oxygen atoms.



The other product is two molecules of water. Each molecule of water is made up of two hydrogen atoms bonded to one oxygen atom or H_2O.

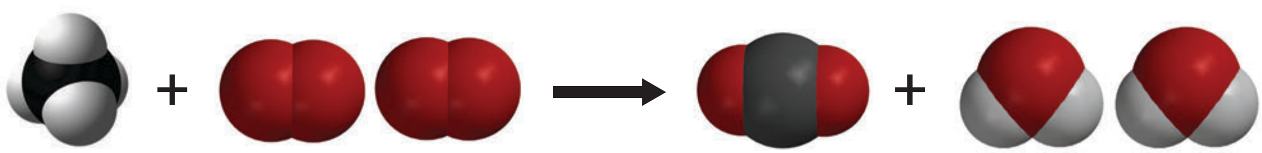
The reason why there is a “2” in front of the H_2O shows that there are two molecules of H_2O.

Where do the products come from?

The atoms in the products come from the atoms in the reactants. In a chemical reaction, the reactants interact with each other, bonds between atoms in the reactants are broken, and the atoms rearrange and form new bonds to make the products.

Counting the atoms in the reactants and products

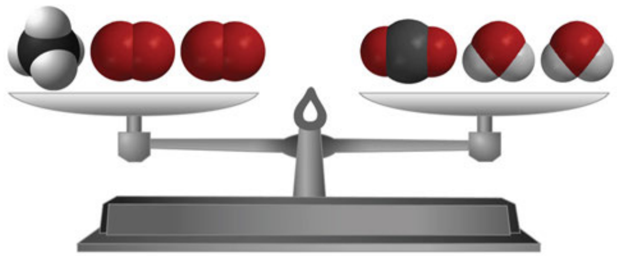
To understand a chemical reaction, you need to check that that the equation for the reaction is *balanced*. This means that the same type and number of atoms are in the reactants as are in the products. To do this, you need to be able to count the atoms on both sides.



Look again at the equation for methane reacting with oxygen. You see a big number (coefficient) in front of some of the molecules and a little number (subscript) after an atom in some of the molecules. The coefficient tells how many of a particular type of *molecule* there are. The subscript tells how many of a certain type of *atom* are in a molecule. So if there is a coefficient in front of the molecule and a subscript after an atom, you need to multiply the coefficient times the subscript to get the number of atoms.

Example: In the products of the reaction there are $2H_2O$. The coefficient means that there are two molecules of water. The subscript means that each water molecule has 2 hydrogen atoms. Since each water molecule has 2 hydrogen atoms and there are two water molecules, there must be 4 (2×2) hydrogen atoms.

If you look closely at the equation, you can see that there is 1 carbon atom in the reactants and 1 carbon atom in the products. There are 4 hydrogen atoms in the reactants and 4 hydrogen atoms in the products. There are 4 oxygen atoms in the reactants and 4 oxygen atoms in the products. This equation is balanced.

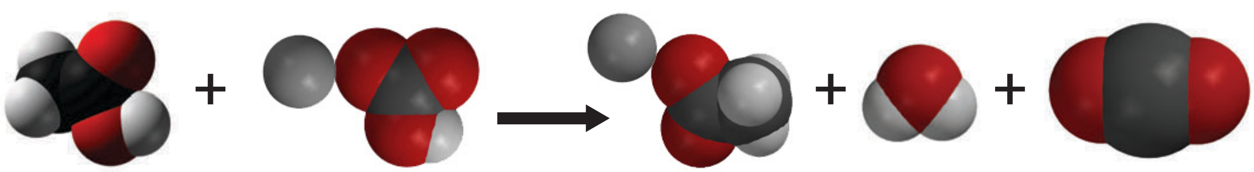


Another way of saying that an equation is balanced is that "mass is conserved". This means that the atoms in the reactants end up in the products and that no new atoms are created and no atoms are destroyed.

Changing the amount of products

If you want to change the amount of products formed in a chemical reaction, you need to change the amount of reactants. This makes sense because atoms from the reactants need to interact to form the products.

An example is the popular reaction between vinegar (acetic acid) and baking soda (sodium bicarbonate).



$C_2H_4O_2$	**$NaHCO_3$**	**$NaC_2H_3O_2$**	**H_2O**	**CO_2**
acetic acid	sodium bicarbonate	sodium acetate	water	carbon dioxide

When you do this reaction, one of the most noticeable products, which you see on the right side of the equation, is carbon dioxide gas (CO2). If you wanted to produce more CO2, you could use more baking soda because there would be more baking soda to react with the vinegar to produce more carbon dioxide. In general, using more of one or more reactants will result in more of one or more products. Using less of one or more reactants will result in less of one or more products. But this principle has limits. If you wanted to make a lot of carbon dioxide, you couldn't just keep adding more and more baking soda to the same amount of vinegar. This might work for a while, as long as there was enough vinegar, but eventually there would be no atoms left of vinegar to react with the extra baking soda so no more carbon dioxide would be produced.

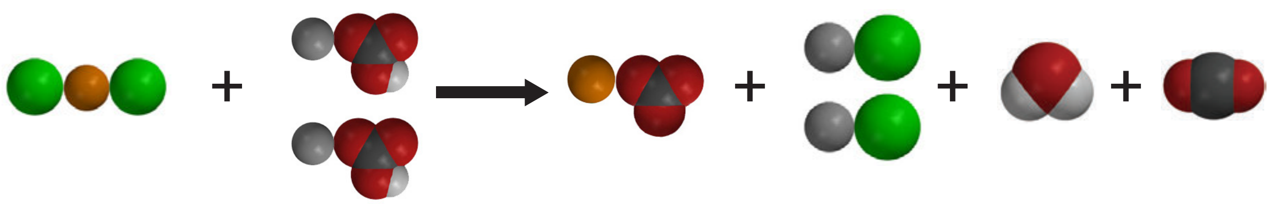
EVIDENCE OF A CHEMICAL REACTION

Production of a gas

The gas produced from mixing vinegar with baking soda is evidence that a chemical reaction has taken place. Since the gas was produced from mixing a solid (baking soda) and a liquid (vinegar), the gas is a new substance formed by the reaction.

Formation of a precipitate

Another clue that a chemical reaction has taken place is a solid is formed when two solutions are mixed. When this happens, the solid is called a precipitate. The precipitate does not dissolve in the solutions. One example of solutions that form a precipitate are calcium chloride solution and sodium bicarbonate solution.
When these solutions are combined, a precipitate called calcium carbonate is produced. Calcium carbonate is the main ingredient in chalk and sea shells, and does not easily dissolve.



$CaCl_2$	**$2NaHCO_3$**	**$CaCO_3$**	**$2NaCl$**	**H_2O**	**CO_2**
calcium chloride	sodium bicarbonate	calcium carbonate	sodium chloride	water	carbon dioxide

Color change

When two substances are mixed and a color change results, this color change can also be evidence that a chemical reaction has taken place. The atoms that make up a molecule and the structure of the molecules determines how light interacts with them to give them their color. A color change can mean that new molecules have been formed in a chemical reaction with different structures that produce different colors.

Temperature change

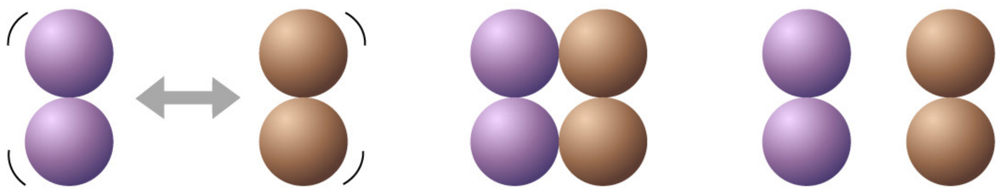
Another clue that a chemical reaction has occurred is a change in temperature of the reaction mixture. You can read more about the change in temperature in a chemical reaction under Chemical reactions and energy below.

RATE OF A CHEMICAL REACTION

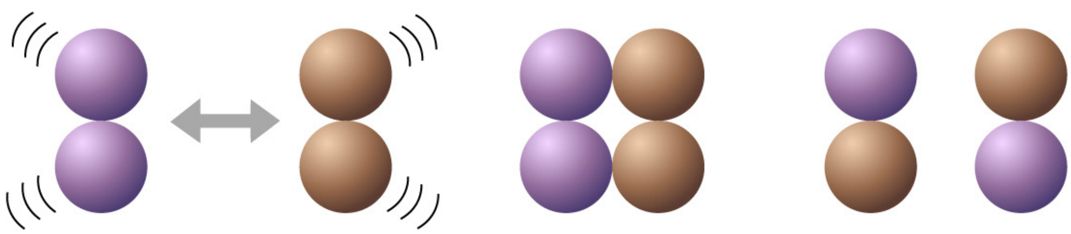
Increasing the temperature increases the rate of the reaction

The rate of a chemical reaction is a measure of how fast the reactants are changed into products. This can be increased by increasing the temperature of the reactants.

For reactant molecules to react, they need to contact other reactant molecules with enough energy for atoms or groups of atoms to come apart and recombine to make the products. If they do not have enough energy, most reactant molecules just bounce off and do not react.



But if the reactants are heated, the average kinetic energy of the molecules increases. This means that more molecules are moving faster and hitting each other with more energy. If more molecules hit each other with enough energy to react, then the rate of the reaction increases.



A catalyst can increase the rate of the reaction

Another way to increase the rate of the reaction is by adding a substance that helps bring the reactants together so they can react. A substance which helps speed up a chemical reaction in this way but does not become a product of the reaction is called a *catalyst*.

A common catalyst in the cells of living organisms is called *catalase*. During normal cell processes, living things produce hydrogen peroxide in their cells. But hydrogen peroxide is a poison so the cells need a way to break it down very quickly. Catalase helps break down hydrogen peroxide at a very fast rate. Catalase and many other catalysts in living things, are large complex molecules. Reactants attach to specific parts of the catalyst which helps the reactants to come apart or bond together. A single molecule of catalase can catalyze the breakdown of millions of hydrogen peroxide molecules every second.

Substances react chemically in characteristic ways

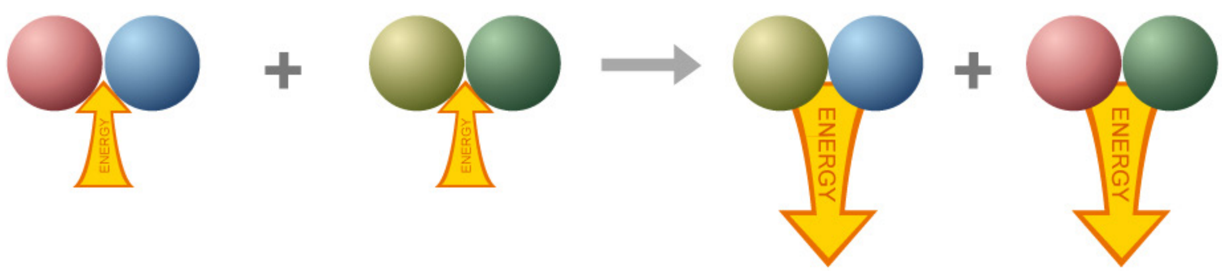
If you tested different substances with a particular liquid to see how the substances react, each would react in its own characteristic way. And each substance that reacted would react the same way each time it was tested with the same liquid. Substances react in characteristic ways because every substance is different. Each one is made up of certain atoms bonded in a particular way that makes it different from any other substance. When it reacts with another substance, certain atoms or groups of atoms unbond, rearrange, and rebond in their own way.

Chemical reactions and energy

Chemical reactions involve breaking bonds in the reactants and making new bonds in the products. It takes energy to break bonds in the reactants. Energy is released when new bonds are formed in the products. The using and releasing of energy in a chemical reaction can help explain why the temperature of some reactions goes up (exothermic) and the temperature of other reactions goes down (endothermic).

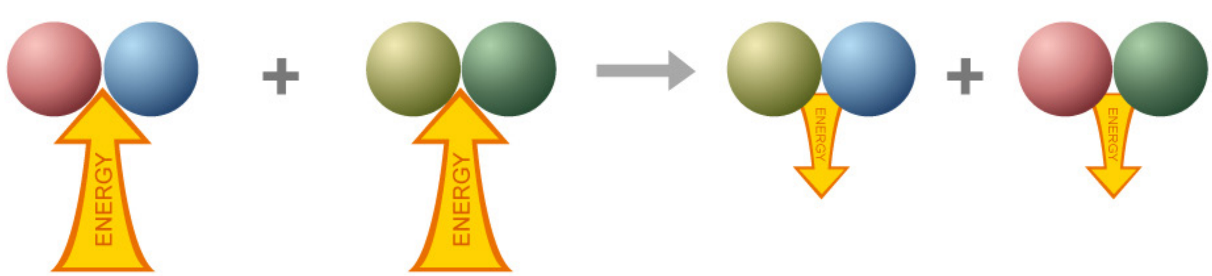
Exothermic

If a reaction is exothermic, that means that it takes less energy to break the bonds of the reactants than is released when the bonds in the products are formed. Overall, the temperature increases.



Endothermic

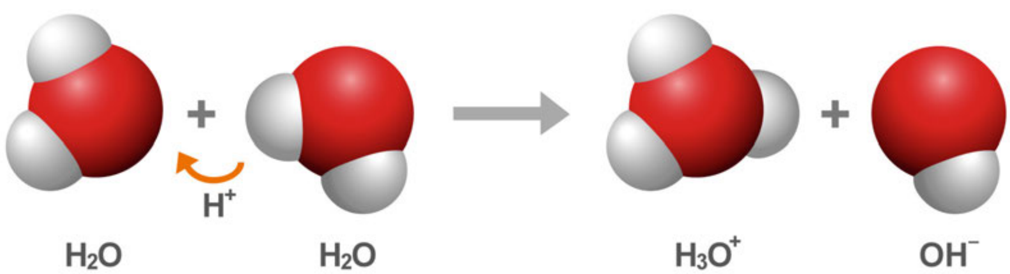
If a reaction is endothermic, it takes more energy to break the bonds in the reactants than is released when the products are formed. Overall, the temperature decreases.



Acids, bases, and pH

You may have heard of the term “pH” when talking about the water in a pool or fish tank. You may have seen people take a sample of water and compare it to colors on a chart to test the pH of the water. The pH scale is a way to measure whether the water is acidic or basic.

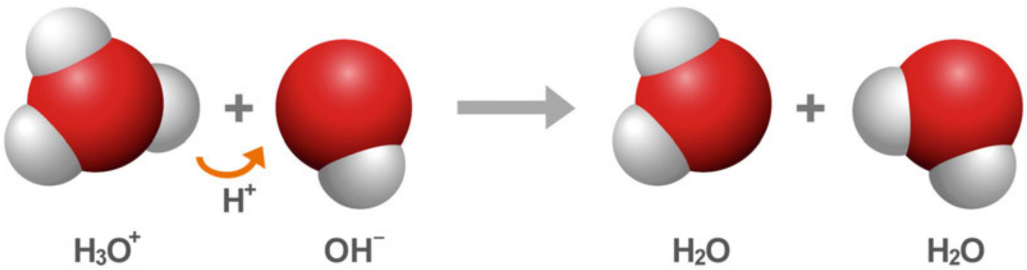
Normally we think of water as good ol’ H_2O, but in fact some water molecules react with each other and become something different. When two water molecules bump into each other and react, a proton from a hydrogen atom in one of the water molecules gets transferred to the other water molecule. This proton leaves its electron behind in the water molecule it came from.



When a proton is transferred from one water molecule to another, it’s as if the molecule gaining the proton is actually gaining another hydrogen atom (but without the electron). So in the reaction between the two water molecules, the one that gained the extra proton has one more proton than electron and changes from H_2O to become the ion H_3O^+.

It works the other way around for the water molecule that lost the proton. It’s as if the water molecule lost a hydrogen atom (but held on to the electron). So the water molecule that lost the proton has one more electron than proton and changes from H_2O to become the ion OH^-.

But the H_3O^+ ions and the OH^- ions also react with one another. In this reaction, the extra proton on the H_3O^+ can be transferred back to the OH^- to form two water molecules again.

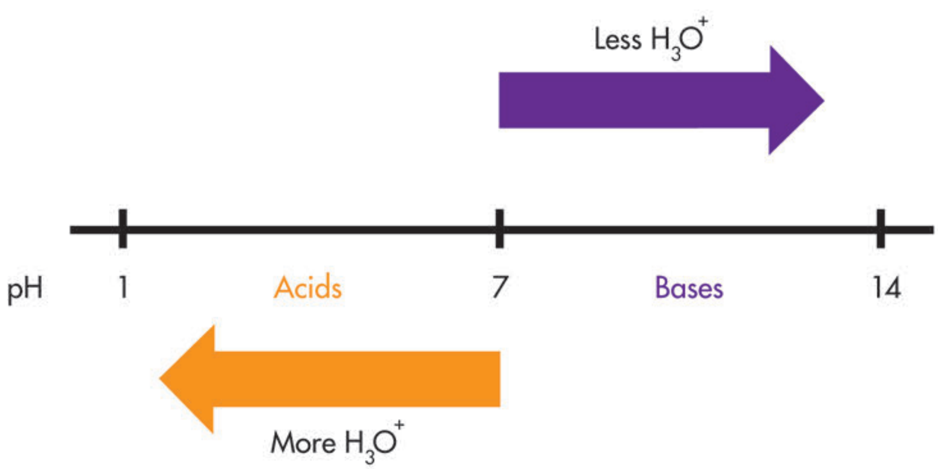


In pure water, these reactions balance one another and result in a small but equal concentration of H_3O^+ and OH^-.

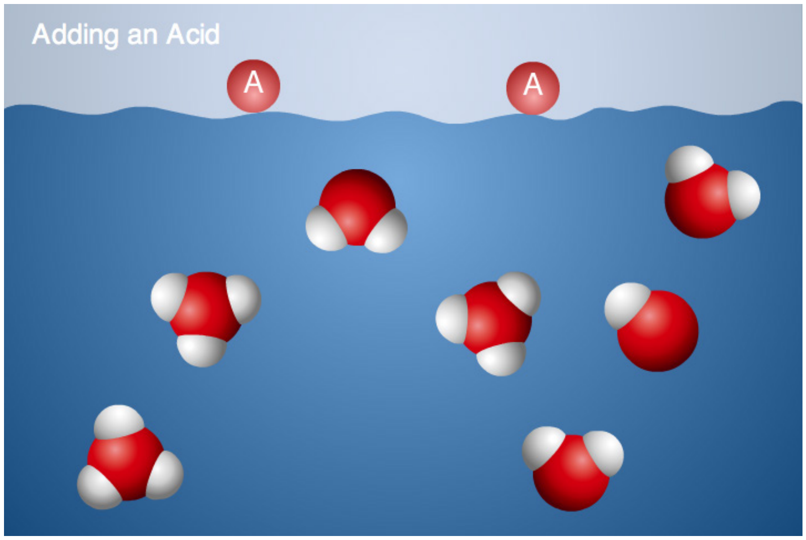
The concentration of H_3O^+ in water determines how acidic or basic a solution is. The pH scale is a measure of the concentration of H_3O^+ in water. Pure water is neutral and measures 7 on the pH scale.

How do acids and bases make water acidic or basic?

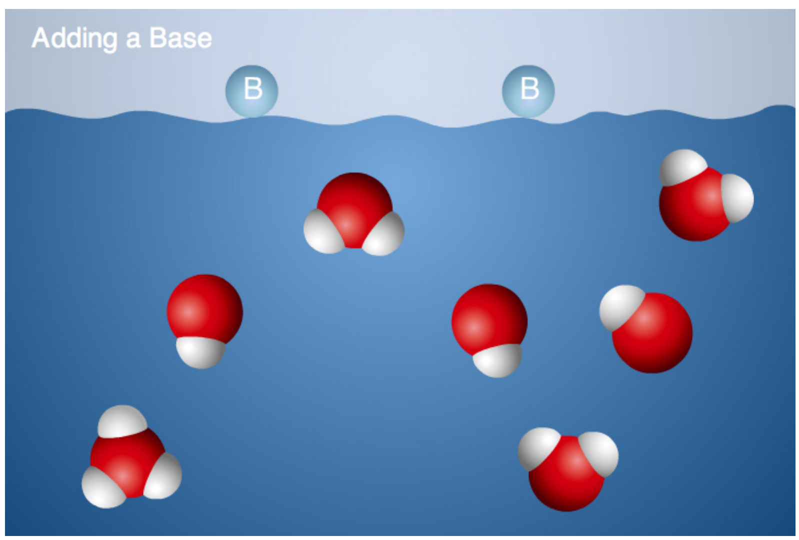
If a solution has a higher concentration of H_3O^+ than OH^-, it is considered an acid. An acid measures less than 7 on the pH scale. If the solution has a lower concentration of H_3O^+ than OH^-, it is considered a base. A base measures greater than 7 on the pH scale.



Acids are sometimes called "proton donors". This means that when an acid is added to water, the acid molecule transfers a proton to water molecules forming more H_3O^+. Since the solution has a higher concentration of H_3O^+ than OH^-, it is an acid.



Talking about bases is a little trickier because you have to look at two steps to see how they affect the pH. Bases are sometimes called "proton acceptors". This means that when a base is added to water, the base molecule accepts a proton from water forming more OH^-. When there is extra OH^- in the water, the H_3O^+ ions transfer protons to the OH^- ions causing the concentration of H_3O^+ to go down. Since the solution has a lower concentration of H_3O^+ than OH^-, it is a base.



Acids and bases are like chemical opposites

An acid can neutralize a base and base can neutralize an acid. This makes sense because if an acid is a proton donor and a base is a proton acceptor, they have the opposite effect on water and can cancel each other.

The acid donates protons and increases the concentration of H_3O^+. The base accepts protons from water molecules making more OH^-. The H_3O^+ transfers a proton to the OH^- and causes the concentration of H_3O^+ to decrease and become closer to neutral again.

STRENGTH AND CONCENTRATION IN ACIDS AND BASES

The effect that an acid or base has in a chemical reaction is determined by its strength and concentration. It is easy to confuse these two terms.

Strength

There are different kinds of acids. There are strong acids, weak acids, and acids in-between. Some acids are so strong that they can make a hole in a piece of metal. Other acids, like citric acid or ascorbic acid (Vitamin C), are weaker and are even safe to eat.

The factor that determines the strength of an acid is its ability to donate a proton, increasing the amount of H_3O^+ in water. A strong acid produces a lot of H_3O^+ in water, while the same amount of a weak acid produces a smaller amount of H_3O^+.

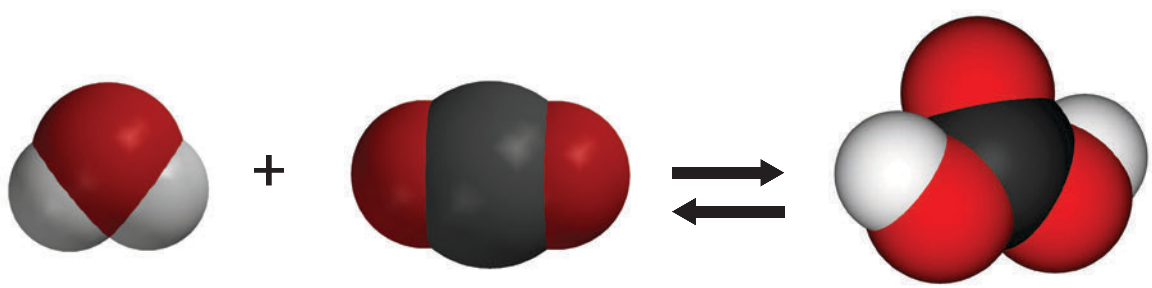
Concentration

Concentration is different from strength. Concentration has to do with the amount of acid added to a certain amount of water.

It is the combination of the concentration and the strength of an acid that determines the amount of H_3O^+ in the solution. And the amount of H_3O^+ is a measure of the acidity of the solution.

Acids and the environment

There's been a lot of news lately about too much carbon dioxide (CO_2) gas going into the atmosphere and contributing to global warming. This is a big problem but CO_2 also does something else which is not in the news as much. Carbon dioxide gas goes into the ocean and reacts with water to form a weak acid called carbonic acid.



H_2O + CO_2 ⇄ H_2CO_3

water | carbon dioxide | carbonic acid

This extra carbonic acid affects the pH of the ocean. The ocean is actually slightly basic. The extra acid makes the ocean less basic or more acidic than it would normally be. The change in ocean pH has an effect on organisms in the ocean, particularly ones that build shells like corals.

These organisms need calcium ions and carbonate ions to make the material for their shell which is calcium carbonate. The extra H_3O^+ from the acid interacts with the carbonate ion and changes it so that it can't be used for making shells. Reducing the amount of CO_2 that gets into the ocean is the first step to helping to solve this problem.

