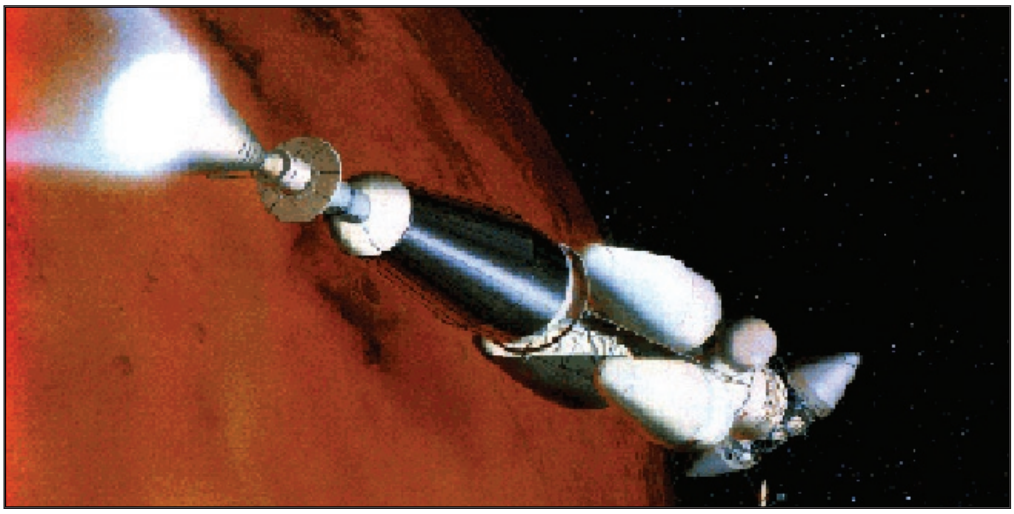
Lesson 4: The Flow of Matter



"Exploration Express" illustration: Rocket inserting a Mars transfer vehicle into orbit; Pat Rawlings, NASA

Students are introduced to chemical change and the conservation of matter during different types of chemical changes.

Main Lesson Concept:
When substances interact and new substances are created, chemical change has occurred. Matter is neither created nor destroyed in this process.

Scientific Question:
What is the process of chemical change? How does this process affect matter?

Objectives	Standards
• Students will explain how molecules may be broken apart and the atoms reorganized into new molecules that have different properties. • Students will demonstrate that when chemical changes occur, matter is transferred but not created or destroyed.	**Partially meets:** 2061: 4D (6-8) #7 2061: 4D (3-5) #4 NSES: B (5-8) #1.2 **Addresses:** NCTM: 4, 5, 9

Assessment	Abstract of Lesson
Responses to Astro Journal final questions.	Students make slime to explore the concept of combining substances to form new substances. They weigh the ingredients to observe a constant weight before and after a chemical change. Students read and discuss types of chemical reactions. Students then kinesthetically model two types of chemical reactions.

Prerequisite Concepts	Major Concepts
• The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules by bonding with other atoms. (Atmosphere Lesson 2) • Different molecules have different properties. Carbon dioxide and water vapor are greenhouse gases, which absorb heat that radiates from Earth's surface and release some of it back towards the Earth, increasing the surface temperature. (Atmosphere Lesson 3) • No matter how parts of an object are assembled, the weight of the whole object made is always the same as the sum of its parts. (2061 4D (3-5) #2) • Substances may move from place to place, but they never appear out of nowhere and never just disappear.	• Molecules can join to create new molecules. • Molecules can interchange atoms to form new molecules. • Molecules can break down into separate molecules and/or separate atoms. • Chemical change is when molecules interact to form new molecules. This is called a chemical reaction. • The new molecules formed have different properties than the original molecules. • During chemical change, the number of atoms does not change. Matter is neither created, nor destroyed.

Suggested Timeline (45-minute periods):

Day 1: Engage and Explore Sections
Day 2: Explain Section (30 minutes)
Day 3: Extend and Evaluate Sections

Materials and Equipment:

- A class set of Astro Journal Lesson 4
- Slime directions for each group
- A class set of Chemical Change Reading
- A class set of Chemical Diagrams Sheet
- Signs or name tags for each student to indicate the element they represent

For Rusting Steel Wool (one set of the following is needed for a class demonstration):
- Steel wool
- Vinegar
- Clear container
- Water
- Hand lenses (optional)

For Slime (each group will need the following):
- $^3/_4$ cup warm water
- 1 cup white water-soluble glue that contains polyvinyl alcohol (PVA), such as Elmer's Glue
- 4 teaspoons sodium borate (Borax soap found in laundry detergent aisle)
- 1 $^1/_3$ cups warm water
- Container (500 milliliter)
- Large container (1000 milliliter plus) that you don't intend to use for anything else
- Large reclosable plastic bag
- Scale
- Newspaper

Note to Teacher: Slime may stick to fabric and hair. You may want to have the students wear smocks.

Preparation:
- Gather materials.
- Prepare rusting wool demonstration: First soak the wool in vinegar for at least 20 minutes. This removes the coating on the wool that protects it from rust. Remove the steel wool from the vinegar and squeeze out any excess liquid. Put the steel wool in a container, add a little water, and allow the rust to form. A day or two should be enough time to view the formation of rust on the wool.
- Duplicate Astro Journal, Slime directions, Chemical Change Reading, and Chemical Diagrams Sheets.
- Prepare classroom. Make sure there's room for the Kinesthetic Chemical Change Activity in the Extend section.
- Prepare chart paper with the major concept of the lesson to post at the end of the lesson.

Note to Teacher: The Rusting Steel Wool Activity in the Explore section requires some preparation. As a part of your Engage session, you might want to demonstrate the preparation of the steel wool for this activity.

Differentiation

Accommodations

For students who may have special needs:

- Have them work with a partner on the Astro Journal writing or report orally to the teacher.
- Provide extra support for the reading assignment (e.g., partner, read aloud, etc.)

Advanced Extensions

For students who have mastered this concept:

- Research and report on the causes of chemical reactions. Under what conditions do different chemical reactions occur?
- Have advanced students do the optional variation of the slime activity.

Engage

(approximately 10 minutes)

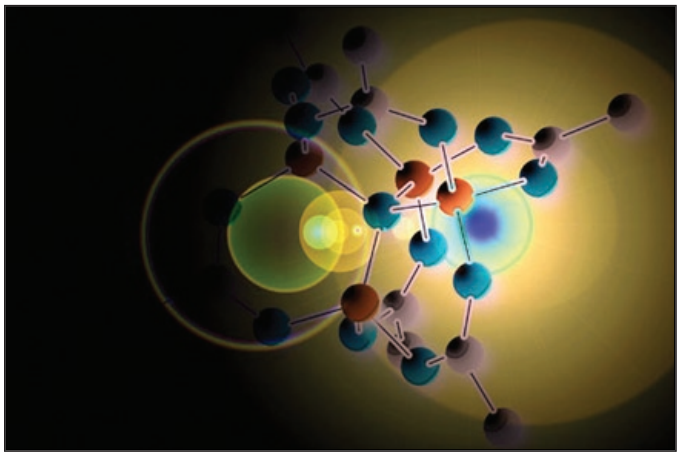


Illustration of beryllium, a silver-gray metal lighter than aluminum and stiffer than steel; Los Alamos National Laboratory, USDOE

1. Review properties of atoms and molecules (Atmosphere Lessons 1 and 2).

- Question: What have we learned about the properties and characteristics of atoms?
- *Answer: The atoms of any element are alike but are different from atoms of other elements.*

- Question: What have we learned about molecules?
- *Answer: Molecules are made up of atoms. Different molecules have different properties. For example, greenhouse gases are able to absorb and release heat.*

- Question: What did we use as a model for atoms and molecules?
- *Answer: Building materials, which are like atoms, and the structures made of the building materials, which are like molecules.*

- Question: If two molecules joined together to form a new molecule, would the new molecule have the same properties?
- *Answer: (Allow students to discuss their ideas about this using the metaphor of building materials and structures.) If two structures were joined into a new structure, it would probably have new properties. It might be larger and less sturdy, for example.*

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2. Draw on students' prior knowledge of combining substances.

- Question: How many of you have ever baked cookies or a cake?
- *Answer: (Try to find a baking experience that all students have engaged in before.)*

- Question: When you bake cookies, how is the baked cookie different from the unbaked dough?
- *Answer: The dough is moist and soft and changes its form easily. The baked cookie is hard, crunchy, and dry and doesn't change form easily.*

- Question: Is the new combination the same as the separate parts? How do you know?
- *Answers may include: No. It tastes different. It may be thicker. It's a different color. It smells different. The powder isn't dry anymore.*

- Say: Today we're going to look at how molecules and atoms can change.

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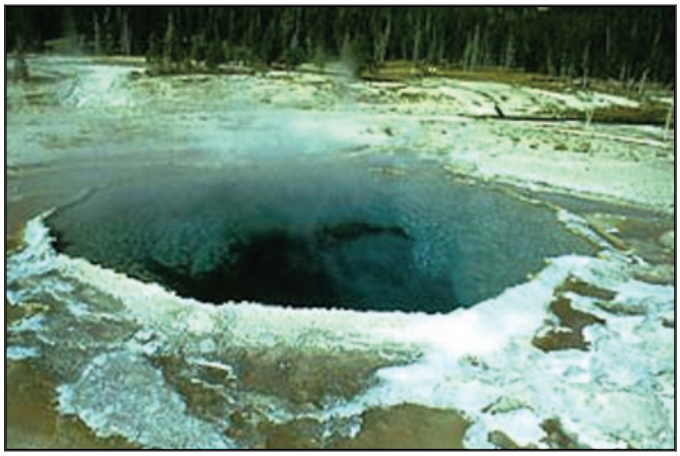
3. Bridge to this lesson and introduce the purpose and Scientific Question.

- Say: Now that we've looked at the properties of atoms by themselves and molecules by themselves, we're going to talk about how molecules can change, and how this affects the molecules and the atoms that make up the molecules.

- Say: The Scientific Questions we will be exploring are:
  - What is the process of chemical change?
  - How does this process affect matter?

Explore

(approximately 35 minutes)



Crusted Pool, Yellowstone National Park, where boiling water can dome to heights of 10 feet; National Park Service, USDI

1. Discuss atoms and molecules as ingredients.

- Say: We've been thinking about atoms as building blocks of molecules, but that picture is incomplete. Bricks can be used to build a wall or to build a support pillar, but the bricks stay as bricks. Another way of thinking about atoms and molecules is that they are ingredients in a baking project.

- Question: What happens when you mix flour, sugar, a bit of baking powder, milk, and eggs together and cook it?
- *Answer: You make a cake.*

- Question: Are the properties of the cake different from the properties of the ingredients? How?
- *Answer: The cake has a greater volume and holds a shape better than the individual ingredients.*

- Question: What has happened to the atoms and molecules of the ingredients?
- *Answer: They have formed into new molecules.*

- Question: What caused the change?
- *Answer: The combination of ingredients and the heat energy from the baking process.*

MISCONCEPTION: Students may think that adding heat to something will always mean chemical change. Use the example of boiling water to challenge this. When heat is added, it turns to water vapor, but the molecules are still H_2O. This is a physical change, a change in state. When a cake bakes, something different is created. This distinction is important.

Another misconception that students might have is that any time we mix ingredients, chemical change is occurring. This is not the case. Ask students for other examples of chemical change. If they give examples such as making juice, ask them what would happen if you let the juice sit for a long time. They should observe that the water will evaporate and the dissolved juice concentrate will separate out from the water, which is why you always have to stir juice before you drink it. Help students see that dissolving or mixing is not a chemical change, if the individual substances can still be separated out. Chemical change generally requires energy to be added or released.

Also students do not understand that substances can be formed by recombination of atoms in the original substances. Rather they see chemical change as the result of a separate change in the original substance, or changes, each one separate, in several original substances. For example, some students see the smoke formed when wood burns as having been driven out of the wood by the flame (http://www.project2061.org/tools/benchol/ch15/findings.htm#Ch4). The weighing of substances and counting of atoms is, thus, important in the following activities so that students come to understand conservation of mass and also that chemical change involves the recombination of atoms.

- Question: Do you think any atoms were destroyed or created in this process?
- *Answer: (Allow students to discuss their ideas about this.)*

- Question: How could we find out if any atoms were destroyed or created?
- *Answers may include: We could weigh the uncooked dough and compare it with the baked cookies.*

- Say: When substances interact to create the new substances, we have an example of chemical change. Baking is an example of substances coming together to form new substances with different properties.

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2. Lead students in the Making Slime Activity.

Student directions:

- Have students observe and record the properties of the ingredients of slime, including the weight of each substance, in their Astro Journals. Be sure to have students subtract the weight of the container holding the wet ingredients.
- Have students predict in their Astro Journals the properties of the substance that will result from putting the ingredients together. Make sure they include a prediction of what the weight of the new substance will be.
- Students follow the procedure to make the slime.
- Have students record their observations of the properties of slime and compare the differences with the original substances.

Note to Teacher: An optional variation that you might have students do is to have various groups alter the amounts of water and see what happens. Then have students observe and record the properties of their slime and compare the differences when the amount of water was altered.

Be sure to instruct students to wash their hands and table surfaces after working with their "slime."

Slime

Ingredients: Glue Mixture
$^3/_4$ cup warm water
1 cup white water-soluble glue that contains polyvinyl alcohol (PVA), such as Elmer's Glue Container (500 ml)

Ingredients: Soap Mixture
4 teaspoons sodium borate (Borax soap)
1 $^1/_3$ cups warm water
Large container (1000 milliliter plus)

Other items:
Newspaper
Scale
Large reclosable plastic bag

Procedure:
1. Cover your work surface with newspapers.
2. In the 500-milliliter container, mix the water and white glue for the Glue Mixture for about 3 minutes.
3. In the 1000-milliliter container, mix the sodium borate and the water for the Soap Mixture until you can no longer see the soap flakes.
4. Pour the Glue Mixture into the Soap Mixture. Let this solution stand for 1 minute.
5. Remove the substance from the liquid and put it into the reclosable plastic bag. Knead the substance into a ball.

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3. Guide students in the Rusting Steel Wool Activity.

- Say: Over the past day or so, this steel wool has been going through a process of chemical change. The iron in the steel wool has been reacting with oxygen in the air to produce a new substance, rust, also known as iron oxide.
- Have students observe the steel wool. If possible, scrape some samples of the rust off and allow students to view them up close with hand lenses.
- Students record their observations in their Astro Journals.

Explain

(approximately 30 minutes)

Rust on iron plate; Lawrence Berkeley Livermore Laboratory, USDOE

1. Discuss conclusions from the activities.

- Question: What properties did you list for water?
- *Answers may include: Water is wet and clear. It is a liquid, so its shape conforms to whatever container it is in.*

- Question: What properties did you list for glue?
- *Answers may include: Glue is white, and wet. It is a liquid and conforms to the shape of its container, but it is less fluid than water.*

- Question: What properties did you list for the soap?
- *Answers may include: The soap is dry, solid flakes, which hold their form.*

- Question: What properties did you list for the combined water, glue and soap?
- *Answers may include: The new substance is soft, thick, gooey, slimy and more solid. It holds its form.*

- Question: Are the properties of slime different from the properties of the individual substances that make slime?
- *Answer: Yes. We got a new substance with very different properties from its parts.*

- Question: How did the weight of the new substance compare with the individual substances?
- *Answer: The weight was equal to the combined weights of the parts.*

Note to Teacher: The weights may not be exactly equal, if measuring is not precise. For example, in order to weigh the final substance, you will probably want students to weigh it in the bag to protect your scale, or use some other covering to protect the scale. If students don't accurately account for the weight of coverings, bags, containers or air trapped in the bag, the weights will not be exactly equal. Most likely the discrepancy will be in the realm of acceptable experimental error. It would be good to bring this to students' attention. Also, you may want to discuss that in chemical reactions where gas is produced, the weight of the gas needs to be compensated for.

- Question: What does this tell you about the matter that makes up the substances?
- *Answer: There is the same amount of matter in the new substance as there was in the two separate substances. No matter was lost or destroyed.*

- Question: What can you conclude from the slime and steel wool activities?
- *Answer: When two substances are combined, they sometimes form a new substance that has different properties. The weight of the new substance is equal to the combined weight of the parts, so no matter is lost or destroyed. This means that there is the same number of atoms in the new substance as the parts.*

- Say: We call this chemical change a reaction. Combining molecules into new molecules is only one kind of chemical change. There are other kinds of changes too. Can you think of some other ways that molecules might change?
- *Answer: (Allow students to discuss their ideas about this using the metaphor of building materials and structures if that helps them.) An atom could be removed from a molecule, which would change it, just like removing part of a structure would change the structure. You could also take out an atom and replace it with a different atom, just like you might take out a part of a structure and replace it with a new building material.*

- Question: When you remove a part of a structure or exchange it, is the removed material destroyed?
- *Answer: No, it still exists. It just isn't a part of that structure anymore.*

- Question: What does this tell you about the number of atoms in chemical changes?
- *Answer: In all chemical changes, we have the same amount of atoms. We do not lose nor create new atoms. We call this "conservation of matter." There is always the same number of atoms. They may combine with other atoms to form new molecules, but the number of atoms never changes.*

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2. Have students read the Chemical Change Reading to reinforce these concepts.

Extend/Apply

(approximately 25 minutes)

Hydrogen model; Savannah River National Laboratory, USDOE

1. Facilitate the Kinesthetic Chemical Change Activity.

- Explain to students that they will be physically modeling two types of chemical changes.

- Students will first model the combining of hydrogen gas and oxygen gas to form two water vapor molecules. You may want to have students look at the Chemical Diagrams Sheet to review the bonds for each of these gases.
  - Guide students to model hydrogen and oxygen gases, as they did in the Extend Day 2 section of Lesson 2 Atmosphere. You may want to have students wear a sign or name tag with the element they represent.
  - Modeling hydrogen gas requires two students who each hold one hand out to "bond" with each other while keeping the other hand at his or her side. (Each student represents one hydrogen atom.).
  - Modeling oxygen gas requires two students who hold both hands out to "bond" with each other. (Each student represents one oxygen atom.)
  - To model one chemical reaction, you will need two hydrogen gas molecules (4 students) and one oxygen molecule (2 students).
  - Tell students that when hydrogen gas burns it reacts with oxygen to form water.

- Tell students they are modeling hydrogen gas and they are now burning. Have them "vibrate" and separate (let go of each other's hand). As they move closer to the oxygen molecule, the students forming the oxygen molecule should separate (let go of each others' hands).

- The students then recombine into two water molecules. Each of the oxygen atoms should keep their two arms outstretched and join the hand of two hydrogen atoms.

Note to Teacher: The actual chemical reaction is more complex than this.

- Discuss the chemical change model.
  - Question: What did we just model?
  - *Answer: We modeled the chemical change of hydrogen gas and oxygen gas combining to make water vapor molecules.*

  - Question: We talked about three different kinds of changes that could happen to molecules. What kind of change did we just model?
  - *Answer: We modeled two molecules combining to make a new molecule.*

  - Question: Does water vapor have the same properties as hydrogen gas or oxygen gas?
  - *Answer: No, water vapor has different properties.*

  - Question: Did the number of atoms change during the reaction?
  - *Answer: No. We had the same number of atoms before they reacted as we did after.*

  - Question: So, was matter created in this reaction?
  - *Answer: No. No matter was created.*

  - Question: Was matter destroyed in this reaction?
  - *Answer: No. No matter was destroyed.*

- Next, students will model the exchange of atoms between two gases (methane and oxygen) to form two new gases (carbon dioxide and water vapor). You may want to have students look at the Chemical Diagrams Sheet to review the bonds for each of these gases.
  - Guide students to model methane and oxygen gases as they did in the Extend Day 2 section of Lesson 2 Atmosphere. You may want to have students wear a sign or name tag with the element they represent.
  - Modeling methane gas requires two students to represent a single carbon atom (who stand back to back and each hold out two hands) to "bond" with four students who each represent a hydrogen atom by holding out one arm to bond with the carbon, and hold their other arm at their side. (Each methane molecule will require 6 students.)
  - Modeling oxygen gas requires two students who hold both hands out to "bond" with each other. (Each student represents one oxygen atom.)
  - To model one chemical reaction, you will need one methane gas molecule (6 students) and two oxygen molecules (4 students).

- Tell students that when methane gas burns it reacts with oxygen to form carbon dioxide and water vapor.
  - Tell students they are modeling methane gas and they are now burning. Have them "vibrate" and separate (let go of each other's hand). As they move closer to the oxygen molecules, the students forming the oxygen molecule should separate (let go of each others' hands).
  - The students should then recombine into one carbon dioxide molecule and two water molecules. Two oxygen atoms keep their two arms outstretched and join hands with the carbon atom. The other two oxygen atoms keep their two arms outstretched and join the hand of two hydrogen atoms.

Note to Teacher: The actual chemical reaction is more complex than this. In the next lesson, this will be explored in more detail.

- Discuss this second chemical change model.
  - Question: What did we just model?
  - *Answer: We modeled the chemical change of methane gas and oxygen gas combining to make carbon dioxide and water vapor molecules.*
  - Question: We talked about three different kinds of changes that could happen to molecules. What kind of change did we just model?
  - *Answer: We modeled two molecules exchanging atoms to form two new molecules.*
  - Question: What atoms were exchanged?
  - *Answer: The hydrogen atoms from methane were exchanged with some of the oxygen atoms in the oxygen gas.*
  - Question: Do water vapor and carbon dioxide have the same properties as methane gas or oxygen gas?
  - *Answer: No. Water vapor and carbon dioxide have different properties.*

– Question: Did the number of atoms change during the reaction?
– *Answer: No. We had the same number of atoms before they reacted as we did after.*

– Question: So, was matter created in this reaction?
– *Answer: No. No matter was created.*

– Question: Was matter destroyed in this reaction?
– *Answer: No. No matter was destroyed.*

Evaluate

(approximately 20 minutes)

Chemist; National Institute of Standards and Technology

1. Have students complete their write-ups in their Astro Journals.

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2. Discuss students' responses in their Astro Journals to ensure that they have mastered the major concepts.

- Question: Describe the process of chemical change.
- *Answer: Chemical change occurs when substances interact and new substances are created. These new substances have different properties than the molecules that formed them. There are different ways that molecules can change in a chemical reaction. They can combine with other substances, interchange atoms with another molecule, or break down into separate atoms. Matter is not created or destroyed in this process.*

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3. Collect students' Astro Journals and evaluate them to ensure that they have each mastered the major concepts:

- When substances interact and new substances are created, chemical change has occurred.
- Matter is not created or destroyed in this process.

4. Bridge to next lesson.

- Today we learned about the chemical changes that can occur between molecules. In the next lesson we'll learn how these changes can be important to human survival.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal Lesson 4: The Flow of Matter

Name _____ Date _____ Class/Period _____

1. List the individual substances used to make slime and describe the properties of each substance. Include the weight of each substance.

Substance	Properties	Weight

2. Predict the properties of the substance that will result from putting the ingredients together. Predict what the weight of the new substance will be.

Properties	Weight

3. Describe the properties of slime and compare and contrast them with the properties of the substances you listed to the left.

Substance	Properties
Slime	

4. How does the weight of the slime compare with the combined weight of the original substances? What does this tell you about the matter that makes up the substances?

Astro Journal Lesson 4: The Flow of Matter

Name _____ Date _____ Class/Period _____

1. Describe the rust on the steel wool and compare it with the unrusted steel wool. What do you think caused this change? Explain.

2. Describe the process of chemical change. Use one of the reactions that was modeled in class as an example. (Hydrogen gas reacts with oxygen gas to form water vapor; or methane gas reacts with oxygen to form carbon dioxide and water vapor.) Draw a picture of what happens to the elements. Explain your picture and how the conservation of matter is maintained in this reaction.

Recipe for Chemical Change

Slime

Ingredients: Glue Mixture

$^3/_4$ cup warm water
1 cup white glue
Container (500 milliliter)

Ingredients: Soap Mixture

4 tsp soap flakes
1 $^1/_3$ cups warm water
Large Container (1000 milliliter plus)

Other Items:

Newspaper
Scale
Large reclosable plastic bag

Procedure:

1. Cover your work surface with newspapers.

2. In the 500-milliliter container, mix the water and white glue for the Glue Mixture for about 3 minutes.

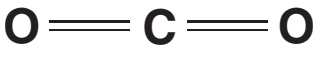
3. In the 1000-milliliter container, mix the sodium borate and the water for the Soap Mixture until you can no longer see the soap flakes.

4. Pour the Glue Mixture into the Soap Mixture. Let this solution stand for 1 minute.

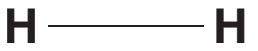
5. Remove the substance from the liquid and put it into the reclosable plastic bag.

6. Knead the substance into a ball.

Chemical Diagrams Sheet

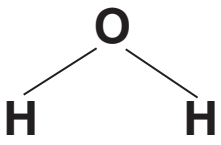


Carbon Dioxide (CO_2)



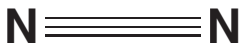
Hydrogen Gas (H_2)

Oxygen Gas (O_2)

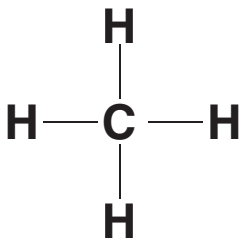


Water (H_2O)

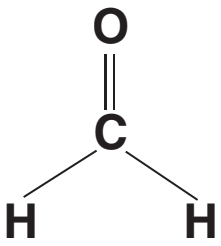
Ozone Gas (O_3)



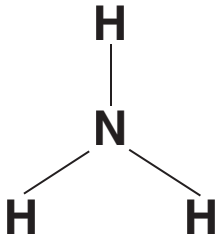
Nitrogen Gas (N_2)



Methane (CH_4)



Formaldehyde (CH_2O)

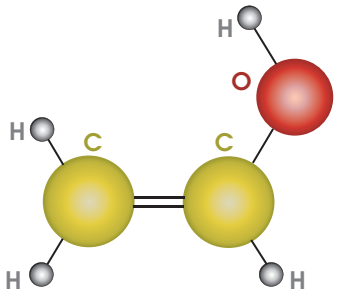


Ammonia (NH_3)

Chemical Change Reading

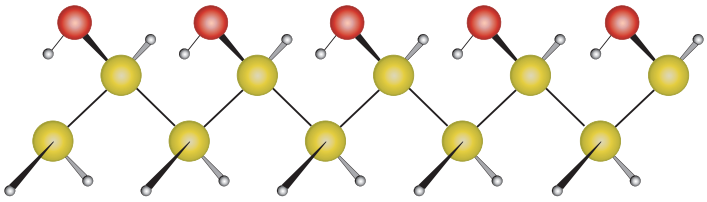
Chemical change is a process that is going on around us all the time. Substances are combining with other substances to create new ones. These new substances have properties that are different from the **properties** of the original substances.

In this lesson so far, you have observed two examples of chemical change: the production of slime and rust. Slime is a fun substance that shows what chemical change can do. Rust is a very common type of chemical change that most people try to avoid since it doesn't look very nice and can hurt the use of objects made of iron. For example, iron screws that rust can be difficult or even impossible to unscrew from what they are holding. Much of the work **chemists** have done with rust has been trying to figure out ways to prevent iron from rusting. In order to get the steel wool in your activity to rust, it first had to be soaked in vinegar. The vinegar removed a protective coating that prevents rust.

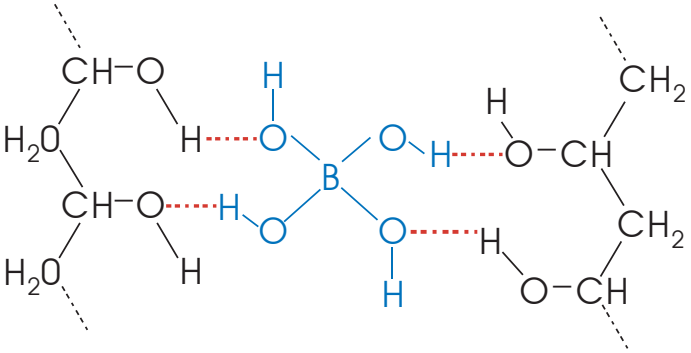


Structure of single vinyl alcohol molecule

What happened in the slime activity to form a new substance? Well, actually there are a few molecule changes that occurred. The glue contained a solution called polyvinyl alcohol (PVA) that is a molecular chain formed of a repeating pattern of atoms. When the PVA is dissolved in water, the PVA units linked up to



Polyvinyl alcohol (PVA) molecular chain



Molecular structure of polyvinyl alcohol

form even longer chains, which made the solution thick and syrupy. When the soap mixture was added to the glue mixture, the chains of the PVA cross-linked to form a new thicker, more solid gel-like substance. The new cross-links are weak, so they continually break and reform under the weight of the substance, or with handling.

Crash test with deployed airbag; Department of Transport, United Kingdom

The combining of molecules to form new molecules is one type of chemical change. Substances can change in other ways, as well. Two molecules might exchange atoms or a molecule might break down into separate atoms.

One chemical change that involves a molecule breaking down into separate substances can save your life! When there is an impact to a car with air bags, the solid sodium nitrate ($NaNO_3$) is ignited and breaks down into other substances including nitrogen gas, which expands and fills the air bags. This change happens so quickly that the bags can inflate in time to provide a cushion for people in the car.

The process of chemical change can also be called a chemical reaction. Using this language, one can describe the process of rusting as a chemical reaction between oxygen and iron. Some elements and substances react easily with other elements and substances. These are said to be more reactive elements or substances. Other elements and substances do not react very easily. These are said to be less reactive elements or inert substances.

There is one very important fact about any chemical reaction—matter is neither created nor destroyed. It simply changes from one form to another. Again consider the rusting process. The original elements that react are iron and oxygen. The substance that is made is rust (also called iron oxide). The molecules of iron oxide are made from oxygen and iron. Other chemical reactions could separate the oxygen and iron from the iron oxide. Nothing is being created or destroyed in either reaction. The atoms are being reorganized into new combinations.

Rusting barge along San Francisco Bay Trail; Association of Bay Area Governments

Most reactions are more complex. Often there are many substances involved in the reaction, and these reactions in turn produce many substances. No matter how complex the reaction, though, the fact remains true. The atoms must come from somewhere (from some elements or substances) and must go somewhere (to different substances). This is called the Conservation of Matter. Matter always comes from some source and goes to some destination. You will experiment with this idea in your next activity.