LESSON 1: Goofy Putty

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Create a new "goofy" substance by mixing a borax solution with glue.

OBJECTIVE

This lesson demonstrates the results of a chemical reaction and compares and contrasts the properties of mixtures and solutions. By making goofy putty, students learn about measurement, mixtures, solutions, physical changes, and chemical reactions. This lesson can be extended to introduce polymers.

CONTENT TOPICS

Scientific inquiry; measurement; properties of matter; chemical reactions; mixtures (solutions); polymers

MATERIALS

- ❑ White school glue
- ❑ Borax (found in the laundry detergent aisle)
- ❑ Measuring spoons
- ❑ Clear bowls, Ziploc® bags, or small cups
- ❑ Spoons
- ❑ Water

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 20 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Most of the things around us are mixtures, like the air, the ocean, lemonade, and pizza! A mixture is made of two or more substances that are combined physically. When you combine glue with water, a glue-water mixture is formed. Combining borax and water creates a borax solution.

A solution is a specific type of mixture. A solution is a uniform mixture in which one or more substances (solutes) are dissolved in another substance (solvent). However, the mixture of glue and water is not a solution, because the glue will not quite dissolve in the water.

Scientists sort matter by its physical and chemical properties. Physical properties can be observed by using our senses and taking measurements. Some examples of physical properties are color, shape, boiling point, melting point, and density. Chemical properties can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability. During the experiment, students can observe the different physical (and chemical) properties of the substances.

LESSON 1: Goofy Putty

When the glue mixture and borax solution are combined, a change occurs. Matter often changes, and these changes can be either physical or chemical. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s).

By adding the borax solution to the glue mixture, you start a chemical reaction. The glue molecules and the borax molecules react with each other to create a stretchy, bouncy new substance.

FORMULAS & EQUATIONS

Hydrous sodium borate (or sodium tetraborate decahydrate) is commonly known as borax.

The chemical formula for borax is $\mathbf{Na_2B_4O_7 \cdot 10H_2O}$ or $\mathbf{Na_2B_4O_5(OH)_4 \cdot 8(H_2O)}$.

The structure of this formula means that each sodium borate molecule has multiple water molecules attached to it.

White glue is primarily a mixture of water and polyvinyl acetate (PVAc).

Water has the formula $\mathbf{H_2O}$.

The formula for PVAc is $\mathbf{(C_4H_6O_2)_n}$. *The* n *stands for any number of molecules.*

Because there are various PVAc molecules and because different types of white glue have slightly different compositions, it is difficult to provide the exact chemical equation for the reaction of the borax solution and glue mixture. Essentially during the reaction, borate ions from the hydrous sodium borate cause the vinyl molecules in the glue to form cross-linked bonds. The formation of cross-linked bonds results in the creation of a new substance made up of a long, flexible chain of molecules.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on mixtures, physical and chemical properties, and chemical reactions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry.*
- Additional information on solutions can be found in the Chemicals by Volume— Solutions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

▶Mixing white school glue and borax will create a new substance that has different properties than the original substances.

Fun Fact

Initially, Silly Putty® was a novelty item marketed toward adults. In 1955, the market for the item changed, and Silly Putty® became a popular toy among kids between the ages of 6 and 12.

LESSON 1: Goofy Putty

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 20, but focus the lesson on describing and classifying matter. Discuss physical properties in more detail and the different uses of different substances.

Another option is to spend more time on the concepts of mixtures, solutions, and chemical reactions. Use pictures and have students write down or state their answers of whether a certain substance is a solution or simply a mixture. For example, show a picture of apple juice—solution. Show a picture of chicken noodle soup—mixture. After students complete this exercise, be sure to remind them that solutions are a type of mixture. Therefore, apple juice is a mixture *and* a solution.

Likewise, use the same method to go over physical and chemical changes in more detail. For example, show a picture of a pencil. Then show a picture of the pencil broken—that's a physical change. Next, show a picture of cake batter and then a baked cake—that's a chemical change!

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Create a polymer by mixing a borax solution with glue.

OBJECTIVE

This lesson demonstrates the results of a chemical reaction, compares and contrasts the properties of mixtures and solutions, and introduces polymers. By making goofy putty, students learn about measurement, mixtures, solutions, physical changes, and chemical reactions, as well as polymers.

OBSERVATION & RESEARCH

A **molecule** is the smallest particle of an element or compound that maintains the chemical properties of that element or compound. It is composed of two or more atoms chemically bonded together by an exchange or sharing of electrons. At the beginning of the 20th century, chemists learned how to create special molecules by combining many smaller molecules in a regular pattern.

These large molecules are called polymers. **Polymers** are long, chain-like molecules that are formed by connecting many repeating units (monomer units). The most common polymers are made of long chains of carbon atoms. A **monomer** is a single molecule capable of combining with other similar molecules.

When you combine the glue and the borax solution, you start a chemical reaction. A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed. During a chemical reaction, the structure or composition of the materials changes. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). When combined, the glue molecules and the borax molecules react with each other and bond together to make a tangled structure of long, flexible, cross-linked chains. This giant molecule, a polymer, is made up of thousands of smaller molecules. Like the goofy putty created in this lesson, nylon and plastics are also polymers.

Borate ions, provided by the borax (hydrous sodium borate), cause the vinyl molecules in the glue to form cross-linked bonds. The process of **cross-linking** continues to alter the physical properties of the polymer. As more and more bonds are formed, the characteristics of the polymer change. The polymer will eventually become brittle as additional cross-linked bonds are formed.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on polymers can be found in the Industrial Applications of Chemistry section of CEF's *Passport to Science Exploration: Chemistry Concepts in Action.*

LESSON 1: Goofy Putty

EXPERIMENTATION

As the students perform the experiment, challenge them to identify the independent, dependent, and controlled variables, as well as whether there is a control setup for the experiment. (Hint: If the amount of borax added to the glue and water mixture changes, do the results change?) Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss variables.

EXPERIMENTAL PROCEDURE

1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue and mix well. (This may be a good time to discuss mixtures.)
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well. The solution will become saturated, so all of the borax will not dissolve. (This may be a good time to discuss the difference between solutions and mixtures. You may also choose to discuss saturation.)
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance and knead it with your hands for one to two minutes.

During this experiment, you will be measuring and mixing substances. If the measurements are not exact, the experiment will not work correctly. If goofy putty doesn't form, see if the students can guess why and then come up with a way to correct the problem, such as adding more borax, adding more glue, or just starting over.

DATA COLLECTION

Have students record data in their science notebooks or on the following activity sheet. For example, what measurements did they use? What physical properties did they observe? You can use the table and Venn diagram provided in the activity sheet (or similar charts of your own) for students to record their data.

NOTES

LESSON 1: Goofy Putty

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to …

- Apply a scientific inquiry process and perform an experiment.
- Understand the importance of measuring the correct quantities to obtain desired results.
- Compare and contrast mixtures and solutions.
- Identify the physical properties of the substances before and after the experiment.
- Define and identify chemical reactions.
- Differentiate between monomers and polymers (see ***Differentiation in the Classroom***).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples or have a discussion to generate other ideas as a class.

- Add some color to your lesson! Students can make their goofy putty different colors by adding food coloring. They'll simply add one drop of food coloring to the glue mixture and stir until the color seems to be spread throughout. Then, when they add the borax solution to their colored glue mixture, their goofy putty will turn out colorful as well! You can also have some students add color after the goofy putty has formed and they have shaped it into a ball. Then, cut open one goofy putty ball that had color added to the glue and water mixture, and cut open another goofy putty ball that had color added once the goofy putty ball was formed. The color added later in the process is not absorbed all the way into the ball. (You may want to have students use plastic bags or gloves when adding color to avoid getting the dye all over their hands.)
- Challenge your students with the question: Is goofy putty a solid or liquid? Let them discuss why they think one way or the other. Then you can explain that it is actually a viscoelastic liquid, which is a material that demonstrates viscous (resistance to flow) and elastic (solid) properties.

REAL-WORLD APPLICATIONS

- If done correctly, the goofy putty should resemble Silly Putty®. Have your students explore the history of Silly Putty®, which was created when engineer James Wright was attempting to create a synthetic rubber for truck tires. Use this example to explain that when doing experiments, scientists do not always get the result they want, but they still may discover something unique!
- Chemical reactions are everywhere and so are polymers! Polymers, like synthetic rubber, plastics, Teflon® (a nonstick coating used for cooking products), and Kevlar® (a synthetic fiber used in bullet-resistant products) have been produced through chemical reactions in laboratories.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the ***Scientific Inquiry*** section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 1 ACTIVITY SHEET: Goofy Putty

OBSERVE & RESEARCH

1. Write down the materials you observe. _____

_____

_____

2. Predict how these materials may be used. _____

_____

_____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture		
Solution		
Physical property		
Chemical property		
Physical change		
Chemical reaction		

4. Consider what will happen if white school glue, water, and borax are combined and why.

▶**Write your hypothesis.** _____

_____

_____

LESSON 1 ACTIVITY SHEET: Goofy Putty

PERFORM YOUR EXPERIMENT

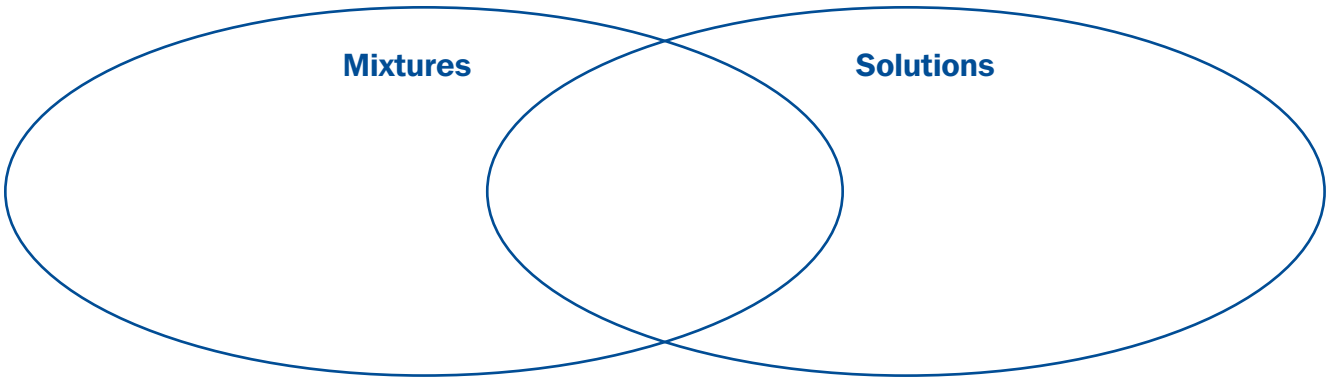
1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue, and mix well.
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well.
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance, and knead it with your hands for one to two minutes.

ANALYZE & CONCLUDE

1. List the physical properties of each substance in the table below.

Glue	Borax	Goofy Putty
White...		

2. Compare and contrast mixtures and solutions.



3. What happens when you combine the borax solution and glue mixture? Explain how you know. _____

_____

_____

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _____

_____

_____

LESSON 1 ACTIVITY SHEET: Goofy Putty

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule		
Monomer		
Polymer		

2. List other substances that are polymers or are made of polymers. _____

_____

_____

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

OBSERVE & RESEARCH

1. Write down the materials you observe. Glue, borax, water, measuring spoons …

2. Predict how these materials may be used. Glue may be used to hold things together. Borax may be used to clean things. Water may be used for drinking, cleaning, and many other things. The different materials may be combined to create something new.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Mixture	A physical combination of two or more substances that can be physically separated.	
Solution	A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent).	
Physical property	A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance.	
Chemical property	A property of a substance that can be revealed by the way the substance interacts with other substances; describes an object's "potential" to undergo some chemical change or reaction due to its composition.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a chemical change.	

4. Consider what will happen if white school glue, water, and borax are combined and why.

▶**Write your hypothesis.** Mixing white school glue, water, and borax will create a new substance that has different properties than the original substances.

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

PERFORM YOUR EXPERIMENT

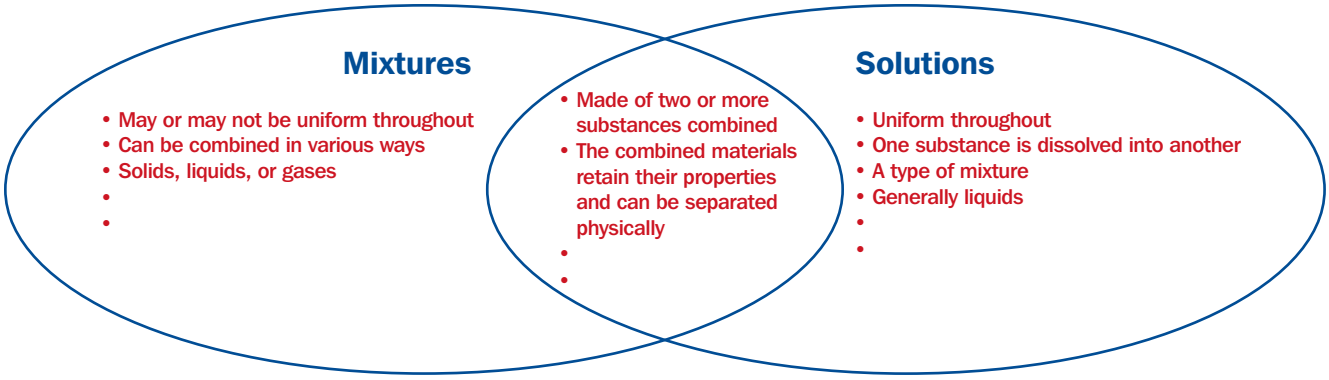
1. Put one teaspoon of water into your cup or bowl. Add one teaspoon of white glue, and mix well.
2. In another cup or bowl, create your borax solution. Mix one teaspoon of borax with four teaspoons of water. Stir well.
3. Add one teaspoon of the borax solution to your original cup of glue and water. Stir for 60 seconds.
4. Remove the substance, and knead it with your hands for one to two minutes.

ANALYZE & CONCLUDE

1. List the physical properties of each substance in the table below.

Glue	Borax	Goofy Putty
• White • Sticky • Viscous—it flows slowly • •	• White • Powdery • Granular—grainy • •	• White (unless food coloring is added) • Stretchy • Can be molded into different shapes • •

2. Compare and contrast mixtures and solutions.



3. What happens when you combine the borax solution and glue mixture? Explain how you know. A chemical reaction occurs. The resulting substance (the goofy putty) has different properties than the original substances.

4. Is your hypothesis valid? Why or why not? If not, what would be your next steps?

Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as …

LESSON 1 ACTIVITY SHEET: Goofy Putty

ANSWER KEY: *Below are suggested answers. Other answers may also be acceptable.*

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Molecule	The simplest structural unit of an element or compound that is made up of atoms held together by chemical bonds and maintains the chemical properties of the element or compound.	
Monomer	A single molecule capable of combining with other similar molecules to form a polymer.	
Polymer	A large molecule formed by combining many smaller molecules (monomers) in a regular pattern.	

2. List other substances that are polymers or are made of polymers. Plastic bottles, rubber bands, tires, polyester clothing, nylon (tights), DNA, proteins …