Bouncing Polymers

PRINCE WILLIAM SOUND RCAC REGIONAL CITIZENS' ADVISORY COUNCIL

Grade Level: 7-12
Length: 60-90 minutes
www.pwsrcac.org/lesson

NGSS Standards

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.

Crosscutting Concepts

Structure and Function The way an object is shaped or structured determines many of its properties and functions.

Scale, Proportion, and Quantity In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

Related Resources

Worksheets Bouncing Ball Data Sheet

Video
https://www.youtube.com/watch?v=khTT2aA4Dng

Overview

Polymers, composed of many molecules cross-linked together, have a wide variety of uses based on their chemical and physical properties.

Objectives

- Students will understand the definition of a polymer.
- Students will create four different polymers in a lab setting.
- Students will compare the characteristics of different polymers.

Materials

- ☐ Elmer's® White Glue-All (2 tablespoons per ball)
- ☐ Elmer's® Blue Glue Gel (2 tablespoons per ball)
- ☐ Borax powder, $Na_2B_4O_7 \cdot 10H_2O$ (1/2 teaspoon per ball)
- ☐ Liquid latex rubber, from craft or hobby store (1 Tbsp per ball)
- ☐ Household vinegar: 5% acetic acid, CH_3COOH (1 Tbsp per ball)
- ☐ Saturated sodium silicate solution, Na_2SiO_3 (aq), (12 mL per ball)
- ☐ 50% ethanol solution, C_2H_5OH (aq), (3 mL per ball)
- ☐ Small disposable plastic cups
- ☐ Plastic stirring rods or wooden sticks
- ☐ Tablespoons and teaspoons
- ☐ Scale
- ☐ Graduated Cylinders
- ☐ Tap water
- ☐ Small Ziploc bags
- ☐ Permanent Marker
- ☐ Paper Towels
- ☐ Bouncy Ball
- ☐ Gumdrops in 3 colors or a molecular modeling kit

Notes

Materials (continued)

- ☐ Toothpicks or a molecular modeling kit
- ☐ Science Notebooks or paper
- ☐ Pencils
- ☐ Worksheet: Bouncy Ball Data Sheet

Background

Polymers are composed of many, often thousands, of small molecules cross-linked to form a macromolecule. Petroleum-based polymers are used for a variety of things we use in everyday life and advanced technology. This lab explores four types of elastic polymers.

>> *Adaptation: If you prefer to use simple, everyday materials you can create and compare only the first two polymers.*

Preparation

1. This activity needs to be performed in a well-ventilated area. Use proper safety precautions at all times, including safety goggles and rubber gloves.
2. Borax is an eye irritant. Liquid latex is preserved in ammonia – avoid inhaling or direct contact with skin or eyes. Sodium silicate solution can irritate the skin.
3. Keep ethanol away from flames, as it is flammable.
4. Set up computer and projector or SmartBoard to show the “How It’s Made – Plastic Bags” video by the Discovery Channel on YouTube (link as of August 2020 is https://www.youtube.com/watch?v=khTT2aA4Dng). This video on YouTube sometime begins with advertisements, so play through these during your preparation.

Introducing the Lesson

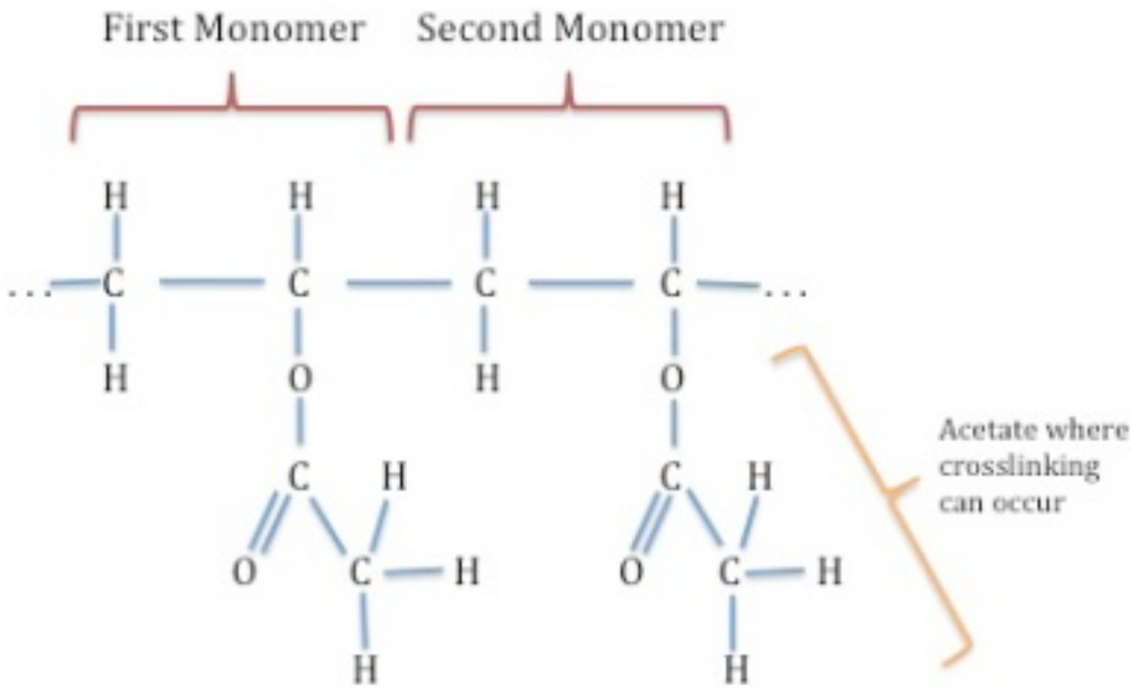
1. Present students with a common polymer, such as a Styrofoam cup or piece of plastic wrap. Ask them to describe its properties. Explain that it is a polymer, composed of many small molecules cross-linked to each other.
2. Show “How It’s Made – Plastic Bags,” a YouTube video by the Discovery Channel. Ask students to write down questions and comments in their science notebooks during the video. Discuss their questions and comments, as well as overall reactions to the video, afterwards.

3. An introduction to the basic molecular structure of hydrocarbons will lay the foundation for the lesson. Explain that the plastic production process often begins by treating components of crude oil or natural gas in a "cracking process." This process creates hydrocarbon monomers such as ethylene and propylene. The monomers are then chemically bonded together to form chains called polymers. In the video, the polyethylene is a polymer made of ethylene monomers. Polymers then crosslink to create a 3D structure. Simply put, polymers are chemicals made of many repeating units. Assist students to visualize the structure of polymers at the molecular level.
4. Polymers are a very important part of our lives. Natural polymers include rubber, silk, plant cellulose & starches, DNA, and proteins such as keratin (wool, hair, feathers) and gelatin (like in jello). There are hundreds of synthetic polymers including glue and plastics such as:
   - Bags and food wraps
   - Polystyrene foam cups, plates, and takeout containers
   - Bottles (soda, juice, milk, water, etc.)
   - Nylon rope and fishing line
   - Clothing (synthetic fleece, spandex, nylon, etc.)
   - Neoprene wet suits
   - PVC plastic pipes
   - Teflon pots and pans
   - Credit and ID cards
   - Absorbent part of disposable diapers
5. Brainstorm with the class why polymers are useful (they are strong and can be flexible), and have students write at least three important uses for polymers in their science notebooks.

Activity

1. Present students with the chance to create their own polymers and shape them into bouncy balls.
2. Divide students into lab groups of 3-4. Provide safety equipment to all students (gloves and safety goggles) and remind them of safe lab procedures.
3. Begin with polymer #1. Explain to students that white Elmer's glue is already primarily composed of the polymers polyvinyl acetate and polyvinyl alcohol. In this experiment they used borax (sodium borate) to crosslink these chain polymers to create a different polymer. The chain polymer is made up mostly of monomers of polyvinyl acetate ($C_4H_6O_2$) linked together.

4. Provide each group with gum drops in three colors and toothpicks, as well as a diagram of the molecular structure of a chain of polyvinyl acetate.
5. Ask them to create a molecular model using the gumdrops and toothpicks. Each color of gumdrop can be a different element (Carbon, Hydrogen, and Oxygen) and the toothpicks represent the bonds between them. Below is a diagram of the molecular structure of polyvinyl acetate. Since it is a polymer, after all, the smaller monomers repeat over and over again. The diagram below has two molecules of the monomer C4H6O2 linked together:

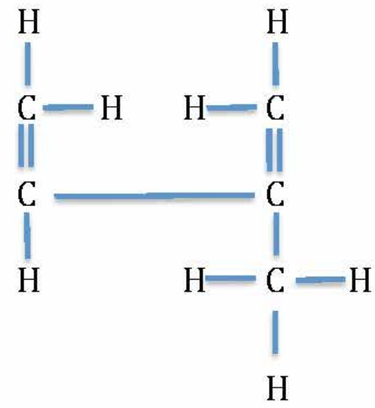


6. Once each group has created their basic polyvinyl acetate model with gumdrops, explain that the borax (sodium borate) crosslinks these polymers at the acetate groups (C2H3O2) that "hang off" the polymer. This results in the long chains of polyvinyl acetate being linked together, which reduces the viscosity of the compound, making it more solid and "bouncy."
7. Have students draw their models in their science notebooks. Now that they have made a model of the molecular structure, it is time to make their own bouncy ball with this polymer.
8. Each group should measure 2 tablespoons of white Elmer's glue into a disposable cup and then stir in 1/2 teaspoon borax until the mixture clumps to the stirring stick. Students then pull the polymer off the stick, rinse it under running water, form into a ball, pat dry with paper towels and place into a Ziploc bag. Label as "Polymer #1".
9. Move on to polymer #2. This polymer is also based on the cross-linking of polyvinyl acetate and polyvinyl alcohol, but slightly

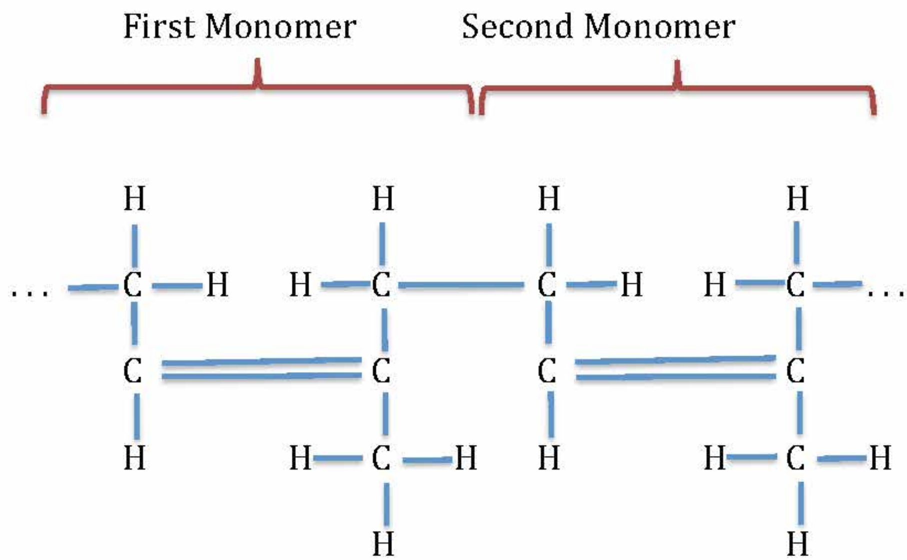
different ratios of these polymers and water results in a slightly different end polymer.

10. Each group needs to measure 2 tablespoons of blue Elmer's glue into a disposable cup and then stir in ½ teaspoon until the mixture clumps to the stirring stick. Again, students should remove, rinse, shape, and dry the polymer before placing it into a bag labeled "Polymer #2."
11. Polymer #3 is a bit trickier. It should be created in a well-ventilated area or under a fume hood. In nature, latex rubber in water polymerizes when it hits oxygen, protecting cuts in the rubber tree. To preserve liquid latex, ammonia is added. Small polymers, or "globs," of rubber are kept separate from each other by the ammonia. When vinegar is added, the pH of the solution changes and the small rubber polymers begin to link together, forming a larger rubber polymer. Rubber is the simple crosslinking of the monomer isoprene (C5H8) into the polymer poly-cis-isoprene. Students can create gumdrop models of isoprene rubber, and, with prior knowledge of how hydrogen and carbon bond, manipulate the isoprene monomers to create polyisoprene polymers:

Isoprene Monomer:



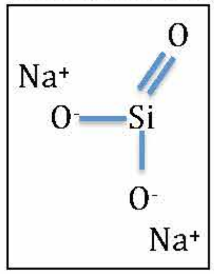
Poly-cis-isoprene Polymer:



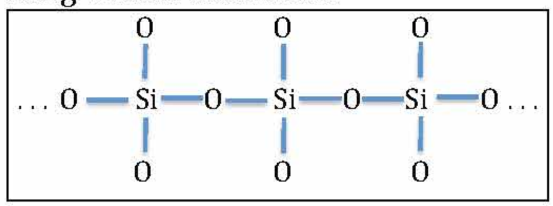
12. To make poly-cis-isoprene, have students measure 1 tablespoon of liquid latex rubber into a disposable cup and mix it with 1 tablespoon tap water. Students should slowly add 1 tablespoon of vinegar to the latex while constantly stirring. After the mixture starts to get rubbery, students should remove it, rinse it under running water, shape, dry, and store in a bag labeled "Polymer #3."
13. Finally, have students create polymer #4. In this experiment, sodium silicate (Na2SiO3) is dissolved in water (H2O). At this point, the solution becomes basic because sodium silicate creates sodium hydroxide (NaOH). In this basic solution, the remaining silicon dioxide (SiO2) links together to form long chains of silicate. When ethanol (C2H5OH) is added, the chains are cross-linked when molecules of ethyl replace two molecules of oxygen in the silicate chain. Of the four polymers, this is the most complex model to create. It may be best drawn on the board,

rather than created with gumdrops and toothpicks, unless you want a challenge!

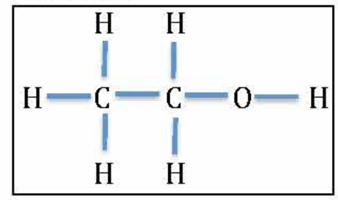
Sodium silicate:



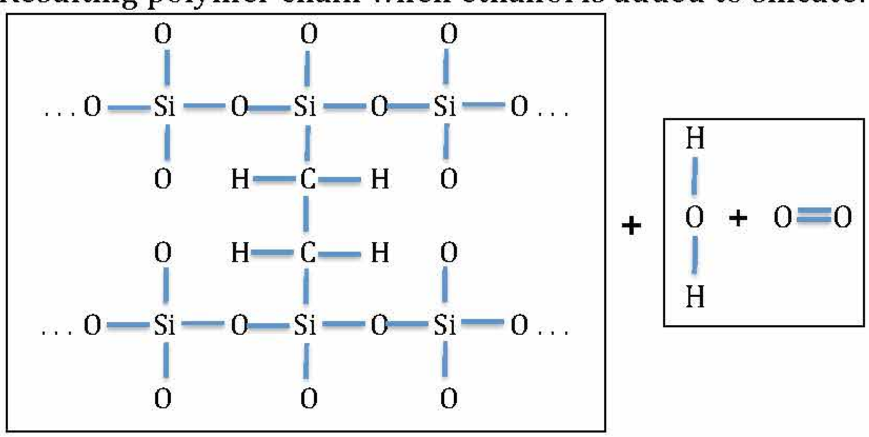
Long chains of silicate:



Ethanol:



Resulting polymer chain when ethanol is added to silicate:



14. Finally, have students create polymer #4 by measuring 12 mL of sodium silicate solution into a disposable cup and mixing in 3 mL of 50% ethanol solution. Once a polymer forms, students should remove it and hold it in the palm of a gloved hand. They will need to gently press on it, occasionally moistening with water. As the ball forms, a mixture of water and ethanol will be pushed out. Students should pat the ball dry with a paper towel and place it in a bag labeled "Polymer #4."
15. Have students examine the bouncy balls, describe their physical appearance, and complete the bouncy ball data sheet. Some playfulness should be encouraged, in a safe manner (not near lab equipment).

Wrap-up

Review the polymers created in the lab. Compare them with a commercially produced bouncy ball. Have students vote on the "best" bouncy ball. Ask students respond to the following prompts in their science notebooks:

- Make a list of at least ten polymers you use in your life
- Prioritize them from most to least important
- Circle the polymers that you think come from petroleum products
- Pick one polymer that is a synthetic material made from natural resources. Describe at least one way this synthetic material positively affects society and one way this synthetic material negatively affects society.

Ask students to share their lists in small groups. As a whole class, spend a few minutes discussing ways to reuse and recycle these polymers when they are used.

Assessment

Observe student participation during group work. The successful creation of polymer bouncy balls can be used as a measure of cooperation, student understanding, and ability to follow multi-step directions and measure ingredients. Assess student data sheets for completeness, neatness, and accurate work. Because the characteristics of each polymer will vary based on factors such as brand of material used and temperature of the room, use common sense, your own observations, and comparisons to other student answers to evaluate. Students who successfully meet the performance expectation will create a gumdrop and toothpick model of two polymers and draw the models in their science notebook. Their entries in their science notebooks should reflect understanding that petroleum-based polymers are derived from natural, nonrenewable resources and impact society.

Bouncy Ball Data Sheet

	Polymer #1	Polymer #2	Polymer #3	Polymer #4
Components/ Ingredients				
Color				
Texture				
Volume				
Density				
Average Bounce Height at room temperature				
Observations & average bounce height after placing plastic bag with polymer in ice water for 2 minutes				
Observations & average bounce height after placing plastic bag with polymer in boiling water for 2 minutes				

Which polymer do you think makes for the best bouncy ball? Why?