Title: Bouncing Polymers

Adapted from *That's the Way the Ball Bounces: A Polymer Education Lab Module for K-12,* by Lauri McDonald and Ann Sullivan, http://pslc.ws/macrog/activity/ball/main.htm.

Theme: 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 what a polymer is.
- Students will create four different polymers in a lab setting.
- Students will compare the characteristics of different polymers.

Duration: 60-90 minutes

Age Range: 7^{th}-12^{th}

Materials:

- Elmer's® White Glue-All (2 tablespoon per ball)
- Elmer's® Blue Glue Gel (2 tablespoon per ball)
- Borax powder, $Na_2B_4O_7 \cdot 10H_2O$ (1/2 teaspoon per ball)
- Liquid latex rubber, from local craft or hobby store (1 tablespoon per ball)
- Household vinegar: 5% acetic acid, CH_3COOH (1 tablespoon 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
- Safety/Lab goggles
- Rubber gloves
- Tablespoons
- Teaspoons
- Scale
- Graduated Cylinders
- Tap water
- Small Ziploc bags
- Permanent Marker
- Paper Towels
- Gumdrops in different colors
- Toothpicks
- Bouncy Ball
- Scale

- Ruler
- 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 4 types of elastic polymers. If you prefer to use simple, everyday materials you can create and compare only the first two polymers.

Preparation:

This activity needs to be performed in a well-ventilated area. Use proper safety precautions at all times, including safety goggles and rubber gloves. 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. Keep ethanol away from flames, as it is flammable.

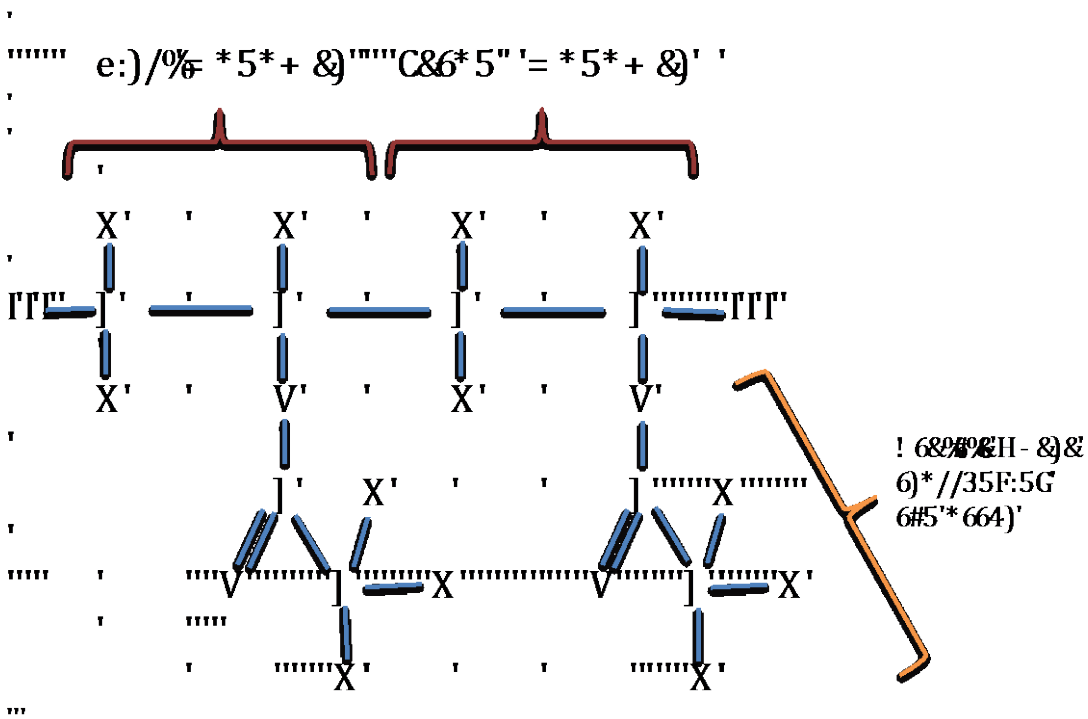
Introduction:

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. A polymer is a substance that is composed primarily of similar units or small molecules cross-linked to each other and bonded together. The properties of a polymer depend on what beginning molecules are used and how they are cross-linked. Polymers may be flexible, rubbery, hard, or sticky.

Activities & Procedures:

Present students with the chance to create their own polymers and shape them into bouncy balls. 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.

Begin with polymer #1. Explain to students that white Elmer's glue is already made up mostly of the polymers polyvinyl acetate and polyvinyl alcohol. In this experiment they are going to use borax (sodium borate) to cross-link these polymers to create a different polymer. It is made up mostly of monomers (smaller molecules) of polyvinyl acetate ($C_4H_6O_2$) linked together. Provide each group with gum drops in three colors and toothpicks, as well as a diagram of the molecular structure of polyvinyl acetate. 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 model 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 $C_4H_6O_2$ linked together:



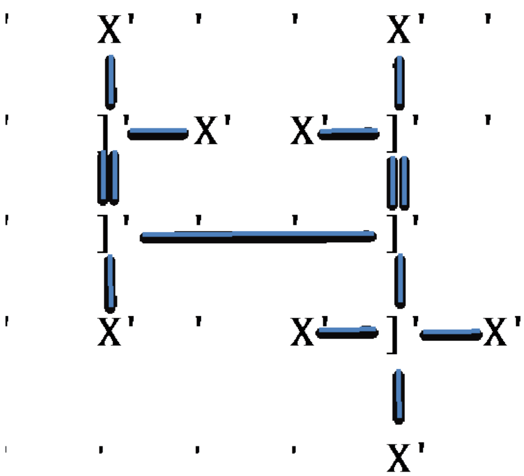
Once each group has created their basic polyvinyl acetate model with gumdrops, explain that the borax (sodium borate) crosslinks these polymers at the acetate groups ($C_2H_3O_2$) that "hang off" the polymer. This results in the long chains of polyvinyl acetate being linked together, which reduces the viscosity of the compound, making it more solid and "bouncy." Now that students understand the basic chemistry, let them give it a go!

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."

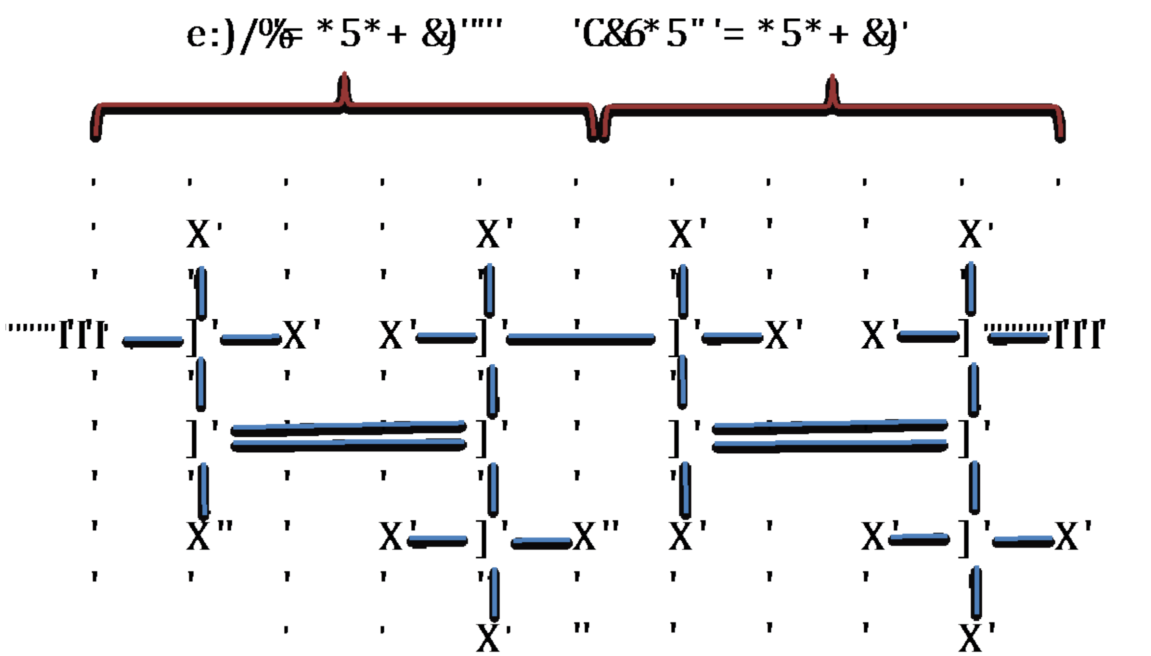
Move on to polymer #2. This polymer is also based on the cross-linking of polyvinyl acetate and polyvinyl alcohol, but slightly different ratios of these polymers and water results in a slightly different end polymer. Each group needs to measure 2 tablespoons of blue Elmer's glue into a disposable cup and then stir in ½ teaspoon borax 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."

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 (C_5H_8) 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:



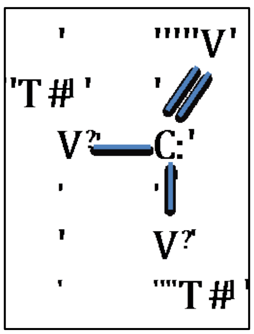
Poly-cis-isoprene Polymer:



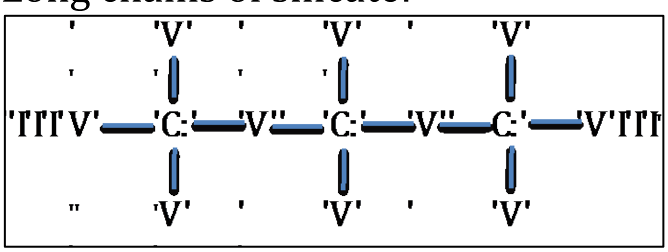
To make poly-cis-isoprene, have students measure 1 tablespoon of liquid latex rubber into a disposable cup and mix it with 1 tablespoon tap water. Students should slowly add 1 tablespoon of vinegar to the latex while constantly stirring. After the mixture starts to get rubbery, students should remove it, rinse it under running water, shape, dry, and store in a bag labeled "Polymer #3."

Finally, have students create polymer #4. In this experiment, sodium silicate (Na_2SiO_3) is dissolved in water (H_2O). At this point, the solution becomes basic because sodium silicate contains sodium hydroxide (NaOH). In this basic solution, the remaining silicon dioxide (SiO_2) links together to form long chains of silicate. When ethanol (C_2H_5OH) 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 complicated to model using gum drops. The diagram is included below, but may be best illustrated as a class on the board rather than with gum drops.

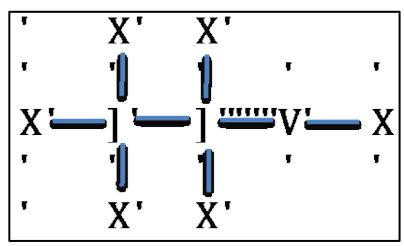
Sodium silicate:



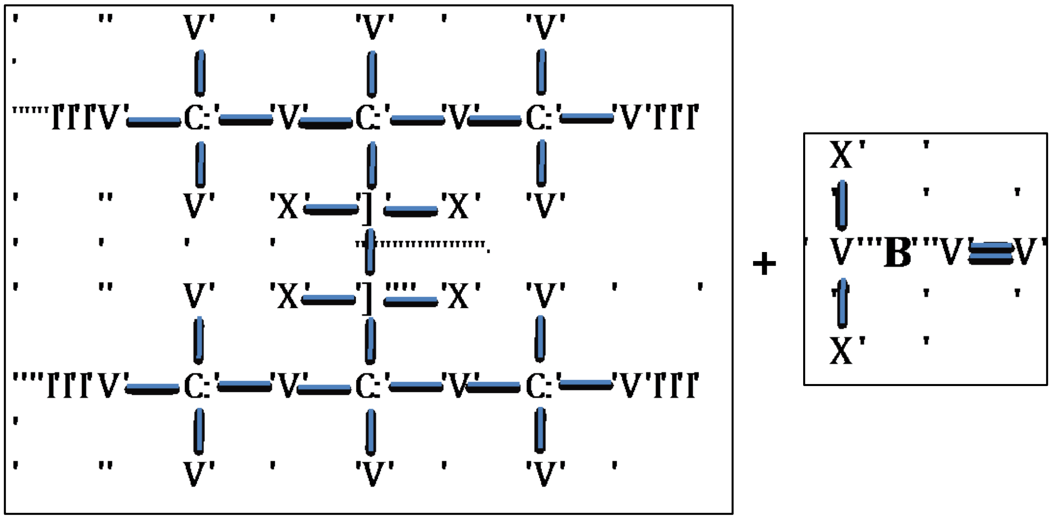
Long chains of silicate:



Ethanol:



Resulting polymer chain when ethanol is added to silicate:



Begin 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.”

Have students examine the bouncy balls, describe their physical appearance, and complete the bouncy ball data sheet.

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.

Then explain that 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
- Soda, juice, milk, and water bottles
- Nylon rope and fishing line
- Clothing such as synthetic fleece, spandex, and nylon
- Neoprene wet suits
- PVC plastic pipes
- Teflon pots and pans
- Credit and ID cards
- Absorbent part of disposable diapers

Ask students to make a list of all the polymers they use in their lives and prioritize them from most to least important. Identify which of these polymers come from petroleum products (hint: pretty much all plastic products!) and discuss ways to reuse and recycle these polymers.

Evaluation:

The successful creation of polymers will serve as a formative assessment of students' ability to follow multi-step directions and measure appropriately. 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 answers on the data sheet. Observe student cooperation, participation, and adherence to lab safety guidelines during group work. Evaluate molecular models for accuracy.

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?

Bouncing Polymers

Science As Inquiry and Process: Students develop an understanding of the processes and applications of scientific inquiry.

SA1
Students develop an understanding of the processes of science used to investigate problems, design and conduct repeatable scientific investigations, and defend scientific arguments

The student demonstrates an understanding of the processes of science by:

[6, 7, 8, 9] SA1.1 asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating

Concepts of Physical Science: Students develop an understanding of the concepts, models, theories, universal principles, and facts that explain the physical world.

SB1 Students develop an understanding of the characteristic properties of matter and the relationship of these properties to their structure and behavior.

The student demonstrates understanding of the structure and properties of matter by:

[6] SB1.1 using models to represent matter as it changes from one state to another

SB3 Students develop an understanding of the interactions between matter and energy, including physical, chemical, and nuclear changes, and the effects of these interactions on physical systems.

The student demonstrates an understanding of the interactions between matter and energy and the effects of these interactions on systems by:

[8] SB3.2 exploring through a variety of models (e.g., gumdrops and toothpicks) how atoms may bond together into well defined molecules or bond together in large arrays