**MIDDLE SCHOOL**

**Green Chemistry**



**Polymer Properties**

**Background:** Plastics are an integral part of our modern world. But what makes plastics unique compared to other materials? At the molecular level, plastics are made up of long chains of repeating molecules called monomers. The name monomer is derived from the Greek works *mono* meaning *one* and *meros* meaning *part*. When strung together in a long chain, these monomers make up what are known as *polymers*. Polymers, or plastics, are used in a huge range of applications, from technology to packaging and everything in between.

These polymers can have different properties depending on how they are connected to each other. Some polymers will *cross-link* in an organized, grid-like fashion, while *branched* polymers will seem to attach in more random patterns. Most plastics are also derived from non-renewable resources like petroleum.

In this lesson, students will explore the basics of polymer science, using pipe cleaners and colored penne to create models. Then, students will create two different slimes using chemical reactions and consider the difference between naturally derived and synthetic materials.

**Additional Resources:**

*Natural vs Synthetic Polymers*

<http://byjus.com/chemistry/differentiate-natural-polymers-from-synthetic-polymers-and-properties/>

*What are Plastics?*

<https://www.plasticsmakeitpossible.com/about-plastics/types-of-plastics/what-are-plastics/>

**Objectives:** Students will….

* Make several polymers
* Make qualitative observations about monomers, cross-linking chemicals, and polymers
* Compare the properties of natural versus synthetic polymers

**Key terms:** polymers, cross-linking, renewable and nonrenewable resources, biodegradability

**Materials (per student group):**

Pipe cleaner engineering challenge:

* Pipe cleaners (15 per group of 2–3, plus 1 per student)
* Tri-color penne pasta (10 pieces per student)
* Spring scales or slotted weights with hanger

Polymer/Slime 1:

* 250-mL beakers
* Graduated cylinder
* Powdered milk
* White vinegar
* Marker
* Paper towel
* Balance or scale
* Stirring rod
* Water
* Weigh boat

(Shared supplies)

* Hot pot
* Waste container
* Baking soda

Polymer/Slime 1:

* 250-mL beakers
* Graduated cylinder
* 4% Borax solution
* Glass stirring rod
* White Elmer’s Glue
* Water

**Time Required:** 60-minute class period

**Standards Met:**

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

**MS-PS1-2.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

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

**Keys to Success:**

* In the pipe cleaner engineering design challenge, there are many ways to measure the weight each shape can hold. A spring scale of slotted weights with a hanger can be used, a basket can be configured to put individual weights in, or other objects of a normal size, like binder clips, can be used for a qualitative measurement.
* Groups of 3 may be ideal for the engineering design challenge. One student will hold the shape, one will hold a ruler to measure the distortion, and one student will add weight.
* **Disposal information:** All products in this lab should be placed in a trash receptacle, as slimes can clog drains and pipes. Remember to have your students neutralize the whey waste from the Polymer 1 lab. If the slimes go into the sink, flush with copious amounts water to dilute.

**Teacher Preparation:**

* Prepare the borax solution (15 g borax in 250 mL of water).
* Set out all materials needed to make both polymers.

**Procedure:**

5E Procedure:

*Engage:*Students define polymers as long, repeating chains of monomers.

* Invite the class to think about what makes plastics unique. Ask them to share their ideas and capture any important considerations on the board.
* Pass out one pipe cleaner to each student and tell the class that they will be making a model of a plastic together.
* Tell students that they will use pasta to string a pattern on their pipe cleaner (it could involve one, two, or all three colors). Allow students to choose about 10 pieces of pasta for their pattern and to string them on the pipe cleaner.
* Share with the class that each individual piece of pasta represents what is called a *monomer*. Ask the students if anyone can remember from math class what “mono” means.
  + *Note:* The word *monomer* comes from the root words “mono,” meaning “one” and “meros,” meaning “part.”
* Explain that when monomers are strung together in a pattern, there is a particular name given to that type of molecule. If monomer means “one part,” what might we call it when there are *many* parts, like on our pipe cleaner? A *polymer*.
  + *Hint:* In geometry, what do we call a closed shape with many sides? A *poly*gon.
* Explain that a polymer is a group of monomers that are strung together to form a long chain of repeating units, like each student’s pipe cleaner strands. We can expand these chains or make them shorter, depending on the properties we want our polymer to have. Polymers are what make up the materials we call *plastics*.
* Allow students to attach their pipe cleaner strand to a neighbor’s to make their chains longer. Ask students to share their observations about how the properties of their chain might change now that it is longer.

*Explore:*Students consider the uses and applications of polymers through a short engineering design challenge.

* Explain the engineering design challenge to students: each group will be given 15 pipe cleaner “polymer strands” without pasta. Their goal is to make a three-dimensional object that can hold weight (hanging from below) without distorting its overall shape. The shape that holds the most weight while distorting the least will win the challenge.
* Divide the class into groups of 3 or 4 students, pass out pipe cleaners, and allow students 10 minutes to work on their challenge.
* After 10 minutes, have group take turn testing their designs in front of the class using the spring scales or weights.

*Explain:* Students consider the different types of polymer linkages using the three-dimensional shape they created.

* Ask students to return to their seats with their groups.
* Explain that when chemists create new polymers and make plastic structures out of them, they will often link them together in different ways.
* Use the PowerPoint to show the pictures of pipe cleaners representing branched polymers and cross-linked polymers. Ask students to raise their hands if they can identify branched polymers in their shape, and then if they can identify cross-linked polymers in their shape.
* Show the slide with the picture of the mycelium. Ask the class to share any observations they have about similarities and differences between the polymers they just considered and the mycelium.
* Ask the class to share what properties their mycelium cell phone case might have because of its similarities to polymers.

*Extend/Elaborate:* Students perform a hands-on lab to make and compare a synthetic and a natural polymer.

* Explain to the class that they will be comparing a natural polymer to a synthetic polymer. As a refresher, ask the class to define “natural” and “synthetic.”
* Tell the class that they will be making slime. Together, come up with the design criteria for a good slime and write them on the board.
* Pass out the Polymer Properties Student Lab Reports to the class and go over the two procedures with the class.
* Divide the class in half for the labs and have them fill in their predictions on their lab reports
* Have students follow the lab report to perform both experiments and capture their observations.
* When students have completed the lab and cleaned up their stations, have pairs complete the Discussion and Conclusion sections of their lab reports.

*Evaluate:*Students discuss as a class their conclusions from their experiments and decide which polymer is “greener.”

* Invite the class to share their answers from the Conclusion section of their lab reports.
* After groups have shared their thoughts and observations, ask the class to vote on which polymer slime they believe is greener, taking cost, safety, and performance into consideration.
* Collect student lab reports for evaluation.

**Polymer Properties Student Lab Report**

**Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Pre-lab:**

Draw the process of a monomer becoming polymer.

**Prediction:**

Read through the materials list for both types of slime and predict which polymer will be “greener.” Justify your prediction.

**Polymer/Slime 1:**

**Materials:**

* 250-mL beakers
* Graduated cylinder
* Powdered milk
* White vinegar
* Marker
* Paper towel
* Balance or scale
* Stirring rod
* Water
* Weigh boat

(Shared supplies)

* Hot pot
* Waste container
* Baking

**Procedure:**

1. Complete the Slime 1 table as you run your experiment.
2. Measure 9 g of powdered milk in a weigh boat.
3. Write your observations of the powdered milk in the Slime 1 table.
4. Pour the powdered milk into the 250-mL beaker and label it “milk solution.”
5. Measure 60 mL of hot water from the class hot pot into your graduated cylinder.
6. Add the hot water to the 250-mL beaker and stir with the stirring rod until the powdered milk is dissolved.
7. Measure 15 mL of white vinegar into a graduated cylinder and record your observations in the Slime 1 table.
8. Pour the vinegar into the 250-mL beaker and stir thoroughly.
9. Once the solid material cools down, take the slime out of the beaker, handle it, and record your observations in the data table.
10. Neutralize your waste liquid (whey) with 2 g of baking soda, then dispose of it in the waste container (*not* in a sink).

**Data:**

|  |  |  |
| --- | --- | --- |
| **Slime 1** | | |
| Initial description | Milk | Vinegar |
| Changes observed |  | |
| Description of final product |  | |

Did a chemical reaction occur? Explain your answer.

**Polymer/Slime 2**

**Materials:** (per group)

* Gloves
* 250-mL beaker
* 10-mL graduated cylinder
* 100-mL graduated cylinder
* 4% borax solution (10 mL)
* Glass stirring rod
* 100 mL of white Elmer’s® glue
* 100 mL of water

**Procedure:**

1. Complete the Slime 2 table as you run experiment.
2. Measure 100 mL of Elmer’s glue into the 250-mL beaker.
3. Measure 100 mL of water into a 100-mL graduated cylinder and add it to the glue in the 250-mL beaker.
4. Stir the mixture with a glass stirring rod, then record your observations in the Slime 2 table.
5. Measure 10 mL of borax solution into a 10-mL graduated cylinder and record your observations of the solution in the Slime 2 table.
6. Slowly add the borax solution to the 250-mL beaker, stirring constantly.
7. Continue to stir until the solution is thoroughly mixed.
8. Remove the material from the beaker and handle it, then record your observations.
9. When both experiments are completed, the slimes can be discarded in the waste container (*not* in a sink).

**Data:**

|  |  |  |
| --- | --- | --- |
| **Slime 2** | | |
| Initial description | Glue and water | Borax solution |
| Changes observed |  | |
| Description of final product |  | |

**Results and Discussion:**

1. Which slime used the least amount of energy?
2. Which slime creates the least amount of waste?
3. Which slime is biodegradable?
4. Look back to your design criteria for slime. Explain how each of your slimes either do or do not meet the design criteria for your ideal slime.

**Conclusion:**

1. Which slime can be classified as greener than the other? Why? Use the 3 criteria of green chemistry—cost, safety, and performance—to justify your answer.
2. Explain how your experiment either did or did not support your prediction for which slime would be greener.