Polymer Synthesis

ND EPSCoR Lesson Plan

Lesson Title: Polymer Synthesis

Lesson Overview: Many of the materials we use in our daily lives are polymers, chemicals made of short repeating units (monomers) linked to one another. In the 20th century we learned how to synthesize artificial polymers, or plastics, from fossil fuels, such as oil and natural gas. Today, increased awareness of the environmental effects of mining these fuels has led to the development of plastics that can be synthesized from natural feedstocks, these plastics are referred to as "bioplastics". In today's first activity, you will model common polymer building blocks, and predict the properties of polymeric materials based on your models. In the afternoon, you will synthesize these polymers, and see how well your predictions match with reality!

Topic(s): Polymers, recycling, natural and synthetic resources

Grade or Grade Band: 6-8

Lesson Objectives:
Students will:

- Identify some different types of polymers.
- Create a model to understand the characteristics of particular molecules and polymers.
- Describe the molecular structure of polymers.
- Analyze the properties of polymers.
- Compare two types of plastic based on their characteristics.

National Next Gen Standards:

- **MS-PS1-1**. Develop models to describe the atomic composition of simple molecules and extended structures.
- **MS-PS1-3**. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

North Dakota Standards:

- **MS-PS1-1**. Develop models to describe the atomic composition of simple molecules and extended structures.
- **MS-PS1-3**. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Time Needed (estimate): Three 50-minute class periods

Lesson Author: Brittany Hagen
Dr. Brittany D. Hagen is an Associate Professor of Education and CAEP Accreditation Coordinator at Mayville State University in Mayville, ND. Dr. Hagen teaches courses related to foundations of education, educational technology, educational assessment, and elementary methods. Additionally, she has developed both online and classroom curriculums for a variety of age groups, including teach-the-teacher programs, assessment data modules, and high school aviation facilitator guides and interactive student activities. Dr. Hagen is also a proud Mayville State alumnus, dedicated to developing highly effective teachers who share a passion for educating young learners.

Scientist/K12 Collaborator & University: Alex Parent, NDSU

Scientist Bio/Research: I'm Alex Parent, an Assistant Professor of Chemistry and Biochemistry at NDSU. I grew up on the east coast and attended Clark University in Massachusetts for my Bachelor of Arts degree in chemistry and Yale University in Connecticut for my Doctor of Philosophy degree in chemistry. I then spent two years working in Fukuoka Japan researching sustainable energy. I am an avid hiker, and love walking the many parks in Fargo and occasionally getting out to the Badlands and upstate Minnesota to experience more vertical trails. (The things I miss most about New England and Japan are the easy access to hills and mountains!) I am also an avid board gamer, with Uwe Rosenberg games being some of my favorites. My research focuses on methods of generating materials from renewable resources, particularly on using air in chemical synthesis. My current projects include developing new catalysts for activating oxygen from the air and studying the process by which current catalysts utilize air to effect chemical transformations in paints.

Preparation/Materials

Background knowledge students must have to be successful
Students need to understand that atoms are the building blocks and molecules are atoms joined together to form bonds. Polymers are made up of many, many molecules all strung together to form really long chains. How polymers act depends on what kinds of molecules they're made up of and how they're put together. The *properties* of anything made out of polymers reflect what's going on at the ultra-tiny (molecular) level. Things that are made of polymers look, feel, and act depending on how their atoms and molecules are connected, as well as which ones we use to begin with.

Differentiation and accommodation to support learning for all students:
When designing any lesson, it is important to address the needs of all learners. Please refer to the following resource for ideas on how to adjust your lesson to accommodate your students' particular learning needs: https://www.understood.org/en/learning-thinking-differences/treatments-approaches/educational-strategies/common-classroom-accommodations-and-modifications

Essential Terminology

- **Chemical bond**- A chemical bond is a lasting attraction between atoms, ions or molecules that enables the formation of chemical compounds.
- **Covalent bonds**- the bond formed by the sharing of a pair of electrons by two atoms
- **Hydrogen bonds**- a weak bond between two molecules resulting from an electrostatic attraction between a proton in one molecule and an electronegative atom in the other.
- **Molecule**- molecular, or covalent bond, is formed when atoms bond by sharing pairs of electrons
- **Monomer**- a molecule that can be bonded to other identical molecules to form a polymer
- **Polymer**- A chemical made from small, repeating units (monomers)
- **Plastic**- A polymer that can be molded or shaped using heat and/or pressure.

Resources:

- This Is Plastics website
- PHET University of Colorado Boulder
- Making Molecules
- North Dakota Established Program to Stimulate Competitive Research STEM page

Websites:

- https://www.thisisplastics.com/plastics-101/how-are-plastics-made/
- https://phet.colorado.edu/en/simulation/legacy/build-a-molecule
- https://elearning.cpp.edu/learning-objects/making-molecules
- https://www.ndepscor.ndus.edu/ndep/nature/sunday-academy/stem-module-topics/

Materials needed:

- Chemistry Model Set
  https://www.flinnsci.com/products/chemistry/models/flinn-molecular-model-sets/
  https://www.enasco.com/c/Education-Supplies/Science/Chemistry/Molecular-Models
- Safety Glasses
- Gloves

- 100 mL Guar Gum Solution
- 0.5 mL Borax Solution
- 100 mL of Skim Milk
- 50 mL of Vinegar
- 3 Large Beakers (~200 mL)
- 2 Graduated Cylinders
- 1 Metal Pan
- 1 Small Beaker (~10 mL)
- 1 Disposable Syringe
- 2 Stir Rods
- 1 Hot Plate
- 1 Stopwatch
- 1 Piece of PET
- 1 Piece of Foil
- 1 Wooden Stick per Person
- 1 Pair of Tweezers or Forceps

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: What are polymers? (50 minutes)

Engage:

1. Hand out an index card or sticky note to each student. Have them write what they think the word "polymer" means. Collect the cards and read them aloud to the group. Highlight key words or concepts from the cards. Fill in any missing information that students did not write on the cards. Keep the cards to review at the end of the lesson.

Explore:

2. Using PPT Slides 1 and 3, review what polymers are and how the periodic table plays a part. Use the notes at the bottom of each slide for reference. Remind students that the number of electrons each atom has available for bonding is given at top of table (ignore transition metals). Bonds are two electrons that are shared between two atoms. Atoms form bonds until each atom has eight electrons (except H). For this reason, carbon forms 4 bonds (8-4=4), and nitrogen forms 3 bonds (8-5=3). Bonds to H often not explicitly drawn in chemical structures. All C atoms assumed to have 4 bonds, bonds not drawn are to H.
3. Consider providing background information on Lewis structure if students are unfamiliar with molecular structures.
4. To visually share the building of molecules, consider showing students the molecule building simulator found at: https://phet.colorado.edu/en/simulation/legacy/build-a-molecule. Encourage students to explore the simulator as time allows. Consider also checking out the Making Molecules simulator and lab: https://elearning.cpp.edu/learning-objects/making-molecules/. There is also a Covalent Bond Gizmo available if your school has access to that platform.

Explain:

5. Using PPT Slides 4 and 5, explain that polymers are any molecule made from smaller, basic molecules. Many natural polymers, DNA, proteins, etc. Plastics are polymers that can be molded or shaped w/ heat and/or pressure. Rubbers are natural plastics. Will model several natural polymers using model kits.
6. Hand out Activity 1 sheet and model kits to students. Have them construct the model molecular structures listed on the worksheet and on PPT Slide 6. Ask them to record observations of the models and to save their ethane, glucose, alanine, and terephthalic acid molecular models.

Extension of learning more about this topic:

7. After the students build the monomers, have them connect the glucose molecules to each other as shown on slide 5 to make amylose. The Terephthalic Acid and Ethene connect alternately to form PET (slide 7), and the alanine should be connected to make polyalanine. In the activities, the polyanaline/guar gum will be crosslinked with BO4 linkages to form a 3-D web/mesh (slides 8 and 9). The polyalanine (casein) will be heated and form concatenated structures like loose cables shaken up in a box.

Evaluation

8. Review the discussion questions with students found on PPT Slide 10. Notes can be found below each slide for reference.
9. Pull out the polymer definition cards created by students at the beginning of the lesson. As a group, put them in order from least accurate to most accurate definition based on what students learned in today's lesson. Lead a discussion about what makes each definition accurate or not accurate.

Lesson 2: Crosslinking: Polymers to Plastics (50 minutes)

Engage:

1. Reflect on previous lesson about building molecules and ask students to share one thing they learned about polymers. Consider writing student responses on the board for reference.

Explore:

2. Review PPT Slides 7-9 to remind students of the natural and synthetic polymers discussed in the previous lesson.
3. Remind students that PET is made from individual PET strands that have cooled and are held together by intermolecular forces (H-bonding and dipolar interactions). Each individual PET strand is quite strong. This is why it can be reshaped when heated (unlike the guar gum and casein polymers). Once again reflect on the molecular models made from previous lesson when looking at strength of each molecular model.

Explain:

4. As a review of the molecular models from the previous lesson, remind students that no chemical bonds will form between casein molecules, they will only be held together by H-bonds and sterics. Also, the polymerized guar gum actually ends up softer because it has more strength, the casein plastic crumbles when force is applied to it.

Extension of learning more about this topic:

5. Hand out Activity 2 Worksheet and have materials available to students. Have them follow the directions on the worksheet and PPT Slide 11. Emphasize the borax needs to be added slowly while stirring, otherwise all of the crosslinks will form in the same region of the solution, and students won't get the desired gooeyness.

Evaluation

6. Review the Lesson 2 Discussion questions found on PPT Slide 12 to check for students' understanding of the content. Notes regarding the discussion questions can be found in the "notes" section of PPT Slide 12.

Lesson 3: Extracting Polymer Strands from Soda Bottles (50 minutes)

Engage:

1. Display two plastic soda bottles for students, one that is whole and intact, and one that is melted. Ask them to turn and talk with a partner and discuss the similarities and differences between the two bottles. Students must use the following terms in their explanations and these terms can be written on the board: molecule, polymer, and plastic. Allow students to share their explanations aloud with the class.

Explore:

2. Ask students to look around the room and locate items that may have come from recycled plastics. Ask them to explain how they know. Lead a discussion on which identified items are made from recycled plastics and which are not.

Explain:

3. Explain to students that soda bottles can be recycled in several ways. Consider showing any of the following videos related to this topic (found on PPT Slide 13:
   a. https://www.youtube.com/watch?v=TRy2sD_k57g
   b. https://www.youtube.com/watch?v=rEaqfA-1JnM
   c. https://www.youtube.com/watch?v=VP_Fk8-vGVg

Extension of learning more about this topic:

4. Hand out Activity 3 Worksheet and have materials available to students. Have them follow the directions on the worksheet and PPT Slide 14. Monitor students' progress and discussion based on the lab to provide feedback, highlight key concepts, and clear up misconceptions as necessary.

Evaluation

5. Review the Lesson 3 Discussion questions found on PPT Slide 15 to check for students' understanding of the content. Notes regarding the discussion questions can be found in the "notes" section of PPT Slide 15. Remind students that the guar gum plastic will be stronger and ask them why this is the case? (Some reasons students might give include molecular linkages in the guar gum, or more connections in the guar gum). The plastics are similar to PET in that they can change shape when heat is applied. Unlike the PET, they cannot be reshaped if reheated (thermoset), while the PET can be reshaped if heat is applied (thermoplastic). At higher temperature the individual strands of PET in the bottle begin to separate from one another, allowing it to be reformed.

**Additional Lesson Resources /
Materials**

References:

Based on "Polymers & Molecular Models: Petretec Industry Example" Beyond Benign 2017 Web. 2 May 2018. https://www.beyondbenign.org/lessons/polymers-molecular-models-petretec-industry-example/

Parent, A. “Polymer Synthesis from Common Materials”. Web. 23 June 2020. https://www.ndepscor.ndus.edu/ fileadmin/ndus/ndepscor/SundayAcademy/2018-19SAPolymerSynthesisLessonPlan_2018-11-16.pdf

Websites for purchasing materials

- Molecular Model kits:
  - https://www.flinnsci.com/products/chemistry/models/flinn-molecular-model-sets/
  - https://www.enasco.com/c/Education-Supplies/Science/Chemistry/Molecular-Models
- General Lab supplies:
- Nasco: https://www.enasco.com/c/Education-Supplies/Science
- Flinn: https://www.flinnsci.com/
- Carolina: https://www.carolina.com/lab-supplies-and-equipment/science-lab-supplies/science-lab-classroom-supplies/10300.ct
- School Specialty: https://www.schoolspecialty.com/science-supplies-and-products
- Amazon: www.amazon.com
- Retailers such as Target or Walmart