Polymers: From Chemistry to Global Consequences

Summary

The definition of a polymer is a chain composed of carbon-based molecules called monomers. Examples of polymers can be found in synthetic compounds such as plastics or in natural compounds such as proteins and chitin. The purpose of this lesson is to teach students the nature and properties of polymers, including how to make them and the environmental hazards they produce.

Main Core Tie

Science - Chemistry

Standard 3 Objective 3

Time Frame

1 class periods of 60 minutes each

Group Size

Small Groups

Materials

- 4% Polyvinyl Alcohol or white glue (such as Elmers) - 30-50mL per student
- Saturated Borax solution (10mL per student)
- one small paper or plastic cup per student
- wooden sticks for stirring
- two graduated cylinders for each group
- small Ziploc bags for storage of finished polymer
- food coloring (optional)

Background for Teachers

The definition of a polymer is a chain composed of smaller carbon-based molecules called monomers. Examples of polymers can be found everywhere. Some polymers that should be familiar to everyone include synthetic molecules such as polyester, PVC, and nylon and natural polymers such as proteins. The trunks of trees are polymers made of the monomer cellulose and the hard shells of lobsters are polymers made of the monomer chitin.

In general, polymers are strong, flexible and light. Because of these properties, they are ideal for many human uses; organic chemists have developed thousands of synthetic polymers. All plastics are polymers. In the case of food packaging, they are light enough to make shipping easy and strong enough to protect food and other goods. The most common type of plastic is polyethylene, and it is graded according the length of the polymer chains. LDPE or Low Density Polyethylene, is used in such products as Saran Wrap and other highly flexible plastic wraps. HDPE (High Density Polyethylene) is used for harder plastics such as milk jugs or rigid plastic containers.

Polyvinyl Alcohol (PVA) is made from a monomer consisting of two carbon atoms, one of which is bonded to two hydrogens, the other to one hydrogen and one hydroxyl (-OH) group. White glue is actually polyvinyl acetate, where one carbon atom of the two-carbon monomer is linked to an acetyl group (-OCOCH3). When the sodium tetraborate molecule is added, the PVA or polyvinyl acetate chains are cross-linked through the borate molecule with hydrogen bonds. Water molecules are trapped inside the cross-linked polymer, making it capable of flowing slowly and acting as a non-Newtonian fluid.

As useful as plastics and other synthetic polymers are, they are causing environmental problems.

Most of the plastics that have ever been created are still present in landfills and in the ocean. Plastics may break into smaller and smaller pieces, but it is still unknown how long it takes to completely break them down. A significant amount of plastic (and other garbage) has congregated in a vast region of the Pacific Ocean, now called the "Great Pacific Garbage Patch," causing severe problems for the animals that live nearby.

Student Prior Knowledge

Students should be familiar with the concepts of elements vs. compounds the differences between chemical and physical changes. They should also have a basic understanding of the structure and bonds in organic compounds.

Intended Learning Outcomes

1. Use Science Process and Thinking Skills
    b. Use comparisons to help understand observations and phenomena.
    h. Construct models, simulations and metaphors to describe and explain natural phenomena.
    3. Demonstrate Understanding of Science Concepts, Principles and Systems
    a. Know and explain science information specified for the subject being studied.
    5. Demonstrate Awareness of Social and Historical Aspects of Science
    a. Cite examples of how science affects human life.

Instructional Procedures

BEFORE THE LESSON:

The Polyvinyl Alcohol must be prepared as directed on the packaging if it is purchased in powdered form. If purchased as a 4% solution, it can be immediately used. PVA can be purchased at many chemistry supply houses, including Flinn Scientific at:
Polyvinyl alcohol at Flinn Scientific
If you are using white glue, it should be diluted with water as 50% glue and 50% water.
The saturated Borax solution should be prepared by slowly adding Borax powder to warm water. Continue to add Borax and mix until the liquid becomes saturated. Borax powder is found in the laundry section of most supermarkets.

THE LESSON:

Introduce the word "polymer" and its definition. Ask students if they know what either "polymer" or "monomer" means. They may have already encountered the prefixes poly- or mono-. Let them know that although these words sound very technical, the general idea is very simple. The word "mer" means "unit." Monomers are the units: small molecules that join to one another during a polymerization reaction to form a larger molecule, like beads on a string.
To make the concept clearer, ask for ten or twelve volunteers for a kinesthetic activity. In teams of two, they will act as "monomers" by linking elbows. Ask the "monomers" to form a polymer... that is, join hands between separate teams. After the "polymer" is formed, demonstrate how the links between the monomers allow for flexibility. Then show the class a glass or metal object (i.e. something that is not a polymer). Point out that the glass is not very flexible whereas the "polymer" can be flexible. Next, point out that although the glass is not flexible, it is strong; ask if the "polymer" can also be strong. This can be demonstrated by letting another student try to run through the hands of the "polymer". Ask the students how they might make their "polymer" stronger. The objective is to help students understand that polymers can be reinforced by a chemical process called cross-linking. This can be demonstrated by creating a second ten-student "polymer" and using a few other students to connect these two strings. The result should be an even stronger structure. After students to return to their seats, review the properties of a polymer: they are flexible, strong, and light.

Students will then be given the chance to create their own polymer. Each student should measure 40 mL of PVA or white glue solution and place it in the paper cup. If food coloring is being used, 1-2 drops should be added to the PVA or glue now. At this point, students should be asked to relate the liquid in their cup to the demonstration of student "monomers" earlier in the lesson. Molecules are moving freely in solution and are not bound to one another. Next, add 5 mL of Borax solution to the PVA and stir. It may be necessary to add up to 10 mL to get the desired consistency. Students should be able to explain what happened to the monomers of PVA or glue in their cup after the addition of Borax. The polymer can be stored in Ziploc bags for up to a week.

The lesson ends with a discussion about how much plastic we all use in our daily lives. Does it break down? Where does it go? What can we do as individuals to improve the situation? National Geographic provides a good student handout entitled "The Perils of Plastic" that can be read as a group to learn about the "Great Pacific Garbage Patch". Some short videos are also available. This discussion should include how recycling can help, but it also requires resources and energy. Students can share ideas about how we can avoid using less plastic (carry your own shopping bags, use a refillable bottle instead of bottled water, look for foods with less wrapping, etc.).

Extensions

Different types of plastics can be collected and displayed during this lesson.
Instead of pre-mixing the glue solution (50-50), this could be turned into an inquiry lab where different groups of two students each try different percentages of water and glue to identify the ideal formula.

Assessment Plan

Assessing student learning for this lesson is done in the following ways:

Successful completion of kinesthetic activity (modeling polymers).

Successfully creating gak using polyvinyl alcohol or polyvinyl acetate (white glue) and borax solution.

Discussing causes and solutions to the build up of plastics in landfills and the Pacific Ocean and evaluating the depth of student conceptual understanding through their comments.

Bibliography

- Nat. Geo. Handout (pdf)
- Great Pacific Garbage Patch Video 1
- Great Pacific Garbage Patch Video 2
- Steve Spengler Science-Making Gak
- Engineering Plastics

Authors

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