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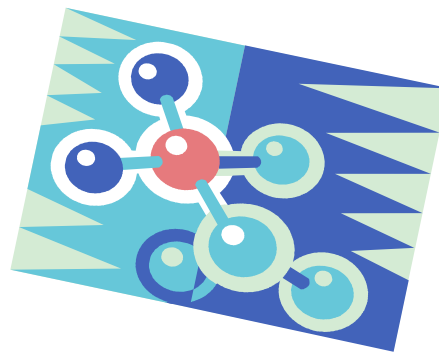
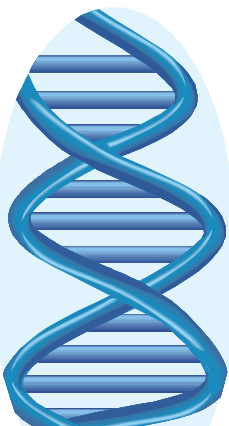
CT – 9.5 and 9.6, High School Chemistry –
Organic Chemistry and Biochemistry

Plastics & Beyond

Connecticut

Science

Center



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Summary

Polymers can bend, stretch, and flow but can also be rigid. They can be natural or man-made and can be both solid and liquid. When we think of polymers, we often think of plastics, but the list of polymers on our planet doesn't end there. Polymers can be found almost everywhere in the world around us and include materials such as rubber, glue, silly putty, amber, nylon, paper and even hair!

Polymers are large molecules, otherwise known as macromolecules, which are comprised of repeating structural units called monomers. Polymers can take on a variety of different characteristics and the possibilities for their uses are endless.

Research involving polymers began as early as 1811. These studies involved cellulose compounds from plants and eventually led to the improved durability of the natural polymer, rubber. At this time, little was known about polymers or how they were held together. However, since the dawn of time, polymers have played a key role in life on earth.

In this activity, students will take on the role of a polymer materials scientist. Their task is to examine the physical properties of polymers by creating their own experiments using the materials provided. Students will have a chance to create their own polymer which they will then incorporate into these experiments. By the end of this program students should be able to explain the versatility of polymers and why they are used for so many different applications.

These activities are designed to reinforce previous knowledge about polymers as well as broaden student's thoughts on the various uses of polymers. This program will link polymers chemical and physical properties as well explore how different various polymers can be. This is a supplemental serious of hands-on activities that are inquiry based.

This program aligns with content standards 9.5 and 9.6 which focus on how the structure of matter affects the properties of materials as well as how science and technology affect the quality of our lives. This program also aligns with the high school chemistry standard focusing on organic chemistry and biochemistry.

The complete CT core curriculum is available at this website:

http://www.sde.ct.gov/sde/lib/sde/pdf/curriculum/science/PK8_sciencecurriculumstandards2009.pdf

The following are the specific sections from the CT Core Curriculum Framework and Inquiry Standards that are addressed in this unit.

Inquiry Standards

| Grades 9-10 Core Scientific Inquiry, Literacy and Numeracy | |
|--|--|
| Content Standards | Expected Performances |
| <p>SCIENTIFIC INQUIRY</p> <ul style="list-style-type: none"> ◆ Scientific inquiry is a thoughtful and coordinated attempt to search out, describe, explain and predict natural phenomena. ◆ Scientific inquiry progresses through a continuous process of questioning, data collection, analysis and interpretation. ◆ Scientific inquiry requires the sharing of findings and ideas for critical review by colleagues and other scientists. <p>SCIENTIFIC LITERACY</p> <ul style="list-style-type: none"> ◆ Scientific literacy includes the ability to read, write, discuss and present coherent ideas about science. ◆ Scientific literacy also includes the ability to search for and assess the relevance and credibility of scientific information found in various print and electronic media. <p>SCIENTIFIC NUMERACY</p> <ul style="list-style-type: none"> ◆ Scientific numeracy includes the ability to use mathematical operations and procedures to calculate, analyze and present scientific data and ideas. | <ul style="list-style-type: none"> D INQ.1 Identify questions that can be answered through scientific investigation. D INQ.2 Read, interpret and examine the credibility and validity of scientific claims in different sources of information. D INQ.3 Formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment. D INQ.4 Design and conduct appropriate types of scientific investigations to answer different questions. D INQ.5 Identify independent and dependent variables, including those that are kept constant and those used as controls. D INQ.6 Use appropriate tools and techniques to make observations and gather data. D INQ.7 Assess the reliability of the data that was generated in the investigation. D INQ.8 Use mathematical operations to analyze and interpret data, and present relationships between variables in appropriate forms. D INQ.9 Articulate conclusions and explanations based on research data, and assess results based on the design of the investigation. D INQ.10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic. |

CT Science Standards and Expected Performances

| Grade 9 | |
|--|--|
| Core Themes, Content Standards and Expected Performances | |
| Strand II: Chemical Structures and Properties | |
| Content Standards | Expected Performances |
| <p><i>Properties of Matter – How does the structure of matter affect the properties and uses of materials?</i></p> <p>9.4 - Atoms react with one another to form new molecules.</p> <ul style="list-style-type: none"> ◆ Atoms have a positively charged nucleus surrounded by negatively charged electrons. ◆ The configuration of atoms and molecules determines the properties of the materials. | <p>D 1. Describe the general structure of the atom, and explain how the properties of the first 20 elements in the Periodic Table are related to their atomic structures.</p> <p>D 2. Describe how atoms combine to form new substances by transferring electrons (ionic bonding) or sharing electrons (covalent bonding).</p> <p>D 3. Explain the chemical composition of acids and bases, and explain the change of pH in neutralization reactions.</p> |
| <p><i>Properties of Matter – How does the structure of matter affect the properties and uses of materials?</i></p> <p>9.5 – Due to its unique chemical structure, carbon forms many organic and inorganic compounds.</p> <ul style="list-style-type: none"> ◆ Carbon atoms can bond to one another in chains, rings and branching networks to form a variety of structures, including fossil fuels, synthetic polymers and the large molecules of life. | <p>D 4. Explain how the structure of the carbon atom affects the type of bonds it forms in organic and inorganic molecules.</p> <p>D 5. Describe combustion reactions of hydrocarbons and their resulting by-products.</p> <p>D 6. Explain the general formation and structure of carbon-based polymers, including synthetic polymers, such as polyethylene, and biopolymers, such as carbohydrate.</p> |
| <p><i>Science and Technology in Society – How do science and technology affect the quality of our lives?</i></p> <p>9.6 - Chemical technologies present both risks and benefits to the health and well-being of humans, plants and animals.</p> <ul style="list-style-type: none"> ◆ Materials produced from the cracking of petroleum are the starting points for the production of many synthetic compounds. ◆ The products of chemical technologies include synthetic fibers, pharmaceuticals, plastics and fuels. | <p>D 7. Explain how simple chemical monomers can be combined to create linear, branched and/or cross-linked polymers.</p> <p>D 8. Explain how the chemical structure of polymers affects their physical properties.</p> <p>D 9. Explain the short- and long-term impacts of landfills and incineration of waste materials on the quality of the environment.</p> |

High School Chemistry Standards

Organic Chemistry and Biochemistry - The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes and chemical properties, and provide the biochemical basis of life.

- Large molecules (polymers), such as proteins, nucleic acids and starch, are formed by repetitive combinations of organic monomers.
- The bonding characteristics of carbon result in the formation of a large variety of structures, ranging from simple hydrocarbons to complex biological molecules and synthetic polymers.
- Amino acids are the building blocks of proteins.

Safety Standards

- Review expectations for appropriate behavior, handling of materials, and cooperative group procedures to be sure those activities are accessible and safe for all students prior to beginning these investigations.
- Make any necessary student modifications.
- Monitor students to be sure they are acting appropriately, handling materials accordingly, and working cooperatively especially when working with chemicals.

For more comprehensive information on science safety, consult the following guidelines:

American Chemical Society –

http://portal.acs.org/portal/PublicWebSite/about/governance/committees/chemicalsafety/publications/WPCP_012287

http://portal.acs.org/portal/PublicWebSite/education/policies/WPCP_010713

Council of State Science Supervisors;

<http://www.csss-science.org/downloads/scisafe.pdf>

Connecticut Department of Education–

http://www.sde.ct.gov/sde/lib/sde/pdf/curriculum/science/safety/science_safety.pdf

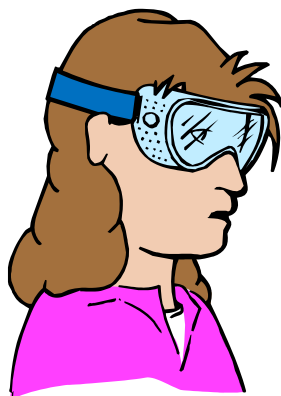
http://www.sde.ct.gov/sde/lib/sde/pdf/curriculum/science/safety/middleschool_sciencesafety.pdf

The Connecticut Science Supervisors Association – Science Safety White Paper –

<http://cssaonline.net/cssapositionpapers.html>

http://www.csta-us.org/Safe_Science.htm

The activities included in this package do not contain anything of a highly toxic nature, but common sense indicates that nothing be put in the mouth.



Discovery Center Activity

Polymers: Plastics and Beyond

Content Covered

See pages 4, 5 and 6 for content covered in this unit

Introduction

The polymer industry has been booming across the globe since these unique chemical compounds were first discovered. Because of the extraordinary range of polymer properties, they can be used in many different ways. Polymers occur naturally in substances such as DNA, cellulose, and rubber. Polymers can also be manufactured synthetically and used as various forms of plastics, foams, and glues. The possibilities of polymers are endless, and because of this they play a vital role in our lives and it is important that we understand them.

In this program, students will explore the many properties of polymers. They will extract DNA, create their own polymer, and even design their own experiments to explore and compare the varying physical properties of different polymers.

Purpose

- Students will discuss examples of natural and synthetic polymers
- Students will gain hands on experience creating their own polymer. They will then test their polymer in various experiments
- Students will examine and compare the physical properties of various types of polymers
- Students will identify the importance of polymers and how their properties effect their functionality
- Students will see how the physical properties of polymers compare with their chemical structure

Advance Preparation

Before students arrive they should have a basic understand of what a polymer is, how they differ from monomers, and be able to name examples of them as well as some of their functions.

Activity

Make sure all materials listed below are available at each station. Task cards (included in this packet) for each activity should also be available at every station. Experiments are designed to have 2 students per station.

Start with discussion about polymers by asking questions such as...

- How are polymers different from monomers?
- What are some examples of polymers?
- Can polymers behave as both liquids and solids?
- Talk about examples of both natural and synthetic polymers. (Natural: DNA, hair, cellulose, rubber, wool, silk, etc... Synthetic: nylon, plastics, Teflon, foam, glue, etc...)
- Looking at models in classroom, discuss...

1. Synthetic polymer polyethylene

- a. Discuss chain structure
- b. What is polyethylene used for? Look at actual sample

2. Natural polymer DNA

- a. What is DNA?
- b. Show model and discuss how it is a chain and is flexible

DNA Extraction

DNA is a natural polymer. The monomer units of DNA are known as nucleotides, and the polymer is known as a polynucleotide. Nucleotides are the building blocks of life on earth and play a central role in metabolism. In this experiment, we will perform a DNA extraction which will allow us to look at these polymers.

Materials:

- Test tube rack with at least 2 test tubes per group
- Small cup of water
- Plastic sandwich bags
- Pipettes with volume marking (at least 4 labeled for water, 1 labeled for alcohol, and 1 labeled for soap)
- Small container with dish soap
- Small glass beaker (empty)
- Stirring rod
- Ice bucket with isopropyl alcohol (should be chilled in freezer at least 1 week before)
- Small medicine cup labeled "DNA solution"
- Pre cut fresh fruit (any monocot plant will work for this)
- Magnifying glass (1 per group)
- Plastic gloves

Procedure:

1. Smash fruit in small beaker with stirring rod. Add a small amount of water and continue smashing until fruit is completely broken down, then add to the plastic sandwich bag
2. Add soap from beaker into the sandwich bag and continue smashing using your fingers from the outside of the bag
 - a. **NOTE:** DNA is located in the nucleus of the cell, which is protected by the cell membrane. A chemical is needed to help break down the cell membranes. Cell membranes are made of phospholipids which are not water soluble. Soap is used because it breaks down materials that are not soluble in water, such as oils. Once smashing is complete, your bag will actually contain a pool of cell contents with no cell membranes
3. Pour DNA solution into cup labeled "DNA solution"
4. Pour DNA solution into a glass test tube by gently bending the cup. Fill each glass test tube about 1/3 of the way full with DNA solution
5. Using pipette labeled "alcohol" add 3 ml of isopropyl alcohol to the test tube. Hold test tube at an angle, and pour very slowly. You will need to create an interface between the DNA solution and the alcohol.
 - a. **NOTE:** This step should be done by presenter to insure interface is created
6. Gently sway your test tube back and force. This creates a reaction across the interface. Within a few minutes you should see a white cloud forming above the interface. This is DNA!

-Look at molecules with magnifying glass. What do you notice about their shape and structure? How does this compare with what we know about polymers?

-Using prepared slide with DNA, get a closer look at these polymers and examine the chain formation.

Create Your Own Polymer

Materials

- Cup with Elmer's glue
- Cup with liquid starch
- Empty cup
- Stirring rod
- Plastic gloves

Directions

1. Find your cup with Elmer's glue and your cup with liquid starch. Pour both of these together into the empty cup and stir
2. When mixture reaches desired texture you may remove it from the cup
3. What are some things you notice about this substance? Do you think it is a liquid or a solid?

4. Does your polymer bounce? Does it stretch? What happens when you stretch it slowly vs. quickly?

Polymer Characterization Test

A company has recently contacted you, a group of expert polymer scientists, with a very important task. They need you to test different polymers in order to collect data on their physical characteristics such as strength, flexibility, elongation/stretch, and water absorption. They have provided you with samples of the polymers they are wondering about and have left the rest up to you. Can your group create a series of fair tests which will examine these characteristics? Remember, you will need to be able to support your findings!

Materials

- Your newly created silly putty
- Bag of various polymers (can be changed depending on availability)
 - Polyamide (nylon)
 - Cellulose (cotton)
 - Polyethylene terephthalate or PETE (beverage/food plastic)
 - Polyethylene foam (insulation)
 - Glucose (monomer of cellulose) and polyvinyl acetate mixture (silly putty)
- LabPro with dual-force sensor and laptop (optional)
- Ruler
- Graph paper
- Various weights
- Scale
- Water
- Graduated cylinder
- Tweezers
- Pipettes
- String
- Tray
- Ring stand
- Plastic gloves
- Goggles

Test 1: Strength

For this test, your group will have to determine the strength of each polymer. Strength is the polymer's ability to resist forces such as stretching, compression and bending. In other words, how much force can be applied to the polymer before it breaks? This can be measured in a variety of different ways, but remember, in order to conduct a fair test each polymer must be tested in the same way!

- Design an experiment using the materials provided to test the strength of each polymer
- Remember to record your findings!
- Which polymer was the strongest? Which was the weakest? How do you know?

Test 2: Elongation

For this test, your group will have to determine the ability of the polymer to elongate. Elongation can be looked at in 2 ways: 1. How far the polymer can elongate before it breaks (ultimate elongation) and 2. How far the polymer can elongate and still maintain its original shape (elastic elongation). You decide how you want to conduct this experiment, but remember each polymer must be tested the same way!

- Design an experiment using the materials provided to test the polymers ability to elongate.
- Did you test ultimate elongation or elastic elongation? What were your results?

Test 3: Water Absorption

For this test, you will have to determine how much water each polymer can absorb. It is very common for polymers to aid in the absorption of fluids. For example, diapers use a super absorbent polymer called sodium polyacrylate which is able to absorb many times its own weight in water.

- Design an experiment using the materials provided to test the polymers ability to absorb water.
- Can you determine how many times its own weight each polymer is absorbing?
- Remember to record your results!

Test 4: Weight Resistance

For this test, your group will have to determine how much weight each polymer can withstand before it deforms or breaks. As you add weight to a polymer, it may, or may not, begin to deform. Create a way to test the deformation of the polymer due to the addition of weight. The weight test can be done in a variety of different ways, but remember, in order to conduct a fair test each polymer must be tested in the same way!

- Design an experiment using the materials provided to test the polymers reaction to the addition of weights
- Can you incorporate a graph in your results? If so, what will be your x and y axis?
- Remember to record your findings!
- Which polymer was able to withstand the most weight before deforming?

Conclusion

You have now completed testing on all of your polymers! Great job! It is time to report your results to the manager of the company...

Make sure to organize your findings so that they can be discussed with the class.

Discussion

- Go over results for each test. Did different groups get different results?
- Why is it important to conduct the test for each characteristic in the exact same way? Why wouldn't the results be valid if we changed our method of testing mid way through the experiment?
- When reporting results to a company, do you think it is better to have done each experiment only once or multiple times? Why?
- What did you learn about the characteristics of polymers? Are they all the same or very different?
- What are some common uses of polymers? Why do you think companies need polymer scientists to do tests like these?
- How do you think the chemical structure of each polymer effects the physical characteristics you tested today?

DNA EXTRACTION

Task Card

Please follow these steps while conducting your DNA extraction.

1. Using the small empty beaker and stirring rod, smash your fruit
 - a. Add water provided and continue smashing
2. Add your smashed fruit and water mixture to the plastic sandwich bag
3. Using the pipette labeled “soap” add the soap provided to the sandwich bag. Using your fingers, from the OUTSIDE of the bag, continue smashing.
4. Carefully pour your mixture into the plastic medicine cup labeled “DNA solution”
5. Gently squeeze the medicine cup and carefully pour your DNA solution into a glass test tube. Fill each test tube about 1/3 of the way with solution.
6. **When you have reached this step please let your instructor know.** At this point, the instructor will come over and add 3 ml of isopropyl alcohol to your DNA solution.
7. Once the alcohol has been added, gently sway your test tube back and forth. After a few minutes, you should notice a white cloud forming above the DNA solution... this is DNA!
8. Using your magnifying glass, examine the DNA. What do you notice?

POLYMER CHARACTERIZATION TEST

Task Card 1

A company has recently contacted you, a group of expert polymer scientists, with a very important task. They need you to test different polymers in order to collect data on their physical characteristics such as strength, weight resistance, elongation/stretch, and water absorption. They have provided you with samples of the polymers they are wondering about and have left the rest up to you. Can your group create a series of fair tests which will examine these characteristics? Remember, you will need to be able to support your findings!

1. STRENGTH TEST

For this test, your group will have to determine the strength of each polymer. Strength is the polymers ability to resist forces such as stretching, compression and bending. In other words, **how much force can be applied to the polymer before it breaks?** This can be measured in a variety of different ways, but remember, in order to conduct a fair test each polymer must be tested in the same way!

- Design an experiment using the materials provided to test the strength of each polymer
- Remember to record your findings!
- Which polymer was the strongest? Which was the weakest? How do you know?

POLYMER CHARACTERIZATION TEST

Task Card 2

2. ELONGATION TEST

For this test, your group will have to **determine the ability of the polymer to elongate**. Elongation can be looked at in 2 ways: 1. How far the polymer can elongate before it breaks (ultimate elongation) and 2. How far the polymer can elongate and still maintain its original shape (elastic elongation). You decide how you want to conduct this experiment, but remember each polymer must be tested the same way!

- Design an experiment using the materials provided to test the polymers ability to elongate.
- Did you test ultimate elongation or elastic elongation?
- What were your results?

POLYMER CHARACTERIZATION TEST

Task Card 3

3. WATER ABSORPTION TEST

For this test, you will have to **determine how much water each polymer can absorb**. It is very common for polymers to have the ability to absorb fluids. For example, diapers use a super absorbent polymer called sodium polyacrylate which is able to absorb many times its own weight in water.

- Design an experiment using the materials provided to test the polymers ability to absorb water.
- Can you determine how many times its own weight each polymer is absorbing?
- Remember to record your results!

POLYMER CHARACTERIZATION TEST

Task Card 4

4. WEIGHT RESISTANCE TEST

For this test, your group will have to determine how much weight each polymer can withstand before it deforms or breaks. As you add weight to a polymer, it may, or may not, begin to deform. **Create a way to test the deformation of the polymer due to the addition of weight.** The weight test can be done in a variety of different ways, but remember, in order to conduct a fair test each polymer must be tested in the same way!

- Design an experiment using the materials provided to test the polymers reaction to the addition of weights
- Can you incorporate a graph in your results? If so, what will be your x and y axis?
- Remember to record your findings!
- Which polymer was able to withstand the most weight before deforming?

Teacher Resources

Safety Disclaimer:

The content of this Teacher's Resource section is intended to serve as an educational resource for teachers and students.

Preparing for the safety of yourself and your students is a critical step in planning for any hands-on science- related activities. Prior to conducting any of the activities included in this resource section, please familiarize yourself and your students with any potential hazards, and take the necessary precautions appropriate for each specific activity.

Connecticut Science Center is not responsible for the contents of any books, videos, websites or other resources to which we provide a reference and does not necessarily endorse the opinions, activities, services, products or information expressed within them.

Professional Development Opportunities

Introduction to Inquiry Professional Development Workshop

The Connecticut Science Center's Introduction to Inquiry Professional Development workshop was launched in the summer of 2005 and funded by the GE Education Foundation. Based upon the Exploratorium's Institute for Inquiry in San Francisco, our Science Center's professional development workshop is a five day immersion experience in inquiry-based learning and teaching plus an additional two days at the Annual Follow up Conference.



The Center's Introduction to Inquiry workshop is tied directly to the CT Science Framework Connecticut adopted in 2004. The workshop's programming addresses requirements in Connecticut's Common Core of Teaching and Common Core of Learning as well.

Classroom Application

This five-day workshop will focus on classroom strategies for implementing inquiry-based experiences. **Only participants who have previously attended the Introduction to Inquiry workshop are eligible to attend this workshop.**

Formative Assessment workshop

This five-day workshop will focus on additional classroom strategies for implementing inquiry-based experiences, as well as formative assessment strategies to be used in the science classroom. **Only teams who have previous attended the Introduction to Inquiry and Classroom Applications are eligible to attend this workshop.**

For more information please visit: <http://www.ctsciencecenter.org/educate/institute-for-inquiry-workshop.aspx>

Teacher Websites

Classroom Materials

Polymer model created from “The Original Giant Molecular Model Set” produced by Molecular Model, Co.

<http://www.molecularmodelscompany.com/>

Software

Vernier LabPRO Equipment: <http://www.vernier.com/products/interfaces/labpro/>

Career Information

A great website with information about polymer science education and careers:

http://education-portal.com/articles/Polymer_Engineering_Education_and_Career_Information.html

American Chemical Society information about material science careers:

http://portal.acs.org/portal/acs/corg/content?_nfpb=true&_pageLabel=PP_ARTICLEMAIN&node_id=1188&content_id=CTP_003394&use_sec=true&sec_url_var=region1&_uuid=bd3aa7b8-45aa-47ac-b6fb-13063ce4b29a

Student Resources

Safety Disclaimer:

The content of this Student's Resource section is intended to serve as an educational resource for students.

Preparing for the safety of yourself is a critical step in planning for any hands-on science-related activities. Prior to conducting any of the activities included in this resource section, please familiarize yourself with any potential hazards, and take the necessary precautions appropriate for each specific activity.

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Websites

http://www.sciencekidsathome.com/science_topics/amazing-polymers.html#more

<http://www.pslc.ws/macrog/kidsmac/>