Activity 8  Plastics

GOALS
In this activity you will:
• Distinguish between thermoset and thermoplastic plastics
• Test materials for product design.

What Do You Think?
In 1909, Leo Baekeland developed the polymer, Bakelite. The polymer industry hasn’t stopped growing since! The term “plastics” was introduced in the 1920s to describe these new materials that were being introduced. Here is a partial list of common items that contain polymers.

- 2-L soda bottles
- balloons
- carpet
- caulking
- cellophane tape
- coffee stirrers
- combs
- computers
- contact lenses
- credit cards
- disposable razors
- epoxy glue
- erasers
- foam cups

- foam rubber
- food wrap
- football helmet
- garbage bags
- guitar strings
- hairspray
- hockey puck
- insulation
- margarine tubs
- milk jugs
- paint
- pantyhose
- raincoat
- rubber bands

- sandwich bags
- shampoo bottles
- shoe laces
- slime
- snorkle and swim fins
- sunglasses
- teflon coating
- tennis ball
- thread
- tires
- toothbrush
- umbrella
- velcro
- vinyl car top

• What properties of plastics have made their use so widespread?
Record your ideas about this question in your Active Chemistry log. Be prepared to discuss your responses with your small group and the class.
Investigate

Part A: Thermoplastic Activity

1. Pour about 300 mL tap water into a 400 mL-beaker. Place the beaker on a hot plate. Turn on the hot plate and bring the water to a boil. Then turn off the hot plate.

2. Wearing gloves, hold one end of a strip of thermoplastic modeling material, and dip the other end into the hot water until it softens. Keep it away from the sides of the beaker. Remove it from the water. With wet gloved fingers, grasp the softened end. Dip the other end in the water until it is also softened.

3. Remove the strip from the water bath, and quickly mold the thermoplastic modeling material into a design of your own choosing. Do not mold it on yourself as a bracelet or a ring as the final product could be difficult to remove! You might mold it into some component of the toy model your group is going to propose. If the polymer becomes too hard, dip it in hot water to soften it.

4. Let the material cool on the countertop.

5. Clean up your workstation and return all equipment as directed.

Part B: Thermoset Activity

1. Get a 2 cm piece of epoxy putty. Note that it is composed of two colored components.

2. Knead the putty until the two components are thoroughly mixed.

3. Quickly shape the putty into a design of your choosing. Again, you might want to shape it into something that you could use in your toy model.

4. Let the putty harden on a paper towel or piece of plastic bag. Do not let the putty harden on the countertop; it may be difficult to remove.

5. As the putty is hardening, test its temperature with your fingertips.

   a) Does the sample change temperature? Describe what you observe.

   b) Describe the difference between the thermoplastic and thermoset polymers.

   c) In what applications would a thermoset polymer be most desirable? Thermoplastic? Explain your reasoning.

6. Clean up your workstation.
Part C: Testing Plastics to Determine Product Use

1. Think carefully about the plastics that may be a part of your toy model. How will it be used, and what type of wear and tear could be expected on each part? How strong will the parts need to be? What type of impact might the parts be subjected to? How bendable will the parts need to be? What other conditions will be important in considering the durability and the quality of your toy? Brainstorm these questions with members of your group.

a) Record your thoughts in your Active Chemistry log.

2. Identify two important criteria that will need to be considered for your toy model. Now, determine a way to test the types of plastic that you are considering, so that you can justify that choice on more than availability and costs. For example:

• If strength of the plastic is important, then you will need to design a method to determine the strength of the material by measuring how large a constant force the plastic can withstand without breaking.

• If resistance to impact is important, then you will need to design a method to determine the amount of impact force the plastic you will be using can take.

• Perhaps your plastic will need to withstand lots of flexing, bending, stretching, compressing, and twisting. Design a valid method to determine the fatigue resistance of your plastic.

3. Design the procedure of the tests you will conduct. Use good experimental design. Collect both quantitative and qualitative data.

a) Record your procedure in your Active Chemistry log.

4. When your teacher has approved your procedure, carry out the tests.

a) Based on your results, justify the best plastic(s) to use in your toy model. (Use your data.)

5. Share your results with other groups. What else did you learn about some of the materials you were considering using?
POLYMERS

Polymers Are Long Chains of Monomers

Often referred to as macromolecules, polymers are enormously long molecules made up of many repeating smaller molecules. The smaller molecules that make up a polymer are called monomers (from the Greek mono, meaning one). Polymers may be made of tens of thousands of repeating monomer units with molecular weights reaching to millions of daltons (one dalton is equal to one atomic mass unit). Monomers are the building blocks of polymers; the links that make up the polymer chains. These molecular chains may be branched or unbranched, interconnected at various points, or interconnected at a great many points so that they form rigid solids. At the molecular level, they may be long chains, or sheets, or even a complicated three-dimensional lattice.

Plastics

A plastic is simply a substance that can be molded into various shapes that then harden. All of the plastics that you come into contact with today are polymers. Not all polymers are plastic however, as starches, cellulose, proteins, and DNA (natural polymers) are not considered plastic.

The first synthetic polymer was created in response to a call for a synthetic substitute for ivory. In 1909 Leo Baekeland received a patent for the first fully synthetic polymer he called Bakelite. Bakelite is a three-dimensional resin network made from the polymerization of phenol and formaldehyde. This polymer is a hard, non-conducting material that cannot be melted and remolded. Such a polymer is called a thermoset polymer — one that is soft enough to be molded when first prepared, but once it is hard, it stays hard. Thermoplastic polymers, on the other hand, are those that can be softened by heat and then remolded.

Polyethylene is a thermoplastic polymer. It is the simplest and least expensive synthetic polymer. It is made from ethylene (CH\_2\_=\_CH\_2). Over 20 million tons of polyethylene are produced in the United States each year.

There are two principal types of polyethylene, high-density polyethylene (HDPE) and low-density polyethylene (LDPE). Trash bags, food wrapping, electrical wire insulation and garment bags are but
**Chem Essential Questions**

**What does it mean?**
Chemistry explains a macroscopic phenomenon (what you observe) with a description of what happens at the nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate. Complete the chart below in your Active Chemistry log.

<table>
<thead>
<tr>
<th>MACRO</th>
<th>NANO</th>
<th>SYMBOLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>What important properties of polymers did you observe in this activity?</td>
<td>Take two of the properties from the macro box and describe how the structure of the polymers gives rise to these properties.</td>
<td>Show symbolically how LDPE and HDPE differ. Then draw two polymer chains with cross-linkers that reduce the mobility of a polymer.</td>
</tr>
</tbody>
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**How do you know?**
Explain how your tests for two properties of a polymer related to the structure of the polymer.

**Why do you believe?**
Plastics are a large part of everyday life; Americans use an astounding amount of polymers each year. Most of these materials are derived from petroleum, a limited natural resource. The polymers are made mostly of carbon as well as other elements. Propose an alternative source of carbon for the creation of future polymers.

**Why should you care?**
It seems reasonable to assume that your toy design may include the use of some plastic. Understanding the nature of and being able to clearly explain your choice of polymer will improve your toy design.

**Reflecting on the Activity and the Challenge**
In this activity, you compared two types of plastics, thermoplastic and thermoset. You found that they had very different properties, which would help determine which type of plastic to use for different design purposes. Thermoplastics can be recycled as long as the polymer chain remains intact. On the other hand, thermoset plastics cannot be recycled. After examining these two types of plastics, you conducted some material tests, much like those that would be done in an industrial setting, to help you determine which plastic would be best for your toy model. Now, you can use your plastic test results to help you complete your toy model and determine a cost analysis for your product.
a few examples of products made of LDPE. The sturdier HDPE is used for toys, milk jugs, CD boxes, containers for oils and chemicals, and many, many more items. The difference between the two types is that LDPE has a great deal of side chains branching off the polymer chains. The branching of the LDPE prevents the molecules from being packed closely together (resulting in low density), so they tend to be very flexible. HDPE is made of mostly linear chains. HDPE molecules, without the branching side chains, can pack together well (high density), so this material is more rigid and has a higher melting point than LDPE.

Checking Up
1. What is meant by the term “macromolecule”?
2. How does a thermoset polymer differ from a thermoplastic polymer?
3. Explain the difference between a branched-chain and a linear-chain molecule.

What Do You Think Now?
At the beginning of this activity you were asked:
• What properties of plastics have made their use so widespread?
How have your ideas about the properties of polymers changed after having completed this activity? List three important properties of polymers that you did not have in your original list.
1. Let’s consider the first part of this activity where you compared two types of plastics.

Thermoplastics

a) Why was it necessary to heat the thermoplastic modeling material in order to shape it?

b) Was this an exothermic or endothermic change?

c) Was this a chemical or physical change or both?

d) How could thermoplastics be used?

Thermosets

e) Why are the two epoxy putty components separated?

f) As the epoxy putty sets, did it feel hot or cold?

g) Was this an exothermic or endothermic reaction?

h) Was this a chemical or physical change or both?

i) Could you remold the material if you did not like the first thing you made? Explain.

j) How could thermoset plastics be used?

2. Draw pictures of what was occurring at the molecular level as you worked with the thermoplastic modeling material and the epoxy putty.

3. Are all polymers products of chemical industries? Explain.

4. What are the advantages and disadvantages of using plastic rather than other materials in your toy model?

5. Speculate as to why so many products today are made of polymers.

6. Preparing for the Chapter Challenge

Consider how you might use plastics in your toy model. Draw a scale model of your toy and label the components and the materials that it is made of. Determine how much of each material will be required to manufacture one of your toys, and develop a cost analysis sheet for your toy that could be included in your final presentation.
Inquiring Further

1. The cost of toys

Investigate toys at a local store. Determine the percentages that are made mostly of plastics. Compile a list of the other materials in the toys. Estimate the cost of manufacturing each item based on the materials and compare that to the retail cost. Discuss the markup that toy products have and what other costs are involved in their manufacturing.

2. Exploring other plastics

Make Slime
Mix 20 mL of a 4% polyvinyl alcohol (PVA) solution with 5 mL of 4% borax solution in a small disposable cup. Stir with a wooden stirring stick. Test its properties (i.e., density, viscosity, malleability, resistance to pressure). Determine how this might be used in a toy product.

Make Gluep
Mix 15 mL each of white glue and water in a small disposable cup. Add food coloring if desired. Add 10 mL of 4% borax solution and stir vigorously with a wooden stirring stick. Knead the gluep and observe its properties and compare them to the properties of slime. Determine how gluep might be used in a toy product.