THERMOPLASTIC AND THERMOSETTING POLYMERS

I. Question:

How does heat affect certain polymers?

II. Background Information

There are two general classes of polymers based on their behavior when exposed to heat. *Thermoplastic* polymers are normally produced in one step and then made into products in a subsequent process. They become soft and formable when heated. The polymer melt can be formed or shaped when in this softened state. When cooled significantly below their softening point they again become rigid and usable as a formed article. This type of polymer can be readily recycled because each time it is reheated it can again be reshaped or formed into a new article.

On the other hand, *thermosetting* polymers are normally produced and formed in the same step. Upon heating, thermosetting polymers will become soft, but cannot be shaped or formed to any great extent, and will definitely not flow.

Polycaprolactone, better known as *Friendly Plastic* ® or *Fantastic Plastic* ®, is a readily available thermoplastic polymer which can be purchased in pellets or strip form, that is natural color or pigmented in a wide range of colors. Most craft supply stores will have ready supplies of the strips or will order pellets or strip for you. The material is safe and non-toxic so it can be used with very young children as well. Not to mention, that playing with it is great fun!!!

If *Friendly Plastic* ® or *Fantastic Plastic* ® cannot be found, polycaprolactone pellets may be obtained from the Mid Michigan Section Education Committee Chairperson, or from

Solvay
www.solvayinterox.com
800-468-3769
Product Name: CAPA â Caprolactones, grade 640 or 650

Sculpey III â is polymer craft product made up of PVC and plasicizer (pthalic esters). It can be safely handled by students of all ages. *Sculpey III* â is similar to clay in many ways but unlike clay, it remains soft and pliable until baked. Once baked, it cannot be reshaped.

III. Materials

Part 1: Supplies: Boiling water
Glass cups or beakers
Polycaprolactone strips or pellets
Spoon or tongue depressor
Sink or bucket to pour off the boiling water

Polycaprolactone was *not* available in craft, toy, Wal-mart or Meijer stores. Polycaprolactone pellets may be obtained from the Mid Michigan Section Education Committee Chairperson or Solvay Corporation as noted above.

Part 2: Supplies:
Small piece of two part epoxy putty
Acetone or nail polish remover for clean up

Part 3: Can be used along with parts one and two or instead of part one if polycaprolactone is not available.

Supplies: Sculpey III ® (Ken's Crafts of Midland)
SARAN® Wrap
Mold (optional), soft bristle brush, talc for mold release

IV. Procedures

Activities 2 and 3 used together will reinforce the concept of initiation, propagation and termination with 7th and 8th grade students. Initiation occurs by kneading in activity 2 but not in activity 3. The exothermic reaction produced when the two-part epoxy putty is kneaded is dramatic proof of propagation. As the "-mers" are used up, the reaction terminates and the epoxy putty cools down. For younger students, emphasize the different properties of the materials instead of the chemistry. *(The Sculpey stays soft until baked. The epoxy putty hardens within minutes, etc.)*

Procedure 1. Thermoplastics

1. Place approximately 10 -20 grams (one teaspoon) polycaprolactone in the beaker.
2. Add the boiling water to the beaker. CAUTION: Use care with the boiling water to prevent burns.
3. Watch as the plastic turns from translucent to transparent. (The crystalline phase is melting).
4. When all the plastic has turned transparent, carefully pour off the water into the sink or bucket.
5. Using the spoon, gather up the plastic allowing the plastic to cool somewhat.
6. While the plastic is still warm (not hot to the touch) mold and shape the material. It will remain rubbery quite a while.

7. To reshape, simply reheat with additional boiling water and repeat steps 2. to 6.

SAFETY: Do not allow students to form rings or bracelets on themselves as the material will shrink as it hardens

Procedure 2. Thermoset

This activity consists of carrying out a chemical reaction which forms a thermosetting epoxy polymer. Two part epoxy is available from the local hardware stores in a variety of forms. For our purposes, we will use the two color putty that is available in ribbons or strips.

1. Arrange equal parts of the two part epoxy putty.
2. Knead and mix the two parts together to form a uniform color.
3. When well mixed, an exothermic (gives off heat) reaction occurs. The mixed putty may feel warm to the touch. You will notice a distinct odor forming.
4. Mold into a shape and set gently on a piece of plastic film, wax paper, or Saran Wrap® to harden. This may take as much as 20 - 30 minutes. (The label will indicate how much time is required).
5. Wash hands immediately after kneading the epoxy.

SAFETY: Do not allow students to form rings or bracelets on themselves as the material will shrink as it hardens

Procedure 3. Thermoset

This activity reinforces the concept of linking the "-mers" (*Introduction to Polymers)*. Here, the reaction is initiated by the heat. Once baked, the polymer chains become rigid.

1. Wash hands and make sure work surface is clean. Knead *Sculpey III â* until soft and smooth.
2. Shape *Sculpey III â* into desired forms. Have each student make two identical shapes – one "experimental" piece to bake and one to hold as an unbaked "control" piece. (Larger pieces many need "bulking out" inside with crumbled aluminum foil and/or armature wire.
3. Bake the experimental pieces on an ovenproof glass surface at 275°F (130°C) for 15 minutes per ¼" (6mm) of thickness, with good ventilation. Do not use a microwave oven. Avoid over-baking. Check accuracy of oven temperature. Thicker pieces may require additional baking time. Most middle schools have a home-ec room where, with some coordination with the home-ec teacher, you can do the baking. For elementary schools, the teacher may have to take the pieces home to bake.

   You probably will not have time within your visit to do the baking. In fact, the results are more dramatic when done overnight or over the weekend. Students may initially want to say that the experimental pieces just dried out faster than the control. Encourage the teacher to

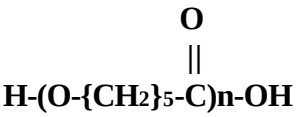
allow this to be an ongoing project. Students should continue to observe the control group until they are convinced that the material is a thermoset polymer.

4. Remove from the oven and allow to cool.
5. Once cool, finished pieces can be polished, sanded, driled, carved, painted with water based acrylics, or covered with *Sculpey â* glaze.

V. Chemistry

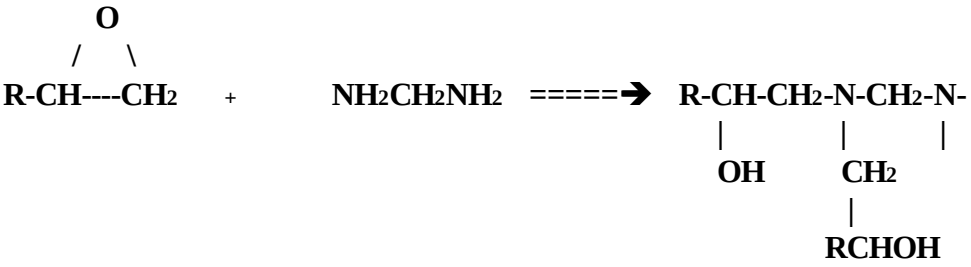
Discussion of the chemistry is should be limited to high school chemistry classes.

Procedure 1:



Polycaprolactone

Procedure 2:



Epoxy + Amine =====➔ Epoxy Resin

VI. Discussion and Evaluation

1. What is the difference between *thermoset* and *thermoplastic*?
2. What characteristics define thermoplastic?
3. What characteristics define thermosetting plastics?

VII. Continuing the Concept

Discuss practical every day applications for thermoplastics and thermosetting polymers.

VIII. References