Experiment 9: Polymer Chemistry

Background

It is impossible to avoid polymers in our everyday lives. In fact, we couldn't exist without them—the many proteins, nucleic acids, and carbohydrates that compose our bodies are all examples of natural polymers. Synthetic polymers, like low-density polyethylene (LDPE) in grocery bags and polyvinyl chloride (PVC) in shampoo bottles, are products that you probably use every day. Understanding the chemistry of polymers will help scientists create products desired by consumers, design medicines that can save lives, and contribute solutions to our environmental problems.

The word *polymer* comes from the Greek meaning "many parts". Polymers are very long molecules that consist of repeating units called monomers. The monomers are linked together by covalent bonds to make long chains. There may also be molecules that cross-link these chains together, changing the flexibility or elasticity of the polymer (See Figure 1 below). Polymers are organic compounds that can contain a variety of functional groups. These functional groups will provide the polymer with its chemical and physical properties.

You will have fun exploring the versatility of these materials.

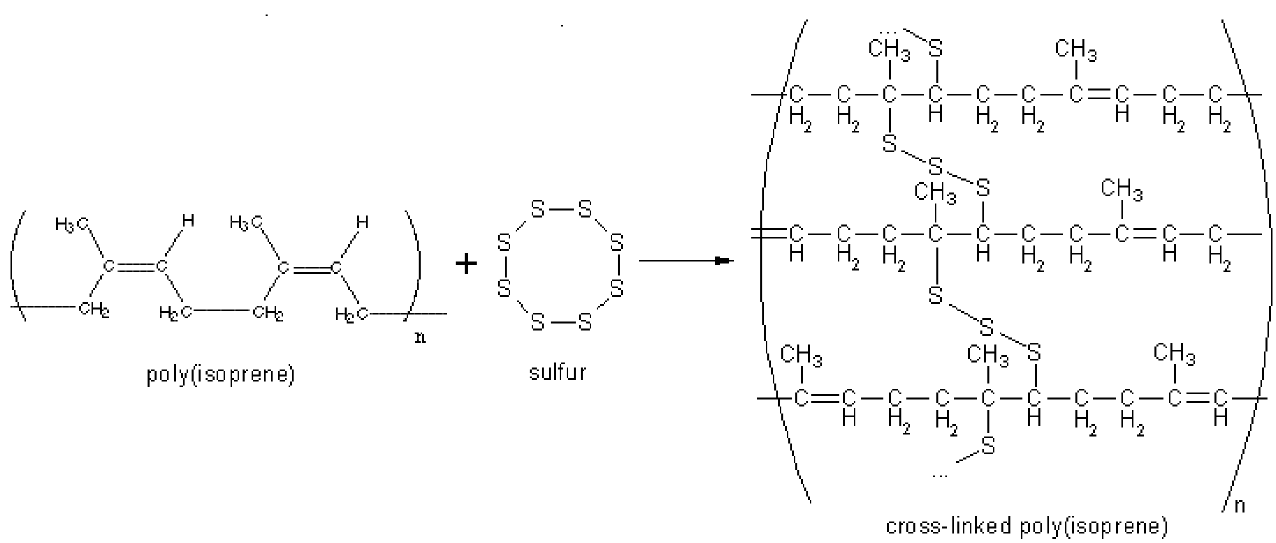


Figure 1. An example of a common polymer, polyisoprene (rubber). When treated with heat and sulfur, the polymer gets cross-linked which modifies its properties.

Station 1: Addition Polymers
In addition polymers, monomer units add (link) together. For example, beta-Carotene is composed of many isoprene monomers linked together.

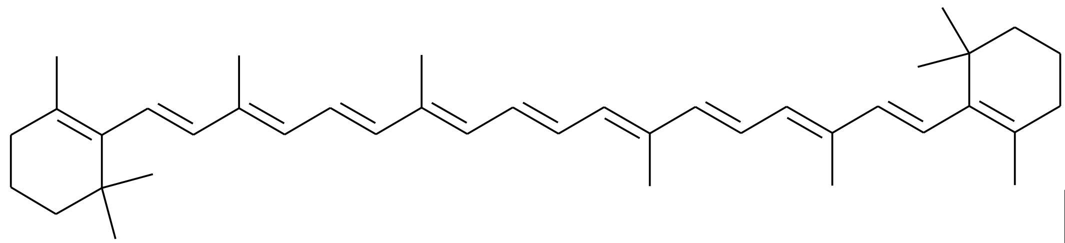
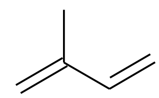


Figure 2. Beta-Carotene



isoprene

1. Circle all isoprene units in beta-Carotene. How many can you find? (Hint: Each isoprene is composed of five carbons and the double bonds move during the polymerization reaction).

Let's look at an addition polymer, polystyrene (styrofoam).
Directions: Take a Styrofoam cup or Styrofoam packing peanuts and place them in a beaker with a shallow amount of acetone. Swirl the beaker. Watch what happens.

2. What do you think is the name of the monomers that make long chains of polystyrene?

3. Why does acetone work better to "dissolve" polystyrene than water? Explain in terms of molecular structure.

4. Why does the volume of material seem to diminish so greatly? What, if anything, is being lost in this process?

Another addition polymer is polyacrylate is a superabsorbent polymer and can absorb up to 1000 times its weight in liquid.
Directions: Obtain a few pieces of polyacrylate fibers from a diaper. Weigh it and place it into a beaker. Pour a known volume of water on it until it swells. How much water can you pour on it until it turns mushy?

5. My polyacrylate absorbed about _______ times its weight in liquid.

Station 2: Thermosetting or Thermoplastic?
You will make two different addition polymers and test whether they have thermosetting or thermoplastic properties. ***Directions***: One person in your group should make gluep and another should make slime.

Gluep In a ziplock bag, mix 4 tbsp glue and 4 tbsp borax. When it reacts, take it out and squeeze it and roll it around in your hands until it becomes easier to work with.
Slime Use polyvinyl alcohol solution instead of glue, same 1:1 ratio with borax.

A **thermoplastic** polymer will get soft when heated. Examples: polyethylene (milk jugs), polystyrene (toys), polycarbonates (CD). A **thermosetting** polymer will get rigid when heated. Examples: bowling balls, kitchen countertops, football helmets.

1. Observe how well your sample bounces. Divide your sample into three pieces. Take one piece of your sample and cool it in ice for 5-10 min. Then check how well it bounces.

2. Put another piece of your polymer in a beaker and set on a hot plate. Heat gently and slowly. Decide whether the polymer is thermoplastic or thermosetting and record your observations and conclusions.

3. Keep the third piece for the next station.

Station 3: Crosslinkers
Isoprene molecules link together to make natural rubber (see Figure 1). Vulcanized rubber (Goodyear tires) are stronger because of short chains of sulfur atoms that are used to crosslink synthetic chains of rubber together. Sulfur chains are also what crosslink keratin (hair) to make hair wavy or curly. When a person gets a "perm", the chemicals in the hair promote the oxidation of sulfur to create these links.

Directions:
Make gluep as you did in station 2, but use concentrated borax instead of the borax used previously.

1. Based on the ratio of glue and borax, which do you think will bounce higher? Make a prediction and explain the basis of your prediction.

2. Roll each one into a ball. Which one bounces higher? ________________________

3. What does this tell you about the role of borax? Is it what you expected?

Station 4: Condensation Polymers
In condensation polymers monomers join together in a way that releases a small molecule (such as water or hydrochloric acid).

Nylon 6, 6 was created in 1937 by Wallace Carothers at DuPont. A monomer of adipic acid reacts with another monomer, hexamethylenediamine.

1. What molecule gets released when these two monomers react to form nylon?

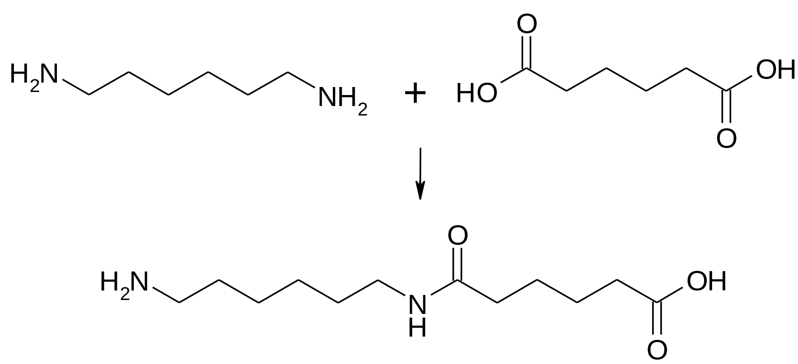


Figure 3. The polymerization of adipic acid and hexamethylenediamine to create nylon.

Ask your instructor to perform the following demonstration:

Directions: In a beaker, add 10 mL layer of hexamethylenediamine then a 10 mL layer of sebacoyl chloride. They are not immiscible.

2. What do you see at the interface of these two liquids?

Take a wire or forceps and slowly pull out the nylon. Make the longest strand you can. Don't touch it with bare hands. When finished, you may collect it and rinse it with acetone and water.

3. Approximate or use a meter stick to measure the length of your longest strand of nylon and record it here.

Another famous DuPont discovery was made by Stephanie Kwolek in 1965. Kevlar is a very strong material and is used today for bike tires and bullet-proof vests.

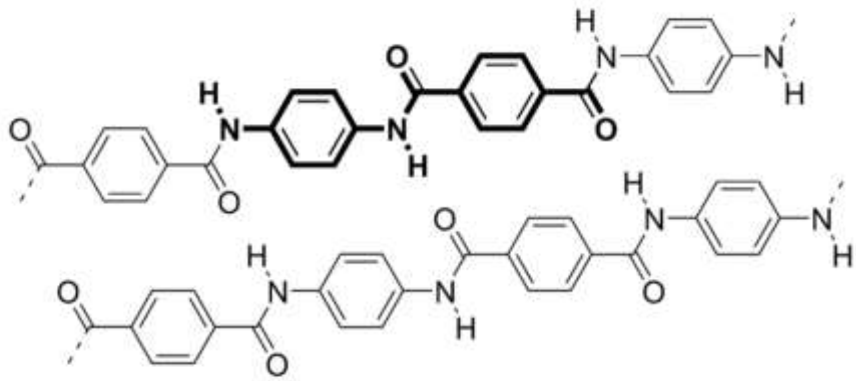


Figure 4. Kevlar is also a condensation polymer.

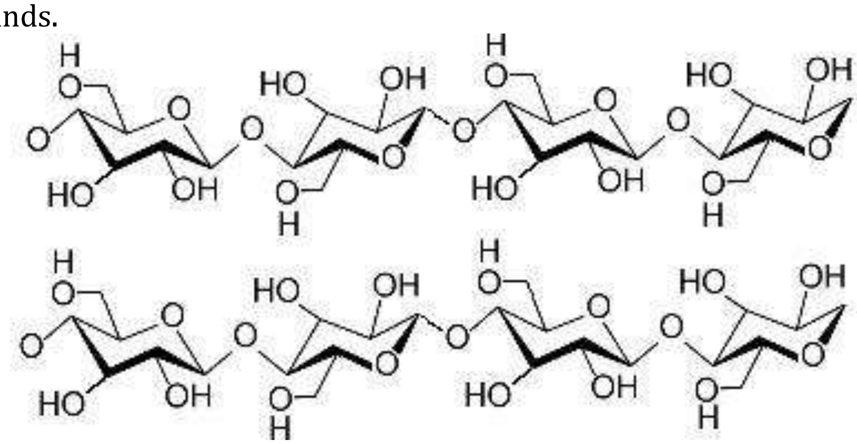
4. Kevlar is also a condensation polymer. Based on this information and what you know about nylon (see drawing above), **draw two possible monomers** that are used to make Kevlar.

5. Kevlar is amazingly strong (it is used as body armor). Give a molecular explanation. (Hint: How do the strands stick together? Look at its structure.)

Station 5: Biopolymers
Our bodies are composed of polymers. Proteins, DNA, and carbohydrates are all examples of natural polymers.

Starch and cellulose are composed of glucose molecules linked together to form long chains.
Cellulose is strong and is commonly found in cell walls of plants. This strength can be attributed to the hydrogen bonds formed between cellulose strands.

1. Below are two parallel strands of cellulose. Draw in the hydrogen bonds between the strands.



Starch is very similar in structure to cellulose (they are both polymers of glucose). Let's study the properties of this polymer in water (this mixture is called Oobleck).
Directions: In an empty bowl, mix about ¼ cup cornstarch and add about 1/3 cup of water. Mix.

2. What happens if you pick up some of the Oobleck?

3. What happens if you squeeze the Oobleck?

4. Do you think Oobleck in the liquid phase or the solid phase? Explain your response.

Oobleck is a non-Newtonian fluid. Examples of others are ketchup, quicksand, and paint. These suspensions have a viscosity that varies with applied force (stress). They are fun to play with and there is interest in developing these types of materials as body armor. Doing a youtube search on Oobleck will also be very entertaining. You may not be able to walk on water, but you can walk on Oobleck!

Pre-lab Assignment

Background information for this lab can be found in Section 12.7 of your textbook.

In this lab you will have the opportunity to explore different kinds of polymers. One common theme is that polymers can be flexible, yet very strong. This poses a problem when disposing such materials. Plastics are notorious for taking too long to degrade in our landfills. Recyling becomes a very important solution.

1) Go to the following website and answer the following questions

   http://www.nationalgeographic.com/resources/ngo/education/plastics/

a) What are 3 natural polymers found on this website?

b) What are 3 man made polymers found on this website?

c) Recycling is an important part of environmental responsibility. Name three polymers and the products they are recycled into on this website.

2) Many products made of plastic have a plastic container code (1 through 7). Find the name of the polymer for each code listed below and give an example of each one. If you use a website, cite it below.

Code	Material	Examples
1		
2		
3		
4		
5		
6		
7		