

Synthetic Polymers and Plastics

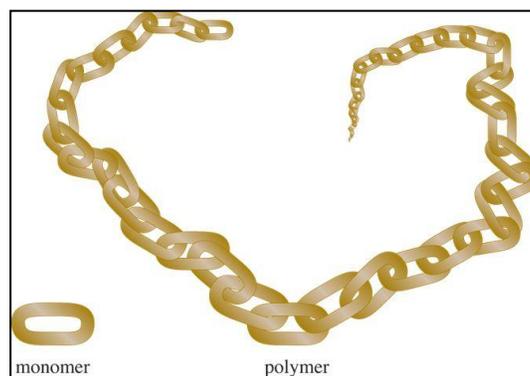
Objectives

The objectives of this laboratory are to:

- Understand properties and uses of synthetic thermoplastics
- Compare the physical properties of “Big Six” plastics
- Identify everyday plastics by their physical properties
- Draw basic structures of polymers when given monomer structure

Background

The word “**polymer**” means “many units”. A polymer can be made up of many repeating units, which are small **monomer** molecules that have been covalently bonded. Figure 1 (from Chemistry in Context) shows a single monomer, and a polymer made of identical monomers linked together. A polymer can contain hundreds of monomers, totaling thousands of atoms.



Examples of naturally-occurring polymers are silk, cotton, wood, cotton, starch, natural rubber, skin, hair and DNA. In the early 1900s, chemists began to replicate natural polymers, and create **synthetic polymers**, beginning with **nylon** which mimics silk in its strength and flexibility.

Plastic is a type of synthetic polymer. Currently, more than 60,000 plastics are manufactured for industrial and commercial purposes. Roughly 75% of the plastics used in this country can be categorized as one of six types, or “**The Big Six**”. These polymers are listed in the table below.

No.	Name	Abbreviation	Uses
1	polyethylene terephthalate	PET	clear bottles and containers, fleece, carpet
2	high-density polyethylene	HDPE	opaque bottles and containers, buckets, crates
3	polyvinyl chloride	PVC	rigid form: pipes & credit cards; soft form: tubing
4	low-density polyethylene	LDPE	bags, films, sheets, bubble wrap, toys
5	polypropylene	PP	bottle caps, yogurt containers, furniture
6	polystyrene	PS	expandable form: styrofoam; crystal form: CD cases



These six polymers are **thermoplastic**: they can be melted and reshaped, or **recycled**. The numbers are used to ease identification of the plastics, so that they can be separated for recycling. The symbol used on plastic packaging materials is three arrows in a triangle shape, with the number of plastic in the middle. This symbol makes recycling easier by making the identification of plastics easier.

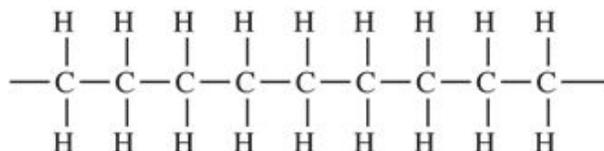
The Big Six thermoplastics have these general attributes:

- recyclable
- insoluble in water
- resistant to most chemicals
- lightweight yet strong
- can be shaped
- can be colored with pigments
- usually made from petroleum
- used to make items that have no alternatives from other materials

The most common of the Big Six plastics is **high-density polyethylene (HDPE)**. It is composed of repeating units of the monomer **ethylene**

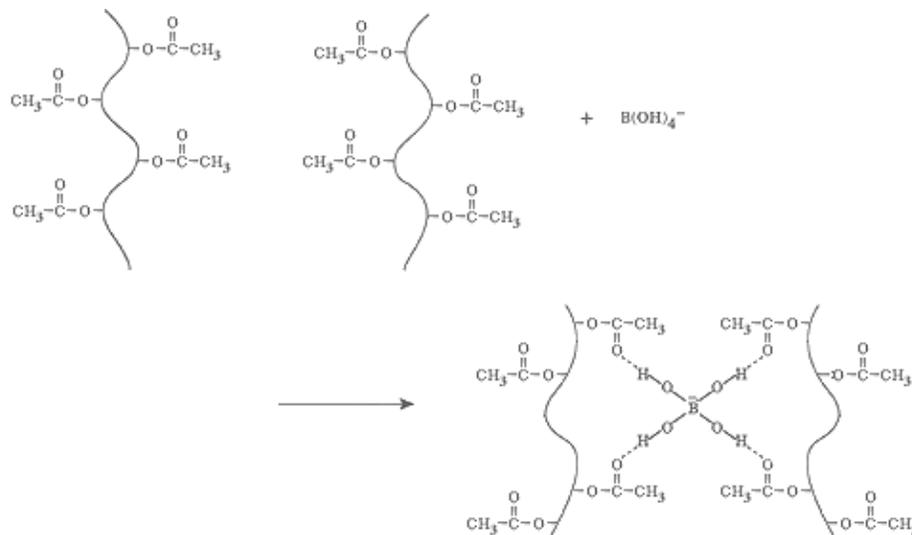


Monomers are linked together in an **addition polymerization** reaction. Each new monomer adds to one end with a covalent bond; the total number of monomers in the polymer is represented by the subscript, n. The resulting polymer is a chain of monomers linked together. The figure at right depicts one part of the polymer chain. How many monomers are present?



In this experiment, you will be qualitatively analyzing plastic polymers for physical characteristics of **opacity**, **flexibility**, **durability**, and **breakability**. You'll also analyze the **density** of each plastic by checking whether pellet samples float or sink in three liquids of different densities.

In this lab, you will make a polymer bouncy ball using a chemical reaction between borax and glue. Glue contains the polymer **polyvinyl acetate**, which cross-links to itself when reacted with **borax** (diagram below). After cross-linking, the glue is no longer fluid, but more solid. Adding cornstarch helps to bind the molecules together so that they hold their shape.



Procedure

Safety

No materials used in this experiment should be ingested.

Personal Protective Equipment (PPE) required: safety goggles, lab coat, closed-toe shoes

Materials and Equipment

samples of Big Six plastics (marked with recycling symbols), pellets of Big Six plastics, 1:1 95% ethanol/water solution, distilled water, 10% NaCl solution, 3 small test tubes, glass stirring rod, wash bottle with distilled water, 3 small beakers, 3 plastic spoons, paper cup, Elmer's glue, borax, cornstarch, ruler

Part A: Physical Characteristics of Plastic Polymers

Samples of different plastics are available at the front bench. Identify the samples by looking for the number/recycling symbol. Use these samples to analyze physical characteristics of each type of plastic: recyclability, opacity, durability/hardness, and flexibility.

Part B: Density Tests of Big Six Plastics

1. Three solutions of different densities will be used:
 - Solution A = 1:1 95% ethanol/water, density = 0.94 g/cm^3
 - Solution B = distilled water, density = 1.0 g/cm^3
 - Solution C = 10% NaCl, density = 1.08 g/cm^3
2. Obtain and label three small test tubes: Solution A, B and C. Add about 3 mL (two full dropper squirts) to each test tube.
3. Place one piece of each plastic into each of the three test tubes. Push each piece under the liquid surface with a glass stirring rod. Surface tensions will cause all of the plastic to float until each is "wetted" and submerged using the rod.

Record whether the sample sinks rapidly, sinks slowly, floats on the surface, or floats below the surface (but doesn't sink to bottom).

If the sample floats, it has a density *lower* than that of the solution. This may be relative to another sample that floats. If the sample sinks, it has a density *greater* than that of the liquid. The sample may also sink rapidly or slowly relative to other samples.

4. Test each of the six plastic types accordingly, to complete the table in the lab report.

Part C: Polymer Bouncy Balls

1. Obtain front bench: paper cup with approximately 100 mL of Elmer's glue (sample cup will be marked to 100 mL), ruler and 3 plastic spoons. Obtain a wash bottle with distilled water.
2. Obtain from your locker: 3 small beakers, stirring rod, small graduated cylinder

Making Polymer Bouncy Ball #1:

1. In a glass beaker, add:
 - 3 level spoonfuls of glue
 - 5 mL distilled water
 - 1 level spoonful of borax powder
2. DO NOT STIR. Allow the ingredients to interact for 10-15 seconds. Then use stirring rod to mix. Once the mixture becomes impossible to stir, take it out of the beaker and mold the ball with your hands. The ball will start out sticky and messy, but will solidify as it is kneaded.
3. Record physical observations about the ball in the table: is the ball stretchy? goopy? slimy?
4. Use the ruler and hold the ball at a height of 30 cm (=12 in) above the bench. Drop the ball and record how high it bounces.

Making Polymer Bouncy Ball #2:

1. In a glass beaker, add:
 - 3 level spoonfuls of glue
 - 5 mL distilled water
 - 1 level spoonful of cornstarch
 - 1 level spoonful of borax
2. Repeat steps 2-4 from previous.

Making Polymer Bouncy Ball #3:

1. In a glass beaker, add:
 - 3 level spoonfuls of glue
 - 1 level spoonful of cornstarch
 - 1 level spoonful of borax
2. Repeat steps 2-4 from previous.
3. You and your lab partner may take home these bouncy balls, as all of the materials are non-toxic. However, please remember that they're not edible!