11: Synthetic Polymers and Plastics (Experiment)

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

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.

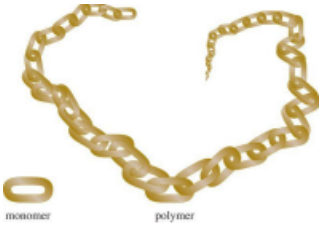

Figure 11.1: Symbolic representation of a monomer and a polymer

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

No.	Name	Abbreviation
1	polyethylene terephthalate	Clear bottles and containers, fleece, carpet
2	high-density polyethylene	

No.	Name

Abbreviation Pa Tuebingen 3034 Uses and containers, buckets, crates

No.	Name	Abbreviation
3	polyvinyl chloride	PVC

No.	Name	Abbreviation	Uses
4	low-density polyethylene	LDPE	bags, films, sheets, bubble wrap, toys

No.	Name	Abbreviation	Uses
5	polypropylene	PP	bottle caps, yogurt containers, furniture parts
6	polystyrene	PS	

No.	Name	Abbreviation and able 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.

Figure 11.2: Symbol labelling thermoplastics

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

— (H2C-CH2)n—

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 below depicts one part of the polymer chain. How many monomers are present?

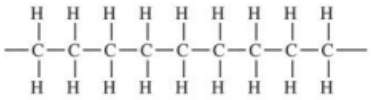

Figure 11.3: Symbol labelling thermoplastics

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.

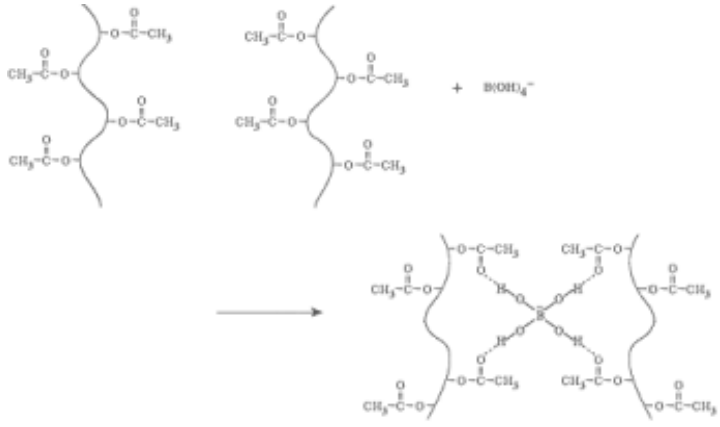

Figure 11.4: Polymerization reaction to form polyinyl acetate

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/cm3
    - Solution B = distilled water, density = 1.0 g/cm3
    - Solution C = 10% NaCl, density = 1.08 g/cm3
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!

Report

Synthetic Polymers and Plastics

Part A: Physical Characteristics

Find or choose one type of each of the following plastic polymers, and report the following characteristics:

Plastic number	Short Name (HDPE, LDPE, etc)	Clear (yes or no)	Opaque (yes or no)	Flexibility (can be bent?)	Durability (hard or soft)	Breakability (can be cracked?)	Recyclable (yes or no)
1							
2							
3							
4							
5							
6							
7							

Part B: Density Tests

Report for plastic samples in each liquid: sinks rapidly, sinks slowly, floats on top, floats below surface

Plastic number	1:1 ethanol/water density = 0.94 g/cm3	Water density = 1.0 g/cm3	10% NaCl solution density = 1.08 g/cm3
1			
2			
3			
4			
5			
6			

Relative Plastic Densities:

Less than 0.94 g/cm3	Less than 1.0 g/cm3	Less than 1.08 g/cm3	More than 1.08 g/cm3

Ranking of densities:
(lowest) _____ _____ _____ _____ _____ _____ (highest)

Part C: Polymer Bouncy Balls

Polymer Ball composition	Approximate height bounced	Physical characteristics
Ball #1:		
Ball #2		
Ball #3		

Questions

1. Which of the Big Six plastics was the most flexible?
2. Which of the Big Six plastics would be the best material for each of the following examples? Use short names to identify each plastic (e.g. HDPE).

   a replacement for a glass window ?
   a take-out container for food?
   a flexible, expandable bag for carrying items? a lightweight bottle cap?

3. An unknown plastic floats in a 10% NaCl solution but sinks in water. What is the range of possible density values this plastic may have? Suggest the composition of this plastic.

4. Why is it important to dislodge any adhering bubbles in the density tests?

5. PET plastic (number 1) is the most valuable waste plastic at the present time. Suggest a way to separate it commercially from other waste plastics.
6. Sometimes plastic containers are made from two polymers and not just one. What would happen to the water density test if HDPE and PVC were mixed?
7. Why are plastic recyclers very concerned about identifying the different polymers and not mixing them together?
8. The figure below depicts polymerization of polystyrene (PS). Circle the original monomers and determine how many monomers are present.

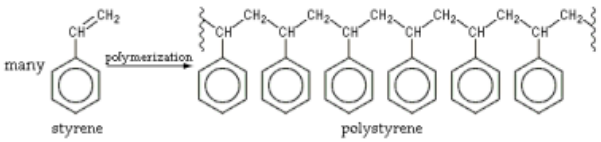

Figure 11.5: Polymerization reaction to form polystyrene

9. Polyvinylchloride (PVC) is composed of the vinyl chloride monomer. The monomer structure and general reaction are shown below.

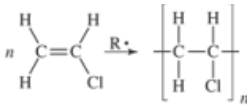

Figure 11.5: Polymerization reaction to form polyvinyl chloride

Draw a polyvinyl chloride polymer composed of five monomers arranged in a head-to-tail pattern.

10. For the bouncy balls you made, what is the name of the monomer?
    What is the role of each of the following in the formation of the polymer?

glue

borax

cornstarch

10. Which ball bounced the highest? Based on your data in the table, which compound was most likely responsible for this?

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