

SORTING PLASTICS FOR RECYCLING
INTRODUCTION

Description

Students use the difference in densities of polymers and flame tests as a basis for the development of a scheme to separate plastics.

Goals for This Experiment

The goals of this experiment are to have students:

1. realize that plastics can be sorted according to their unique properties,
2. devise a feasible plan to identify the different types of plastics and discuss the advantages and disadvantages of their plan,
3. think about the environmental and cost concerns companies face when developing new procedures, and
4. familiarize students with polymer properties.

Recommended Placement in the Curriculum

This scenario should be placed in the second semester of the General Chemistry laboratory course after students are familiar with the different types of bonding and are able to understand polymers. Students also need to have an understanding of the term density.

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BACKGROUND

One of the principles of chemistry is that matter can be neither created nor destroyed. In one sense, this might mean that everything can be recycled. In practice, recycling depends upon what is profitable or easily done. Consider the plastic material high-density polyethylene (HDPE). It is quite heat- and light- stable, as well as resistant to acids, bases, and oxidation at ambient temperatures. These properties mean that the plastic could, in principle, be freed from labels, paper, glue, and other foreign materials; cleaned; and chipped or cut into small pieces. These pieces would be expected to be quite similar to virgin plastic pieces for plastic fabrication.

YOUR TASK

Your task in this experiment is to determine what physical property of HDPE makes it a good candidate for recycling and design a system that could be used to separate HDPE from other recycled plastics (LDPE, PS, PETE, PVC, PP). (Hint: Imagine chipping and cleaning (or cleaning and chipping) plastic milk bottles into pieces. What could be used for cleaning? What happens to the paper, glue, and other stuff? What happens to the plastic pieces, and how do these considerations suggest a feasible project?)

FIRST STEP

As a first step, you will need to understand the basic procedures and principles involved in polymer identification. You will follow the procedures of Part I and II, making sure that you understand what you have done and why you have done it. You will work in pairs throughout this investigation.

Part I: Relative Density

1. Team with another pair of students to prepare the four standard-density solutions listed below. (Two pairs can share the solutions, but they should perform the investigations separately.)

Solution	Components	Density
A	100 mL 70% isopropyl alcohol/40 mL water	0.91 g/mL
B	80 mL 70% isopropyl alcohol/40 mL water	0.93 g/mL
C	150 mL water	1.00 g/mL
D	75 g (3 Tbsp) sugar/150 mL water	1.14 g/mL

2. Obtain samples of the seven known polymers and one unknown. Make sure that the identity of each of the known samples is clearly marked.
3. Drop one of the known samples into solution A. Record whether it floats or sinks.
Note: Be certain that the sample breaks the surface tension of the solution to prevent any false observations.

4. Remove the sample with the forceps and dry it off.
5. Repeat Steps 3–4 until the other six known polymer samples and the unknown have been tested in solution A.
6. Double-check the observations from Steps 3–5 by placing all of the known polymer samples into each density solution and stirring. Note which samples sink and which float.
7. Repeat Steps 3–6 until all the known and unknown polymer samples have been tested in all four density solutions. (After using the sugar solution, be sure to rinse the plastic samples with water and dry them off.)
8. Compare your results with those obtained by other students to determine a density range for each of the known plastic samples.

Part II: Flame Test

Note: Make sure that this part of the experiment is performed in a well-ventilated area away from the solutions used in Part I. Isopropyl alcohol, used to prepare some of the solutions, is flammable. Keep away from flames. See the MSDS.

1. Set up the heat source and begin to heat a clean, dry sample of one of the known polymers (except the PVC) using tongs to hold the sample in the edge of the flame. Observe and record the results of testing, including the ease with which the sample ignites, the color of the flame, the color of the smoke, the odor, and the aftereffect of removing the sample from the flame. Repeat this procedure until all the known polymers (except the PVC) have been tested.
2. For the polyvinyl chloride (PVC) sample only: Place the small loop at the end of the piece of copper wire into the flame for 30 seconds or until it is red hot. Take the wire out of the flame and place the sample of PVC on the hot loop. Place the loop and the PVC sample back into the flame. It should burn with a green flame.
3. Repeat Step 1 for the unknown polymer sample. Repeat Step 2 only if you expect the unknown to be PVC.

Part III: Applying What You've Learned

1. Use the procedures you've learned and the information you have collected to complete the task described above.
2. Critique your plan by answering the following question: What are the advantages and disadvantages of the tests you propose?

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INSTRUCTOR NOTES

Time Required

The laboratory experiment should take between 2–2½ hours to complete. An extensive pre-lab discussion may be needed if students have not learned about polymers before. In this case, the laboratory experiment would take closer to 3 hours to finish.

Group Size

Students should work in pairs to perform Parts I and II and to develop a plan to sort and share their thoughts on the advantages and disadvantages of their plan.

Materials Needed

per pair of students:

- a source of heat such as a burning candle or Bunsen burner
- samples of the following 6 polymers (cut into 1-cm x 2.5-cm strips)
 - polyethylene terephthalate (PETE): 2-L bottles (recycle code 1)
 - high-density polyethylene (HDPE): milk jugs (recycle code 2)
 - polyvinyl chloride (PVC): dish detergent bottles (recycle code 3)
 - low-density polyethylene (LDPE): dry cleaning bags (recycle code 4)
 - polypropylene (PP): yogurt containers (recycle code 5)
 - polystyrene (PS): clear plastic cups (recycle code 6)

Do not use foamed polystyrene!

- 15-cm (6-in) length of 18-gauge copper wire
- tongs, forceps, or tweezers
- scissors or another device for cutting the material into pieces

for every four students:

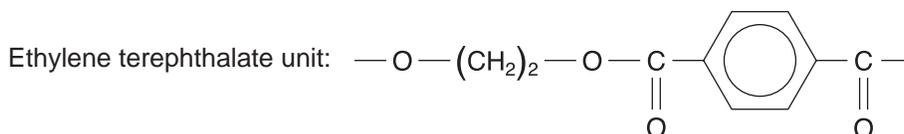
- materials for students to prepare the following solutions:
 - 1 L of Solution A, density = 0.91 g/mL: Mix 100 mL of 70% isopropyl alcohol and 40 mL of water.
 - 1 L of Solution B, density = 0.93 g/mL: Mix 80 mL of 70% isopropyl alcohol and 40 mL of water.
 - 1 L of Solution C, density = 1.00 g/mL: 150 mL of water
 - 1 L of Solution D, density = 1.14 g/mL: Mix 80 mL (⅓ cup) sugar and 150 mL of water.

Safety, Disposal, and Special Handling

Review the Material Safety Data Sheets of any chemical used in the experiment for information regarding safety and handling. Dispose of waste according to your local ordinances.

Points to Cover in Pre-Lab

- Explain polymers to students.
- Explain the bonding of carbon, that it is tetravalent, can form single, double, or triple bonds, and can form bonds to other carbon atoms as well as to other nonmetals. Give examples such as methane, ethane, ethylene, carbon dioxide, ethyne, and hydrogen cyanide.
- Define the terms “mer” (a unit), “monomer” (a single unit), and “poly” (meaning many). You can then ask the students what they think polymer means.
- To help illustrate how polymers are made from monomers, use several paper clips. Define one paper clip as a monomer. Hook several paper clips together to form a chain. This can represent a polymer. (This analogy works well on an overhead for a large class.)
- Show students the structure of the monomer unit of the polymer they will be working with, polyethylene, as well as other polymers (polypropylene, polystyrene, etc.).



- Ask students what they think the structures of the polymers are.
- Discuss some characteristics of polymers such as the following:
 - the type of bonding. Primary bonding is covalent since most polymers contain carbon.
 - molecular weight, which varies between molecules of a polymer and is sometimes referred to as an average molecular weight. The molecular weight is important in determining properties of a polymer.
 - density—polymers have characteristic densities. Ask the students how the densities of the polymers could be estimated (by placing them in a solution of a known density and observing if they sink or float). If they have completed the scenario “Sorting Plastics for Recycling” this idea will come to them easily.

- burn properties—the way a polymer ignites, the color of the flame and smoke, the smell, and whether or not it burns when removed from a flame are all characteristics that when combined are unique to that type of polymer.
- Ask students if there is another way to identify the different polymers (infrared spectrometry—they will only know this if they have had some prior experience with infrared spectroscopy).
- Point out to students that sometimes surface tension causes items to float despite being more dense than the fluid. They need to make sure the items they test float because they have a smaller density, not because of surface tension.

Likely Play-out of Lab

In Part I, students will observe the following:

Polymer	Density Range (in g/mL)	Solutions (density in g/mL)			
		A (0.91)	B (0.93)	C (1.00)	D (1.14)
Low-density polyethylene (LDPE)	0.92–0.94	sink	***	float	float
High-density polyethylene (HDPE)	0.95–0.97	sink	sink	float	float
Polystyrene (PS)	1.05–1.07	sink	sink	sink	float
Polyethylene terephthalate (PETE)	1.38–1.39	sink	sink	sink	sink
Polyvinyl chloride (PVC)	1.16–1.35	sink	sink	sink	sink
Polypropylene (PP)	0.90–0.91	float	float	float	float

*** Depends upon the sample tested

Advantages and Disadvantages of Each Test

Density Scheme for Separating Plastics

Possible Advantages

- Can identify and separate plastics based on density all in one step.
- Solutions needed can be re-used and are fairly non-toxic.
- The system could be automated.
- Fewer workers would be needed (eliminating the expense of employing them). A decrease in the cost margin is always a good incentive for a company to adopt a procedure.

Possible Disadvantages

- Large amounts of solutions are needed.
- Sophisticated machinery is needed to separate, which could be expensive.
- Due to automation there would be a loss of jobs.
- Accurate density of the solutions must be maintained. Monitoring the density would lead to an added expense.
- Size of the pieces may vary and may not be ideal.
- Surface tension may interfere.

Flame Test Scheme for Separating Plastics

Possible Advantages

- Can identify the different plastics without question.

Possible Disadvantages

- Does not separate the different types of plastics from each other. This would have to be done in another step.
- Some polymers are toxic when burned.