JCE Classroom Activity

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A Novel, Simplified Scheme for Plastics Identification

JCE Classroom Activity 104

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Instructor Information

In this Activity, students identify seven recyclable plastics as they follow a flowchart in the Student Activity section. The flowchart scheme includes making density comparisons of the plastic samples in water and alcohol and observing physical changes of plastic samples subjected to boiling water temperatures and exposure to acetone. This scheme is simplified from previous published papers to make it usable with middle school students as well as high school students. Completing the flowchart activities requires about 45 min. The Student Activity section, student data table, and suggested answers to the Activity questions are included as supporting material.

Background

Previous schemes for identification of plastics have included Hands on Plastics kits from the American Plastics Council and the American Chemistry Council; however, these kits are no longer available *(1, 2)*. The *Journal* has published other schemes, including those by Kolb and Kolb *(3)*, Anderson *(4)*, and Hughes, Ceretti, and Zalts *(5)*. This Activity uses only boiling water, acetone, and alcohol, making it safer for students compared to previous identification methods. All of these schemes are based on differences in densities of the plastics. This Activity also adds a seventh plastic to identify, polylactic acid (PLA), sometimes referred to as corn plastic.

Both the chemical composition of the plastics and the packing of the polymer chains determine the density of recycled plastic pieces. See Table 1 for the densities of the seven plastics used in the Activity. The more open-chained arrangement of polymer chains will produce a density less than 1 g/mL: observers will see that three of the seven plastics float in water. Low-density polyethylene (LDPE) has a branched-chain structure compared to high-density polyethylene (HDPE), which has a closer-packed structure. The densities of these two plastics can vary by values of 0.01−0.05 g/mL, but both are less dense than water. Polymer chains that contain larger molecular structures—like the phenyl group located in or on the carbon chain, as in poly(ethylene terephthalate) (PET) (Figure 1) and polystyrene (PS)—will sink in water. Chlorine atoms attached to the carbon backbone will also produce a higher density plastic such as polyvinyl chloride, PVC.

Four of the plastic pieces are subjected to a boiling water test. All four will soften at 100 °C but they do not melt. Two concepts need to be addressed here to explain the rigidity and flexibility of synthetic polymers. Plastics can contain either or both amorphous (noncrystalline) regions and crystalline regions, but amorphous regions are more common. The melting transition occurs in the crystalline regions of the plastic while the amorphous regions undergo a softening ("glass transition") at a temperature defined as the glass transition temperature, T_g. Both of these transitions are due to increased mobility in the regions, and both are expressed as a softening of the material. The four plastics do

Table 1. Selected Physical Properties of Common Plastics

Number	Plastic Type and Composition	Density/(g/mL)	Glass Transition Temperature/°C *(7)*	Melting Temperature/°C *(7)*
1	PET or PETE: poly(ethylene terephthalate)	1.38−1.39	60−85	250−265
2	HDPE: high-density polyethylene	0.95−0.97	∼−125	∼138
3	PVC or V-poly(vinyl chloride)	1.16−1.35	81−98	200−300
4	LDPE: low-density polyethylene	0.92−0.94	−128 to −30	∼138
5	PP: polypropylene (isotactic when all methyl groups are on the same side of the chain)	0.90−0.91	−8	174−177
6	PS: polystyrene	1.05−1.07	80−100	240
7	PLA: polylactic acid *(8)* (D and L conformations cause numbers to differ)	1.25−1.26	50−80	173−178

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not melt at 100 °C (i.e., when placed in boiling water), as their melting points are above 130 °C, but these four plastics do have a T_g at or below 100 °C *(6)*. These plastics are brittle and hard at room temperature but soften as they cross their respective glass transition temperatures when placed in boiling water. Table 1 lists selected physical properties of common plastics, including the glass transition and melting temperatures for the seven recycled plastics. Even pure polymers exhibit differences in T_g, depending on production methods and subsequent processing. Recycled materials have even more variation, so the values given in Table 1 should be considered approximate.

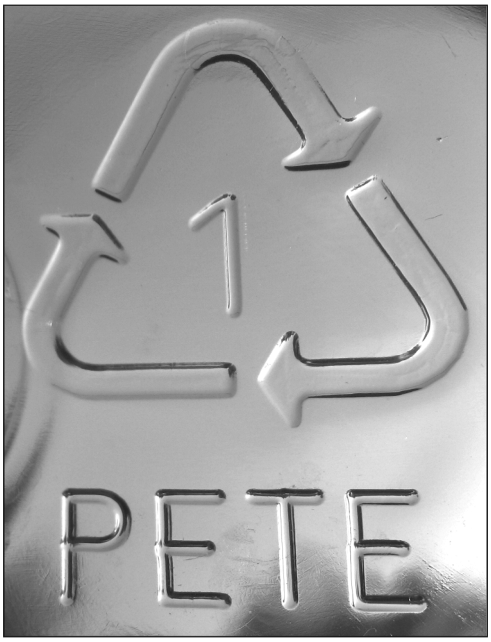

Figure 1. Close-up of a container made using PETE with a recycle code of 1. (Photo credit: Hal Harris.)

Integrating the Activity into Your Curriculum

This Activity could be used at the beginning of the year when density of solids and liquids is explored. It also fits in with discussions of chemistry in the news when recycling and plastics are mentioned. This Activity would also fit a forensics unit in which students need to identify a plastic from a crime scene. After using this Activity, instructors could continue the idea of recycling using a previous *JCE* article where students design a system to separate commingled recyclable trash to simulate sorting in a recycling center *(9)*.

About the Activity

Working alone or in pairs, students follow the four tests shown in the flowchart (see Figure 2) to identify seven recyclable plastics. They can be given clean and dry plastic containers with their recycle codes removed (but labeled with a permanent marker A–G for instructor identification) so that they may cut pieces (1.5 cm × 1.5 cm) for analysis; alternatively, the

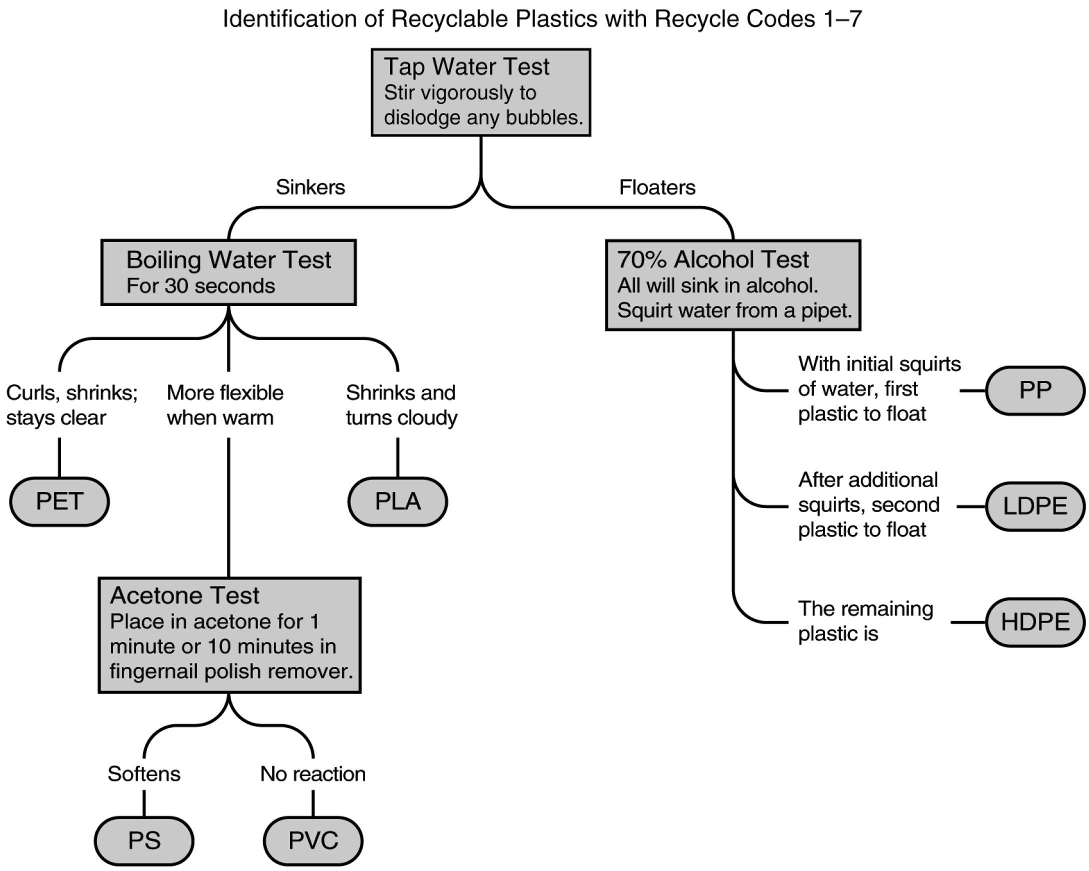

Figure 2. Flowchart for identifying types of recyclable plastic.

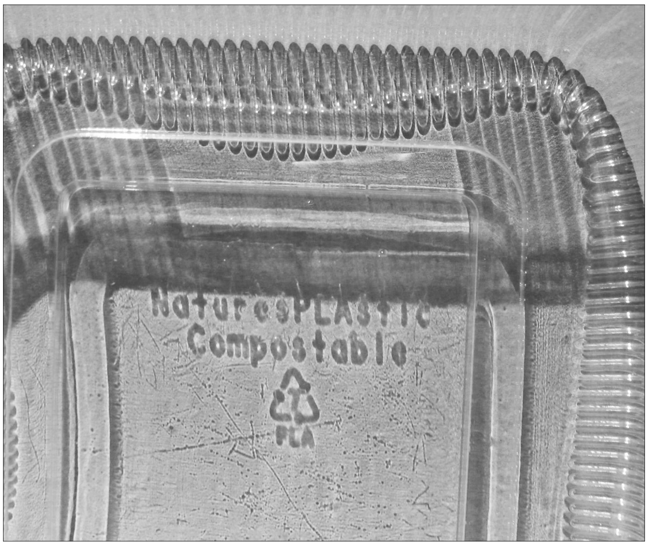

Figure 3. Container made of PLA with a recycle code of 7. (Photo credit: Mary Harris.)

instructor can prepare the cut plastic pieces. If containers have the same color, differently shaped pieces (triangles, rectangles, etc.) should be used to distinguish between them. We also recommend that all cut pieces be flat. Note that no foam containers should be used because the density of a foam container is much less than that of a nonfoam container of the same type of plastic. Plastics labeled as 7 can be confusing. If the recycle code on a container says “7” and “other” or “mixed” it is not suitable for this scheme because it is made from two or more kinds of plastics. You will need a number 7 plastic labeled “PLA” or polylactic acid for this Activity. See Figure 3 for an example of the PLA recycle code. If you cannot find PLA containers, then continue with the other six. Because some additives will alter the density of a plastic piece slightly and produce variable results, we highly recommend that teachers test the activity using the selected containers before the plastic pieces are given to the students.

Tap Water Test

In tap water, three plastics will float (PP, LDPE, and HDPE), while the remaining four sink (PET, PLA, PS, and PVC).

70% Alcohol Test

The three that float in water are then added to 70% isopropyl alcohol. They will sink because the alcohol solution is less dense than those samples of plastic. With addition of water to the alcohol solution, the solution becomes denser so that the plastics begin to float in reverse order of their densities. All three of the floaters in water must be present in order to determine which is the least dense, next dense, and most dense in 70% isopropyl alcohol—water solution.

Boiling Water Test

Several beakers of boiling water and tongs should be available for the class. All four of the sinkers in water have some kind of reaction to boiling water so students will need to make careful observations. PLA and PET pieces of plastic will shrink, indicating that the polymer chains have memory. Plastic bottles and deli containers are made using heated, softened polymer, which is stretched into sheets or thin walls of a bottle so that the polymer chains are aligned. These containers are then cooled quickly. When the polymer in PLA or PET is subsequently heated to 100 °C, the chains rearrange themselves into a less ordered pattern and the plastic pieces shrink in size, reverting to an initial form. PVC and PS polymers do not exhibit this rearrangement when heated to 100 °C.

Acetone Test

The reaction in acetone is a softening of the plastic. If one uses fingernail polish remover containing acetone instead of pure acetone, the wait time is about 10 min instead of 1 min. Acetone will evaporate quickly if it is not kept covered; it is also highly flammable. Acetone may be saved and reused at a later date. Students should use forceps or tongs to retrieve their plastic pieces from acetone.

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Supporting Information Available

Student activity worksheet; answers to student questions; student data table. This material is available via the Internet at http://pubs.acs.org/.