**Teacher Activity**
**Plastics and Other Ploymers: Separating and Identifying Plastics**
**Companion Web pages:**
http://www.chemheritage.org/classroom/chemach/plastics/index.html

## Procedural Notes

### Pre-Lab Demonstration

This demonstration will prepare students for their experiment by exposing them to the idea of separating objects by density. Before students begin their actual experiment, prepare a 45% (V/V) solution of isopropanol. You will need this solution both for their experiment and for your demonstration. If you use the 70% rubbing alcohol from a drugstore, you will need 65 mL of alcohol and 35 mL of water for every 100 mL of solution. The volume of alcohol you need depends on the size of the containers you will use for the demonstration. The larger cylinder (100-mL) is easier to fit pieces of plastic into, but it requires more alcohol solution.

### Demonstration Materials

- 2 liters of 45% solution of isopropanol (1 liter if you use 500-mL cylinders)
- 2 pieces of low-density polyethylene (LDPE), one square and one cut into the shape of an “L,” both as large as will fit freely into the cylinders
- 2 pieces of high-density polyethylene (HDPE), one square and one cut into the shape of an “H,” same sizes as LDPE pieces
- Food coloring to tint the alcohol solution (not yellow, for aesthetic reasons)
- 2 identical tall cylinders, 500-mL or 1,000-mL (graduated cylinders are okay, but ungraduated ones might be even better without numbers and lines to distract students)

### Safety

- The alcohol solution is flammable, so be sure to keep open flames away from the demonstration area.
- Wear safety goggles.
- Save the solution for future use rather than disposing of it.

### Procedure

Students should have already brought in samples of plastics from home, so they should be somewhat familiar with the recycle codes.

1. Have the two cylinders of 45% alcohol solution ready in the front of the classroom. They should be filled almost to the top. They need not be visible to students at this time.
2. Ask students if they know the difference between low-density and high-density polyethylenes. (Connect these terms to the HDPE and LDPE symbols on the plastic samples they brought to class.) The response will probably be the obvious: their densities must be different.
3. Ask students if they know how to tell the two apart. Some might suggest measuring their densities (difficult to do directly since the mass and volume have to be

measured and the density calculated), while others might suggest testing for sinking and floating.

4. Place the square pieces in the two cylinders and let students observe the differences and draw their conclusions.
5. Use the “L” and the “H” to visually confirm their findings.
6. Ask them if they think they could use this method to separate the other plastics as well. This question will set the stage for the students’ experiments.

You can retrieve the HDPE samples when you pour the alcohol from the cylinders. You can keep the alcohol in a sealed container for the next year’s demonstrations.

## Student Experiment

### Materials and Teacher Preparation for Test Stations

**Alcohol/Density 2 Test Station, for 2 lab groups simultaneously testing**

- 2 beakers each, 250-mL, or clear plastic disposable tumblers
- 2 stir rods, craft sticks
- 2 plastic spoons
- 200 mL of 45% isopropyl alcohol (dilute 130 mL of 70% isopropyl rubbing alcohol from drugstore with 70 mL of water; stir to mix thoroughly and pour approximately 100 mL into each of the two beakers)

**Oil/Density 3 Test Station, for 2 lab groups simultaneously testing**

- 2 beakers, 250-mL, or clear plastic disposable tumblers
- 2 stir rods, craft sticks, or plastic spoons
- 2 plastic spoons
- Paper towels
- Corn oil (Mazola oil)

**Acetone/Softening Test Station, for 2 lab groups simultaneously testing**

- 2 beakers, glass, 100-mL, or small clear **glass** containers (for acetone)
- 2 small petri dishes to cover the beakers when not being used for tests
- 2 stir rods or craft sticks
- 2 pair of tongs or forceps
- 1 glass waste receptacle (beaker or small glass jar is fine)
- Acetone

**Boiling Water/Heat Test Station, for 2 lab groups simultaneously testing**

- 2 beakers, 250-mL
- 2 pair of tongs or forceps
- 2 electric hot plates (these can be shared among several lab groups)
- Water

**Preparation for Lab**

1. It is strongly recommended that you set up the four test stations in different areas of the room to isolate the individual tests, which will make the lab more manageable. It will also keep the acetone and alcohol away from any open flames. Both liquids are extremely flammable. If you choose not to set up the stations, it will be very difficult to oversee all the groups to make sure that none of them have the alcohol and acetone in close proximity to their burner flames during the copper-wire tests.
2. Provide large signs so students can easily find the four test areas, or make sure students know where the stations are located before they begin.
3. The materials list above gives the amounts necessary to allow two lab groups to work simultaneously on a specific test. If you have more space for groups to work, you can provide extra station setups and thus increase the number of groups that work simultaneously at one test area; conversely, if you have less space, you can have only one lab group working on one test at a time, which will result in some lab groups waiting until test stations open up.
4. To save time in the lab, you can cut up all six recycle code plastics (from the items students brought to class or ones you supply) into small pieces (2- to 3-cm squares) and have all six types of plastics already mixed together in small zippered plastic bags, one bag for each lab group. Students should probably have about 5 pieces of each resin type in the bag. Or you might have six cups or beakers lined up, each containing many pieces of one of the six plastics and have students take their samples from each container.
5. It is a good idea to choose only one color for each type of plastic resin (taken from one source of plastic, e.g., a milk jug or Tide bottle, and to make sure that all six resins are different in color). This color differentiation will help students organize their work and allow them to record their observations by color, but it also helps you see at a glance whether a specific color of plastic (recycle code number) is not behaving as it should (or as it did for all other lab groups). Just tell students that specific types of resins are not necessarily that same color everywhere and that plastics can be made in almost any color.
6. If you cannot get a different color for each plastic type, or you need to use two sources of the same plastic (which are different colors), you can simply mark all the same type of plastic with a letter code that matches the recycling code (known only to you) in indelible ink, as from a Sharpie pen. Mark all the plastic pieces, and students can then use the letters of the plastics instead of colors when filling in their data tables.
7. If students supply the plastic items, they will probably bring in small things like yogurt cups or 16-mL water bottles. If you supply the plastic items, you can solve the one-color-per-plastic-type problem by obtaining large objects as your sources. For instance, 2-L bottles and vegetable-oil bottles are polyethylene terephthalate (PETE), gallon milk jugs or laundry-detergent bottles are made of high-density polyethylene (HDPE), plastic cat-litter containers and plastic plumbing pipe (and maybe clear ice-melt crystal bottles) are polyvinyl chloride (PVC), coffee can–type lids (and lab wash bottles) are low-density polyethylene (LDPE), yogurt containers and sour cream containers are made of polypropylene (PP), and the clear,

breakable deli and bakery trays are made of polystyrene (PS). Check your sources for the correct recycle code printed on the bottom of the item.

**During the Lab**

8. Be sure students understand the need to submerge the pieces of plastic and stir thoroughly to release any air bubbles that may have attached to the pieces. Attached air bubbles will cause all the pieces to float, negating their inherent density differences.
9. Keep open flames away from the Alcohol/Density 2 Test! Isopropyl alcohol is very flammable. This station should also be established away from the hot plate for the same reason.
10. For the **Copper-Wire Test** insert the end of the length of copper wire into the large cork so that the cork can serve as a handle for students to use when heating the wire. Alternatively, a pair of forceps, pliers, or vise grips could be used to hold the wire. Watch carefully to make sure that students do not touch the hot copper wires as they get hot all the way to the opposite end. Larger-gauge wire used in house wiring also works here. Strip about 1.5 to 2 inches of the insulation from the end of the wire. The rest of the insulation helps you hold the wire in the flame so it does not get too hot to hold.
11. If you prefer not to have students all doing this flame test at their lab stations, you can choose to do this as a demonstration for the entire class.
12. At the Acetone/Softening Test area, be sure to cover the beakers containing the acetone between uses to minimize student exposure to acetone vapors.
13. Since acetone is extremely flammable, set up this station so that it is away from both the hot plates and open flames! Students should be advised to avoid breathing in the fumes from the acetone. Make sure there is good ventilation in the lab area. Perhaps this test could be done in the fume hood, if one is available. Ask students to leave the resin tested in the acetone at the station for disposal—after the acetone has evaporated—to minimize the risk of fire or inhalation of acetone fumes at the lab benches.
14. For the Boiling Water/Heat Test, half-fill the beakers with water at the beginning of the lab activity, then place them on the hot plates and turn on the hot plates. Use a setting on the hot plates that will keep the water at a rolling boil throughout the lab. You will need to add water from time to time to prevent the beakers from boiling dry.
15. Ask students to return the used resin pieces at the end of the activity to the appropriate labeled (1 to 6) “recycle” containers you have set up, so you can reuse them in later classes.
16. As an extension to this activity, after students have gone through the complete resin test cycle, you can give them unknowns from other plastics sources (that do not look just like the ones they already tested) to identify. Examples might be to use a green PET bottle in place of the colorless one used in the original tests or a milk jug (HDPE) instead of the laundry detergent bottle.

**Student Skills Required**

1. Students must be able to work carefully and safely in the laboratory.
2. They must be able to read and interpret the instructions in the lab procedure.

## Student Misconceptions

1. **"All plastics float in water."** Many students (and adults) believe this to be true, and most do float but not all. The student's own results from this activity will dispel this misconception.
2. **"All plastics have similar properties."** If this statement were true, there would be no need for different recycling codes; we would not have to sort plastics before recycling them because they could all be recycled together; their densities would be alike; and we could use any plastic for any specific use (e.g., all plastics would be flexible—or not). Many factors affect a plastic's physical and chemical properties. This may (if they have had some basic carbon chemistry) or may not (if this lab is done at the beginning of the year) be the time to discuss such factors as size and shape of side branches on the chain, length of chain, degree of entanglement, methods of processing, and so on.
3. **"The bigger an object is, the denser it is."** Density is an intrinsic property since it is independent of the amount of material, while mass is an extrinsic property. Although this misconception is not directly addressed in this experiment, it would be easy to point out to students that this experiment does not require a specific size for each piece of plastic and that different lab groups probably have differently sized pieces, yet the experiment still works. This fact hints that density does not differ with size.

   You might want to have differently sized pieces of HDPE and LDPE as an "extra" in the opening demonstration to show students that size is irrelevant. You might also want to do the demonstration described in the *Journal of Chemical Education* article "Discrepant Event: The Great Bowling Ball Float-Off" (Diana Mason et al., 81:9 [Sept. 2004], 1,309). The article discusses using bowling balls of different masses to show how density varies with mass, while volume is held constant. (Just having something as large and massive as a bowling ball that can float is counterintuitive for students.) You can access the abstract at http://jchemed.chem.wisc.edu/HS/Journal/Issues/2004/Sep/abs1309.html. If you are a subscriber to the journal, you can access the full text of the article here, as well as a supplement that shows the student directions and results and photos of three bowling balls of different masses floating at different levels in water.

## Answers to Pre-Lab Questions

1. What property did you use to differentiate between high-density and low-density polyethylene?
   *We used density to differentiate between the two plastics.*
2. Would the same thing happen if these same two plastic pieces were placed in water? Explain.
   *No. In water they would both float. The density of water is much greater than that of the alcohol solution. Thus water provides more buoyant force. If the density of the plastic is less than that of water, it will float. This is the case for both LDPE and HDPE (densities: 45% alcohol, 0.95; HDPE, 0.96; LDPE, 0.93; water, 1.00)*
3. Do you think the other recyclable plastics can be separated the same way? Why or why not?

*Yes, but only into two groups, sinkers and floaters. We will have more than one type of plastic in each group. If we want to subdivide these two groups further, we will need to use other liquids with different densities.*

**Answers to Post-Lab Questions**

1. What colors of plastics were floaters in the Water/Density 1 Test? Which colors were sinkers?
   *Student answers here depend on the colors of the plastics you chose for your experimental samples.*
2. Based on the densities of the recyclable plastics and knowing that the density of water is 1.0 g/mL, identify the types of plastic that floated in water.
   *HDPE, LDPE, and PP were all floaters.*
   Which types sank in water?
   *PETE, PVC, and PS were all sinkers.*
3. In the Alcohol/Density 2 Test, which colors of the plastics were the floaters? Which colors were the sinkers?
   *Student answers here depend on the colors of the plastics you chose for your experimental samples.*
4. What is the identity of the sinker in the Alcohol Test? How do you know?
   *HDPE sank in alcohol. HDPE has the highest density of the three plastics that floated in water.*
   What types of plastic floated in the Alcohol Test?
   *LDPE and PP floated in alcohol.*
5. You may recall that an object sinks if the density of the liquid holding it up is less than the density of the object, but the object will float if the liquid's density is greater than the object's. Using this information, estimate the density of the alcohol solution based on the density table and the results of your tests.
   *Since LDPE and PP both sink in alcohol, the density of the alcohol must be greater than 0.92, but since HDPE floats, the alcohol's density must be less than 0.95. Student estimations around 0.93 to 0.094 would meet these requirements. The actual density of the alcohol solution is 0.94 g/mL.*
6. In the Oil/Density 3 Test, what was the color of the plastic that floated? What color was the sinker in the Oil Test?
   *Student answers here depend on the colors of the plastics you chose for your experimental samples.*
7. What is the identity of the sinker in the Oil Test?
   *LDPE sinks in the Oil Test.*
8. What is the identity of the floater in the Oil Test?
   *The floater in the Oil Test was PP.*
9. Estimate the density of Mazola oil.
   *The density of Mazola oil must be greater than that of PP (0.90 to 0.91), but less than that of LDPE (0.92 to 0.94). Therefore, a good estimate of the density of the Mazola oil is 0.91 to 0.92 g/mL. [The density is actually 0.917.]*
10. In the Copper-Wire Test, polyvinyl chloride (PVC, #3) burns with a green flame in the presence of copper. What color was your PVC?

*Student answers here depend on the colors of the plastics you chose for your experimental samples.*

11. Polystyrene (PS, #6) softens in the presence of acetone. What color was your polystyrene plastic sample?
    *Student answers here depend on the colors of the plastics you chose for your experimental samples.*
12. What recyclable plastic is left?
    *PETE is left.*
13. Polyethylene terephthalate (PETE, #6) will soften somewhat in boiling water. What color is your sample of PETE?
    *Student answers here depend on the colors of the plastics you chose for your experimental samples.*Complete the following table for your experiment:

| Recycle Code | Name of Plastic | Symbol | Color (or Letter) of Sample |
|---|---|---|---|
| **1** | Polyethylene terephthalate | PETE (PET) | student answer |
| **2** | High-density polyethylene | HDPE | student answer |
| **3** | Polyvinyl chloride | PVC (V) | student answer |
| **4** | Low-density polyethylene | LDPE | student answer |
| **5** | Polypropylene | PP | student answer |
| **6** | Polystyrene | PS | student answer |

**Assessment**

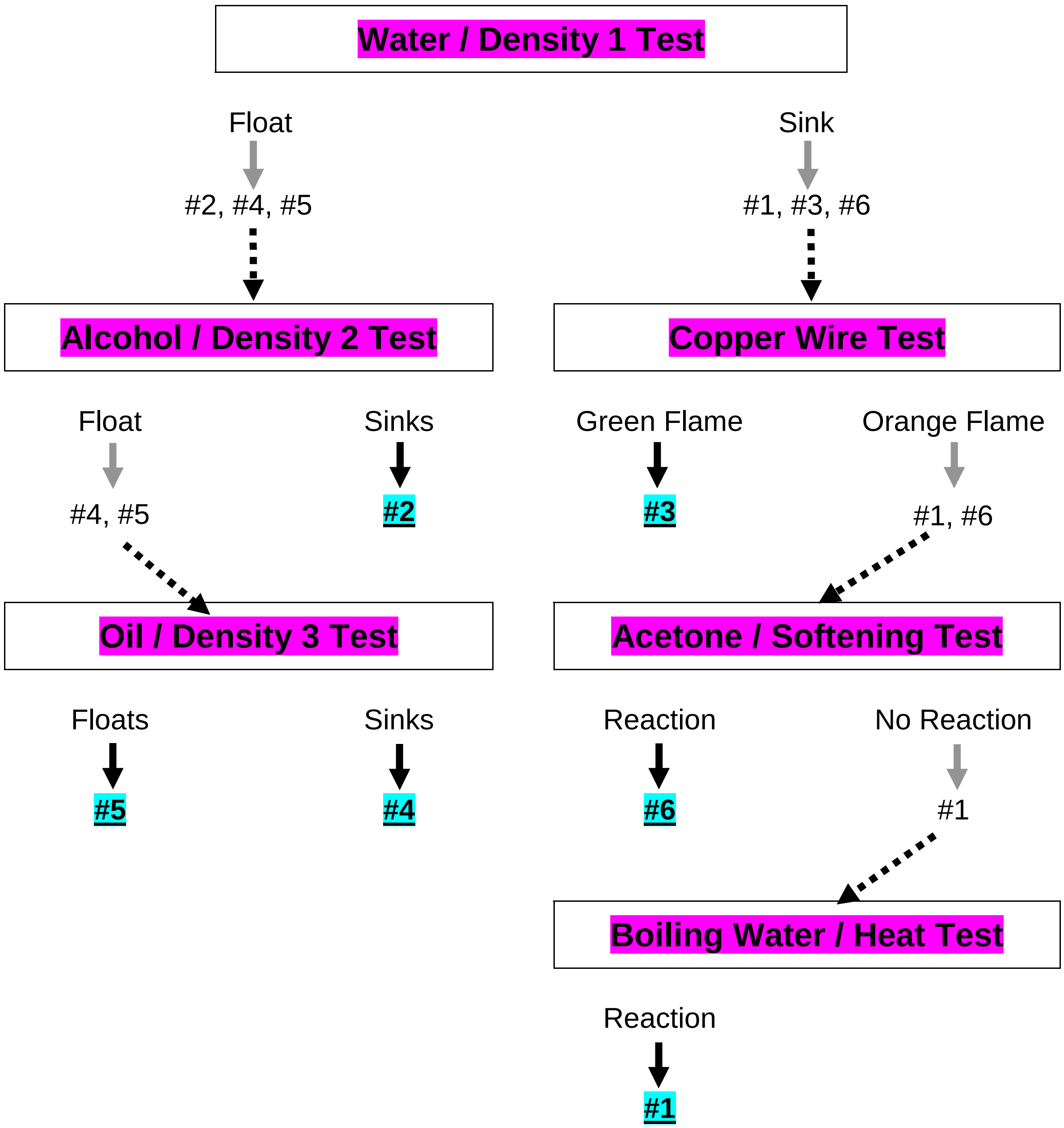
1. The extension questions are the true assessment of a student’s understanding of this experiment.
2. You might give students the task of using their own flow chart to identify several plastic types on the basis of data you give them. For example,
    - Plastic A has a density of 1.06, gives an orange flame test with the hot copper wire, and softens in acetone.
    - Plastic B floats in water and floats in isopropyl alcohol.
    - Plastic C floats in water, floats in isopropyl alcohol, and floats in oil.
    - Plastic D sinks in water and gives a green flame with the hot copper-wire test.

- Tell how you would differentiate between polyethylene terephthalate and polystyrene.

Answers:
*A is polystyrene (PS).*
*B is either low-density polyethylene (LDPE) or polypropylene (PP). There is not enough information to identify it completely.*
*C is polypropylene (PP).*
*D is polyvinyl chloride (PVC).*
*Polystyrene (PS) softens when submerged in acetone; polyethylene terephthalate (PETE) does not. PETE softens in boiling water.*

**Answers to Extension Questions**

1. Construct a flow chart to illustrate what you did in this experiment.




2. Use your flow chart to test in the lab a sample of an unknown recyclable plastic given to you by your teacher.
   *Results here depend on flow chart used and type of recyclable plastic given for unknown.*

**References**


The basic design of this student experiment was adapted from "Hands on Plastics: A Scientific Investigation Kit," by the National Middle Level Science Teachers Association

(NMLSTA) and the American Chemistry Council (ACC). The program is standards based and contains teacher and student versions of the materials. You can access "Hands on Plastics" (HOP) here. The program is aimed at middle school, but it can be geared up for the high-school level.

The HOP program has been made into a kit of materials that is from time to time available free from ACC. Their Web site says that the kits presently are not available, but you might try the telephone number or writing them. The information is at the NMLSTA Web site, http://www.nmlsta.org/hands.htm.

NMLSTA and ACC have also produced an updated version of HOP, called HOP2. It is designed around the learning cycle and the 5Es: engagement, exploration, explanation, elaboration, and evaluation. It has replaced the copper-wire test (the Bielstein test), the acetone test, and the boiling-water test with another series of density tests using concentrated calcium chloride solutions (from ice-melt crystals). These concentrated solutions have greater densities than water, allowing students to use them to separate and identify individual resins from the group of resins that sank in water. It is cleaner and simpler, but it has removed the chemical property tests from the lab, perhaps more in keeping with a middle-school activity.

**Additional Teacher Resources**

The HOP Web site also provides an "interactive multimedia walk-through of lab," which shows animations of the steps in each of the tests done in this experiment. This series of animations would be particularly useful if students do not understand a specific step or for students who are absent on the day the experiment is done.

For more resources on educational materials for grades 9 to12 in polymers and plastics, visit the ACC grades 9-12 Web site.

Another version of this experiment by David Brooks of the University of Nebraska–Lincoln can be found at http://dwb.unl.edu/chemistry/smallscale/SS069c.html. He uses ethanol instead of rubbing alcohol and magnesium chloride solution as the denser liquid to take care of the denser-than-water plastics. He includes videos of each step in his procedure.

You can find a chart of information about plastic packaging resins, including codes, descriptions, properties, product applications, and products made with recycled content on the ACC Web site at http://www.americanchemistry.com/s_plastics/bin.asp?CID=1102&DID=4645&DOC=FILE.PDF.

Juniata College's Science in Motion program offers a lab to identify plastics by microdensity measurements and calculations. If you have analytical balances available, try this one at http://www.juniata.edu/services/ScienceInMotion/chem/labs/phprop/denspla.doc.

An early *Journal of Chemical Education* reference (April 1991) to separating plastics by density, written by Ken and Doris Kolb, can be found at http://www.jce.divched.org/Journal/Issues/1991/Apr/jceSubscriber/JCE1991p0348.pdf.

If you would like your students to know more about Carothers and nylon, see "The Nylon Drama" at http://invention.smithsonian.org/centerpieces/whole_cloth/u7sf/u7materials/nylondrama.html.

**Student Data Table**

**Initial Observations**

| Color of Plastic | Observations |
|---|---|
| PETE | 2-L bottle material is transparent, flexible |
| HDPE | Translucent to opaque, flexible, but not as flexible as low-density polyethylene |
| PVC | Thin sheets are flexible, perhaps transparent<br>PVC pipe is opaque, rigid |
| LDPE | Very flexible, transparent or translucent |
| PP | Flexible, translucent or opaque |
| PS | Fragile—cracks easily, transparent |

**Test Observations**

Record plastic color(s) in proper boxes in first two empty columns. Record observations and conclusions in next two columns.

| Test | Float | Sink | Observations (will vary with samples) | Conclusion (Code #s) |
|---|---|---|---|---|
| Water / Density 1 | 2<br>4<br>5 | 1<br>3<br>6 | | 2, 4, 5 float<br>1, 3, 6 sink. Continue. |
| Alcohol / Density 2 | 4<br>5 | 2 | | 4, 5 float: continue.<br>2 sinks: 2 is LDPE. |
| Oil / Density 3 | 5 | 4 | | 5 floats: 5 is PP. 4 sinks: 4 is HDPE. |
| | | | | |
| | Green Flame | Orange Flame | | |
| Copper Wire | 3 | 1<br>6 | | 3 has green flame: 3 is PVC. 1, 6 continue. |

| | | | | |
|---|---|---|---|---|
| | Softens | No reaction | | |
| Acetone | 6 | 1 | | 6 softens: 6 is PS. 1 doesn’t soften, may be PETE. |
| Boiling Water / Heat | 1 | | | 1 softens in boiling water: 1 is PETE. |

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# Plastic Resins Recycle Codes

| Code | Density (g/mL) | Name | Symbol | Uses |
|---|---|---|---|---|
| 1 | 1.38 – 1.39 | Polyethylene terephthalate | **PETE (PET)** | 2-L soda bottles, Polartec® fleece, carpeting, etc. |
| 2 | 0.95 – 0.97 | High-density polyethylene | **HDPE** | Gallon milk jugs, shampoo bottles, etc. |
| 3 | 1.16 – 1.35 | Polyvinyl chloride | **PVC (V)** | Pipe for plumbing, clear bottles for oils, etc. |
| 4 | 0.92 – 0.94 | Low-density polyethylene | **LDPE** | Dry-cleaner bags, zip sandwich bags, etc. |
| 5 | 0.90 – 0.91 | Polypropylene | **PP** | Yogurt cups, plastic lids, etc. |
| 6 | 1.05 – 1.07 | Polystyrene | **PS** | Disposable clear cups, deli trays, etc. |
| 7 | Varies | Other | **Other** | Blended plastics, mixtures of plastic types, non-recyclable |

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