

Vanderbilt Student Volunteers for Science

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Density Column Using Recyclable Plastics.

7th/8th Grade

Spring 2004

Goal: To explain the concepts governing the recycling of plastics, problems encountered in the recycling process due to the different types of plastics used, and to gain an understanding of the differing properties of each type of plastic using density to illustrate the concept. The different types of plastics used in this lab will focus on the current six recyclable types as outlined in the Society of Plastics Industry's recycling codes implemented in 1988.

Lesson Outline

I. Introduction

Discuss the general polymer chemistry of all types of plastics.

II. Six Types of Plastic Recycling Codes

Explain the differing properties of the six types of recyclable plastics and association with a triangular symbol/number. Use a density column to help exhibit the different properties of each type of plastic and demonstrate that density is a good method to determine the type of plastic. Discuss the wide range of products made from recycled plastics.

III. Identifying Unknown Plastic Types

Students will test an unknown plastic sample to attempt to determine what type of plastic the sample represents through the use of a density column.

IV. Discussion of Student's Results

Students will make an educated guess about the type of plastic their sample represents with a brief explanation for their conclusion. Briefly discuss some problems faced in the recycling process.

Materials

- 1 Large Density Column (500 mL graduated cylinder) with rubber band and lid
- 1 Demo Bag (six total pieces of plastics – one piece for each plastic type)
- 6 Example bottles (one for each type of plastic)
- 1 Corn Syrup (200 mL bottle)
- 1 Glycerin (200 mL bottle)
- 1 Water (200 mL bottle) – slight yellow hue
- 1 Castor Oil (200 mL bottle)
- 1 2-propanol/hamamelis mixture (200 mL bottle) – slight green hue
- 5 6oz jars containing 80mL Corn Syrup (one per group)
- 5 6oz jars containing 80mL Glycerin (one per group)
- 5 6oz jars containing 80mL Water (one per group)
- 5 6oz jars containing 80mL Castor Oil (one per group)
- 5 6oz jars containing 80mL 2-propanol/water mix (one per group)
- 5 #1 bags (each bag contains 6 unknown plastic pieces)
- 10 9” tongs
- 10 8” forceps
- 5 small plastic bags marked “USED”
- 1 waste container for the demo column (800ml)
- 30 Student Handouts
- 30 Student Data sheets

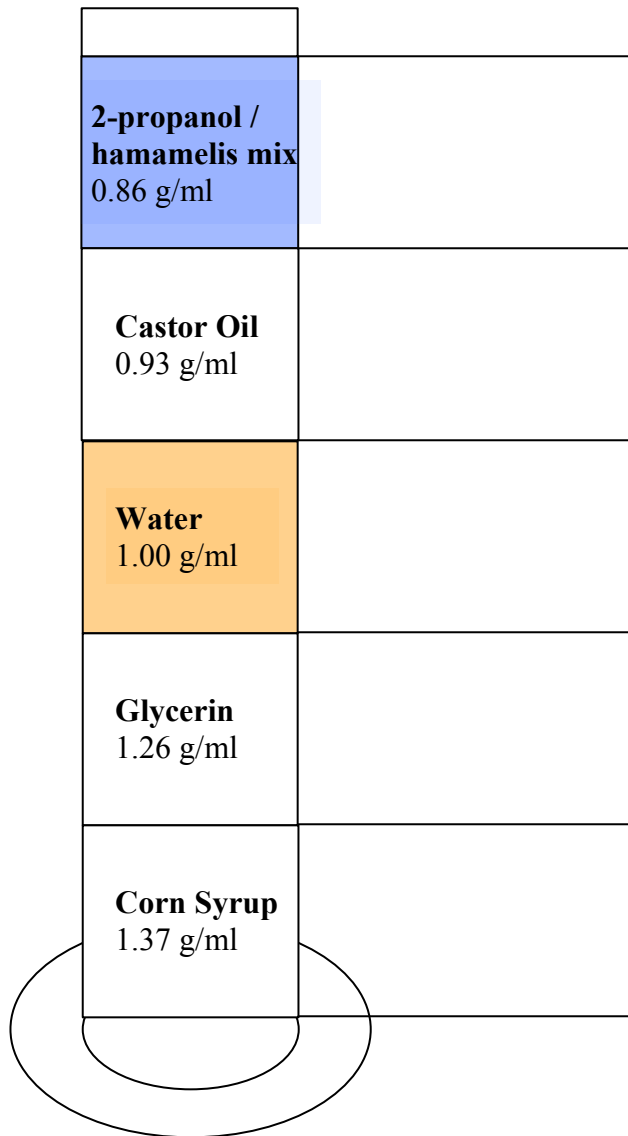
Pre-lesson Setup

Split the students into four or five groups (each group should have 4 to 6 students) for the hands-on-activity, later in the lesson.

The VSVS volunteers can accomplish the following items, while one volunteer gives the introduction portion of the lesson.

- a. Setup the large Density Column Demo in the 500ml graduated cylinder. Remove the plastic wrap and rubber band from the top. Save to use at the end of the lesson. Drop in the V piece. Pour a 90ml to 100ml portion of corn syrup from the stock bottle into the center of the vertical graduated cylinder. The goal is to get no corn syrup on the sides of the graduated cylinder. If some gets on the side of the cylinder, allow the corn syrup a couple of minutes to drain down. Drop in the PETE piece. Next, slowly pour a 90ml to 100ml portion of each of the following liquids down the side of the slanted graduated cylinder and add a plastic piece in this order: **glycerol, PS, water, HDPE, castor oil, and 2-propanol/hamamelis mixture** (commonly known as rubbing alcohol and witch hazel). Allow the liquid to drain down for a minute before pouring the next liquid. Verify that there are five distinct layers in the column. Each stock bottle contains 200ml which is sufficient to set up the column twice, if the first attempt does not work.

- b. Draw the Density Column (the following diagram) on the board. Make sure that it is large enough for all the students to clearly see the distinct separation of the five liquids. The numbers following the liquids are the density of that liquid.



I. Introduction

This lesson is designed to help the students gain an understanding of the plastics found all around them everyday including food containers, furniture, carpets, kitchen utensils, and clothing.

Ask the students, “Can anyone list some recyclable materials?”

Accept logical responses and direct the conversation toward **Plastics**.

Explain that today, you will discuss those little triangles and numbers found on the bottom of plastic bottles. You will gain an understanding of why local recycling centers do not accept all plastic bottles, and ask that you sort out the bottles by type and remove the caps and paper labels before dropping them off at a recycling center.

(Hand out the Plastics Information Sheet to the students)

Begin by defining all plastics as different types of polymers. Make sure that the students understand the concept of a polymer. [A basic unit (monomer) that is repeated over and over again]. The monomers of the six types of plastics that are discussed today are shown on the handout. Make the distinction that some polymers occur naturally, like proteins and starches, but plastics are synthetic polymers which means that they are man-made.

Since plastics are synthetic, they can be manufactured in a controlled manner and given different properties. Some plastic polymers are very hard and rigid (bowling balls, football helmets), while others are soft and flexible (foam mattresses). Some polymers are resistant to heat (adhesives used in aircraft), while others can be readily melted (milk jugs). Some polymers can be molded into useful objects over and over, while others may resist being reformed during the recycling process. And all of these plastics have differing densities. These properties depend on the structure of the polymer.

Chemists can produce plastic polymers to meet specific industrial needs by controlling the various factors that contribute to a plastic polymer's properties. These factors include the size of the polymer, the structure of the polymer (is it linear or does it have branched chains) and whether or not additives, such as pigments, are present. **The same plastic resin can have different properties (~~HDPE and LDPE~~) and one version of a plastic resin can be "foamed" by adding gases** (EPS [Styrofoam] is air injected Poly Styrene). [Put an emphasis on this statement, later in the lesson the students will be asked to make a connection to this idea and come up with the 'striethrough' example in parentheses.] The end goal of these modifications during the manufacturing process is to produce plastic resins that are resistant to chemicals, are light weight, and strong.

II. Six Types of Plastic Recycling Codes

Direct the students' attention towards the six triangular symbols on their handout. Tell the students that while there are hundreds of different types of plastic polymers, today the focus will be on the six types of recyclable plastics. A number 7 symbol also exists. This is a designation for 'other' meaning that the plastic is not one of the other six types of resin or is a mixture of multiple resins. (Generally found in frozen food containers and some bottles.)

(Allow the VSVS volunteers to walk around with the sample bottles and show the students that each bottle contains one of the six recycling codes.)

Explain that each number (1 through 6) corresponds to a different type of plastic. Briefly go through the six symbols and connect them with the plastic's abbreviation, properties, and some

of the possible recycled products. **Make the point that these plastics cannot be recycled back into the same product, but their properties can be manipulated chemically to create a new plastic object that may differ functionally from the original object.** Use an example, such as recycling 2-liter PETE soda bottles into fiberfill insulation for winter jackets, to make sure that the students understand this concept.

Density Column Demo

Materials

- Large Density Column (prepared)
- Demo Bag (containing six identified plastic samples)
- Six bottles representative of each type of plastic

(Do not shake the density column. While the column will sort back out into the five layers, the chosen liquids take a very long time to separate once mixed and are partially soluble with each other.)

Tell the students that one good method to determine what type of plastic a sample represents is to find the density of the plastic. Since density is a property of a substance, each type of plastic has a different density. This fact explains why separating the pieces of plastic by density allows for the determination of what type of plastic the sample represents. Explain that the large graduated cylinder displayed in front of them is called a density column. There are five liquids in the column and each has a different density. [Ensure that the students understand the concept of density as $D = \text{Mass}/\text{Volume}$ and that a liquid of lighter density will float on top of a liquid of heavier density. Use the water/oil example if necessary.] Direct the students' attention towards the diagram on the board. Go through each of the five liquids in the density column starting with the most dense and working the way to the top of the column with the least dense liquid.

Tell the students that by dropping a piece of plastic in the column, it will sink until the plastic piece encounters a liquid that is **more** dense than the plastic. Since the density of the liquids are known, an estimate of the plastic's density can be made. The density of the plastic piece falls in the range less dense than the density of the liquid that the plastic is floating on top of, and more dense than the density of the last liquid the plastic piece floated through.

Using the six plastic bottles, show the students the bottle and associate it with a plastic piece of the same type of plastic. Drop the remaining two plastic pieces (LDPE; then PP) into the density column and ask the students to watch the pieces sort out by density. The pieces are in the following order: V, PETE, PS, HDPE, LDPE, PP.

Type	Color
V	Grey
PETE	Green
PS	Orange
HDPE	Blue
LDPE	Yellow
PP	White

Fill in the corresponding line on the board diagram with the location of the plastic piece. The pieces should sort out in the same order that they were dropped into the density column. V (vinyl) should be below the corn syrup, then PETE, PS, HDPE, LDPE, and PP floating on the very top. (Since many pieces will take a minute or two to sink through the glycerin and corn syrup layers, due to the thickness of these two layers, four pieces have already been added. The viscosity of the liquids does not affect the density, but only slows the rate of descent.)

III. Identifying Unknown Plastic Types

Materials

- 5 6oz jars containing 80mL Corn Syrup (one per group)
- 5 6oz jars containing 80mL Glycerin (one per group)
- 5 6oz jars containing 80mL Water (one per group)
- 5 6oz jars containing 80mL Castor Oil (one per group)
- 5 6oz jars containing 80mL 2-propanol/hamamelis mix (one per group)
- 5 #1 bags (each bag contains 6 unknown plastic pieces)
- 10 9" tongs
- 10 8" forceps
- 5 small plastic bags marked "USED"
- 30 Student Data sheets

Tell the students that now they will identify the type of an unknown plastic piece by using a density column. Instead of using one large density column, the students will test each piece of plastic in each liquid separately. Connect that the five jars that will be passed out to the group contain the five liquids that are in the large demo density column. Pass out one set of five jars each containing a different liquid to each group, one #1 Bag to each group, 2 forceps, and 2 tongs to each group. **The tongs/forceps and plastic pieces must be wiped off with a paper towel between testing in different liquids. This is done to prevent contamination of each type of liquid and to improve results.**

Pass out one Student Data sheet to each student.

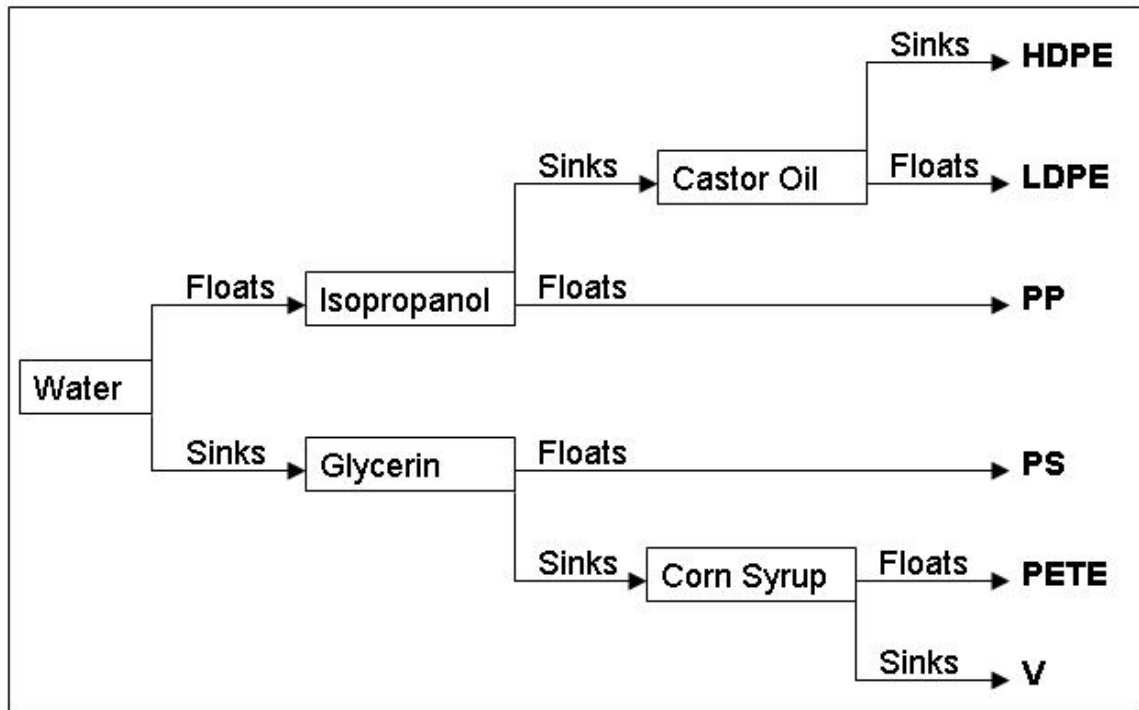
Ask the students to listen to the following instructions and tell them that a volunteer will be available to help each group through the testing procedure.

On the back of the student handout is a flow chart that will guide them through the process of identifying the type of plastic in their unknown sample. Each student should select one plastic sample piece from Bag #1. Tell the students to remove the lids from the testing jars only when they are using a jar. Following the flow chart on the next page, a pair of tongs will be used to push the larger plastic piece half way down through the liquid layer in the jar. The smaller forceps should be used for the smaller plastic pieces that are orange or purple. The tongs are then released from the plastic piece. Sufficient time should be given to see if the sample piece will float or sink in the liquid. Based upon the results, the students will then test the sample piece in the next liquid according to the flow chart. All students should start with the jar containing water. Used plastic pieces should be placed in the extra plastic bag marked "used". Make sure to replace the lids on any uncapped testing jars. After determining the type of

plastic represented by the sample piece, the students should record their results on the data sheet by writing the name, color, and approximate density on the line where the sample would be floating if tested in the large density column.

Stress to the students that the color **does not** affect the density and is only being used to identify the unknown plastic sample.

(The corn syrup, glycerin, and castor oil are thick liquids. This **does not** affect the density, but will slow down the rate at which a plastic piece sinks through this layer. Enough time should be given for each piece to come to rest on top of a liquid layer to ensure accurate results.)



After the students have recorded their results on the data sheet, the VSVS volunteers can reveal what type of plastic each piece was based on the color. (Bag #1 may not contain all six types of plastic and may contain the same type of plastic in more than one sample.)

The following table provides the type of plastic of each unknown sample for Bag #1:

Color	Plastic Type	Symbol #	Approx. Density	Liquid layer floating on top of
Green	PETE	1	1.37 – 1.26	Corn Syrup
Red	HDPE	2	1.00 – 0.93	Water
---	V	3	> 1.37	On bottom of Corn Syrup
White Bead	LDPE	4	0.93 – 0.86	Castor Oil
Purple	PP	5	< 0.86	2-propanol/hamameis mix
Orange	PP	5	< 0.86	2-propanol/hamameis mix
Translucent white	PS	6	1.26 – 1.00	Glycerin

IV. Discussion of Student's Results

In the individual groups, ask each student to tell the group the type of their unknown plastic sample and briefly explain how they arrived at this conclusion. *(The data from the unknown floated on top of a certain liquid layer. Based on the demo density column, the plastic that was given to float on top of a certain liquid layer should also be the type of plastic in the unknown.)*

After every student has tested an unknown sample, bring the groups back together as a class for a brief discussion.

Ask the students if anyone encountered a problem in determining the type of plastic that their unknown sample represented. If any problems were encountered, this was most likely due to small pockets of air that became trapped on the underside of the sample. The air pockets would affect the density of the plastic causing the sample to have a lower density in the column.

Remind the students that the same type of plastic can have multiple forms, each with different properties. Tell the students that of the six types of plastic discussed in today's lab, two of the plastics are in fact the same plastic polymer with different properties.

Ask the students, "Can anyone identify which two plastics are really the same polymer with different properties?"

The answer is HDPE and LDPE. If the students need help grasping this, direct them towards the student handout. On the handout both the HDPE and LDPE have the same monomer. Tell them that chemical modifications during the manufacturing process lead to the different properties found in this single type of plastic polymer.

Problems in recycling plastics

The need to recycle plastics is clear. Over 22 million tons of plastics are discarded each year in the trash. While plastics account for only 9.2% (in 2000) of the trash Americans generate each year, plastic products do not decompose in landfills and are difficult to reduce in size. In the

open, plastics can be degraded very slowly. Photodegradation (UV light causing breakage of polymer chains) can breakdown plastic resin, but this process can take decades. Even longer, biodegradation of plastics takes centuries. The use of recycled plastics in the manufacturing industry has grown in the past several years, but other problems still exist.

The largest problem in recycling plastics is separating the plastics by type and number. In the current recycling system, the plastics must be separated by type. During the reprocessing of plastic containers, if the plastic is not of a uniform type, the raw plastic resin is unusable in the manufacturing industry.

Once the problem of sorting the resins has been overcome, the recycling loop is still not closed. Reprocessed plastic resin faces a weak market. Simply collecting plastic for recycling does not mean that there will be a manufacturer willing to pay for the raw material. Most often in the manufacturing process, it is cheaper and easier to use new, nonrenewable resources to make plastic containers. Recycled plastic resin has limited value as a manufacturing resource because its quality degrades every time it is reheated during the recycling process. Consequently, **most plastic is only reprocessed once before it goes to a landfill.** "Downcycling" is a more accurate term than "recycling" when it comes to plastic. Unlike glass or paper, plastic recycling does not "close the loop" because most postconsumer bottles are not made into new plastic bottles. Instead, milk jugs, soda containers and other bottles are turned into lower-grade products such as jacket fill, fleece, carpet, toys or plastic lumber. None of these products are in turn recyclable. Therefore the recycling process only delays the plastic's disposal. The final destination for all plastic is either a landfill, where it does not decompose, or an incinerator, where it can release harmful chemicals into the atmosphere when burned.

Clean up instructions

Do not pour the liquid in the density column back into the large liquid containers. Instead pour the large demo density column into its marked waste container. You do not need to try to remove the plastic sample pieces from the liquid. Secure the plastic wrap and rubber band around the top of the graduated cylinder. Make sure that all of the unknown plastic pieces have been removed from the student testing jars and placed in the plastic bag marked "USED". Recap the testing jars tightly. They will be reused in future lessons. When the tongs are collected, make sure that they have been thoroughly wiped off. Return all the materials to the VSVS lab (SC 5416).







References: Environmental Protection Agency, Office of Solid Waste. "Methods to Manage and Control Plastic Wastes". February 1990. (EPA/530-SW-89-051)

The American Plastics Council
1300 Wilson Blvd. 13th Floor, Arlington VA 22209

Lesson written by: Vaughn Hetrick, UGTF, Vanderbilt University

Coordination/Advice from: Dr. Melvin Joesten, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University

Plastics Information Sheet

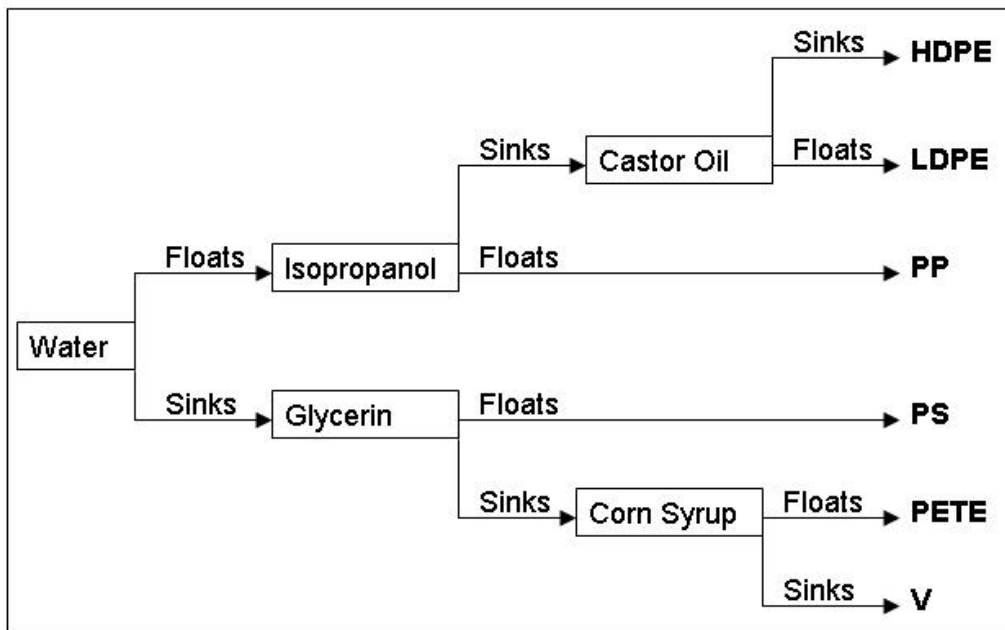
Recycling Symbol	Name	Density (g/mL)	Monomer (base unit of the plastic polymer)	Product Examples	Recycled Products
	PETE Polyethylene Terephthalate	1.31	$\left[\text{C}(=\text{O})-\text{C}_6\text{H}_4-\text{C}(=\text{O})-\text{O}-\text{CH}_2-\text{CH}_2-\text{O} \right]_n$	Soft drink bottles Food containers Rope Fabrics	Fiberfill in coats Carpet Camera film Lumber
	HDPE High Density Polyethylene	0.96	$\left[\text{CH}_2-\text{CH}_2 \right]_n$	Milk jugs Grocery bags Toys Juice containers	Trash cans Floor tile Flower pots Garden furniture
	V Vinyl	1.40	$\left[\text{CH}_2-\underset{\text{Cl}}{\text{CH}} \right]_n$	Clear food packaging Shampoo bottles Credit cards Drainage pipes	Floor mats Flexible hoses Playground equipment
	LDPE Low Density Polyethylene	0.88	$\left[\text{CH}_2-\text{CH}_2 \right]_n$	Bread bags Frozen food bags Grocery bags Container lids	Floor tile Furniture Garbage can liners
	PP Polypropylene	0.86	$\left[\text{CH}_2-\underset{\text{CH}_3}{\text{CH}} \right]_n$	Food containers Medicine bottles Rope Wrapping films	Videocassette cases Lawn mower wheels Battery cables Landscape boards
	PS Polystyrene	1.05	$\left[\text{CH}_2-\underset{\text{C}_6\text{H}_5}{\text{CH}} \right]_n$	Compact Disc jackets Disposable utensils Foam cups Toys	Flower pots Trash cans Thermometers Rulers

Student Handout

Instructions for identifying the unknown plastic piece

- Each student should select one plastic sample piece from Bag #1.
- Only uncap testing jars that are in use.
- Follow the flow chart below using the provided procedure
 - The large tongs are for large sample plastic pieces
 - The smaller forceps are for the two small plastic pieces (orange and purple)
- Use a pair of tongs to push the plastic piece half way down through the liquid layer in the jar.
- Then release the tongs from the plastic piece.
- Sufficient time should be given to see if the sample piece will float or sink in the liquid.
- Based upon the result, test the sample piece in the next liquid according to the flow chart. The tongs and plastic piece should be wiped off with a paper towel before moving on to the next liquid
- **All students should start with the jar containing water.**
- Used plastic pieces should be placed in the extra plastic bag marked “used”.
- After determining the type of plastic represented by the sample piece, record the result on the data sheet by writing the name, color, and approximate density on the line where the sample would be floating if tested in the large density column.

The color **does not** affect the density and is only being used to identify the unknown plastic sample.



Student Data Sheet

Color Plastic Type Symbol # Approx. Density
(g/mL) Liquid layer floating on top of