Supporting Information for:

The Dynamic Density Bottle: A Make-and-Take, Guided Inquiry Activity on Density

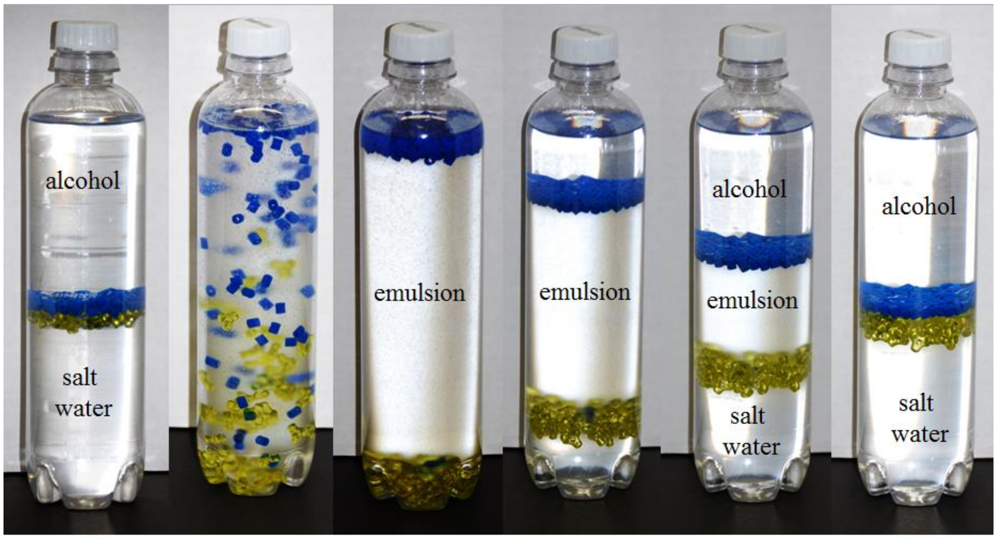
Thomas S. Kuntzleman, Department of Chemistry, Spring Arbor University, Spring Arbor, MI

Information for Teachers for the Dynamic Density Bottle Activity

Information for Teachers for the Dynamic Density Bottle Activity

Introduction In this experiment students use simple materials to make an interesting toy called a Dynamic Density Bottle (Figure 1). This toy was invented by Lynn Higgins, a retired public school teacher from Chicago. You can learn more about Lynn (and also more about polymers) at www.polymerfun.org. The Dynamic Density Bottle illustrates the concept of density in a thought-provoking way. Inside the bottle are two different liquids and two different plastics. These liquids and plastics all have different densities and as a result layer according to density (Figure 1). The two liquids in the bottle are isopropyl alcohol (D = 0.79 g mL^{-1}) and salt water (17% NaCl by weight, D = 1.12 g mL^{-1}). The two plastics in the bottle are low density polyethylene (LDPE, D = 0.93 g mL^{-1}) and polystyrene (PS, D = 1.05 g mL^{-1}). Because salt water is more dense than alcohol, it sinks beneath alcohol. Both plastics are more dense than alcohol but less dense than salt water. Thus, the plastic pieces float at the interface between the two liquids (but notice the more dense, yellow PS pieces are situated beneath the less dense, blue LDPE pieces in Figure 1). Alcohol and 17% NaCl solution are **immiscible**; that is to say these liquids will separate from one another if they are mixed (two **miscible** liquids will dissolve one another when mixed). However, upon *first* mixing salt water and isopropyl alcohol, the two liquids initially appear to form a single, mixed liquid. This metastable mixture is called an emulsion (Figure 2, page following, panel at ~1 s).

Figure 1: The Dynamic Density Bottle. The liquids and solids layer according to density. From top to bottom: alcohol, blue pieces comprised of LDPE, yellow pieces comprised of PS, 17 % NaCl solution (see also Figure 2, panel at 0 s). Bottle shown is 23 cm high, 20 cm in diameter and holds 500 mL of fluid. See http://www.sparklingice.com/product/blackraspberry for an example of a product with a bottle of these dimensions.



0 s ~1 s 10 s 20 s 40 s 60 s

Figure 2: Time dependent floating and sinking behavior observed in LDPE plastic (blue pieces) and PS plastic (yellow pieces) in a thoroughly mixed isopropyl alcohol-salt water mixture. Left to right, 0 s, 1 s, 10 s, 20 s, 40 s and 60 s after mixing. Bottle shown is 23 cm high, 20 cm in diameter and holds 500 mL of fluid.

The emulsion has a density that is approximately 1.0 g mL^{-1}. Thus, the LDPE plastic (D = 0.93 g mL^{-1}) pieces float in the emulsion, whereas the PS pieces (D = 1.05 g mL^{-1}) sink in the emulsion (Figure 2, panel at 10 s). Over time, the emulsion separates back into alcohol and salt water and the plastic pieces return to their original position (Figure 2, panels at 20 s – 60 s).

Presentation:

The Dynamic Density Bottle can be used as an instructional tool in a variety of ways. I happen to currently use it during laboratory instruction. I show my students a large, completed Dynamic Density Bottle. After shaking the bottle and observing the behavior of the contents within the bottle, students are challenged to describe their observations using scientific principles. Students complete a self-paced worksheet (see pages 9 – 13 of this document) to help them complete this task during a single laboratory period. This worksheet guides students through a series of experiments that facilitates an understanding of how the Dynamic Density Bottle works. The worksheet follows a guided inquiry model in which students are provided with a question to answer, the necessary background to answer the question, and procedures to carry out that will help to explain the question posed. Equipped with the results of experimentation, students are challenged to explain the physics and chemistry behind how the Dynamic Density Bottle works. As written, I find that most students require between one and two hours to complete the worksheet, construct a working Dynamic Density Bottle, and to sufficiently explain what is going on when the bottle is shaken. In the student worksheet, students make an 8 ounce Dynamic Density Bottle using 91% isopropyl alcohol.

Modifications to Increase Opportunities for Inquiry Learning:

Teachers are free to modify the student worksheet as they see fit to either increase or decrease opportunity for student inquiry. For example, instead of explicitly stating which particular plastic is high density and which is low density, the plastics could be identified by color (or type). In this case, students would need to discover the relative densities of the plastics on their own. A particularly tricky twist on this lesson is to eliminate the discussion of emulsions. This allows students to figure out what is happening on their own as the alcohol and salt water is mixed. If you make these modifications to the lesson, be sure to modify the student worksheet accordingly. Finally, students can simply be shown a working Dynamic Density Bottle and challenged to construct one on their own – no student worksheet provided. This latter approach is most challenging if students are not allowed to open the Dynamic Density Bottle to explore the properties of its contents. It should be recognized that each of these modifications require increasing amount of time for students to complete the task. I have found that students require three to four, 3-hour laboratory periods to construct a working Dynamic Density Bottle using their own.

Sources of PS and LDPE:

Craft stores or craft sections in retail stories almost all carry Pony beads, which are a nice decorative source of PS (Figure 3), the higher density plastic in this activity. I have found just about any translucent, decorative plastic found in craft stores works as a source of (or at least behaves like) PS in this activity.

Figure 3: Decorative Pony Beads as a source of PS.

Perler or "melty" beads are an outstanding source of LDPE (Figure 4), the lower density plastic in this activity. These can also be found in craft stores or craft sections in retail stores.

Figure 4: Perler "Biggie" beads (left) and melty beads (right). Perler beads are also sold in sizes essentially identical to melty beads.

Alternative Sources of Plastics

UV beads (sold by Educational Innovations http://www.teachersource.com/product/ultraviolet-detecting-beads/light-ultraviolet or Steve Spangler Science http://www.stevespanglerscience.com/uv-color-changing-beads.html) may be used as a source of lower density plastic for this activity (Figure 5). My guess is that these beads are made of HDPE, but I'm not sure about this. UV beads are a nice option if you want a source of beads that is essentially identical in size and shape to Pony beads (Figure 3)

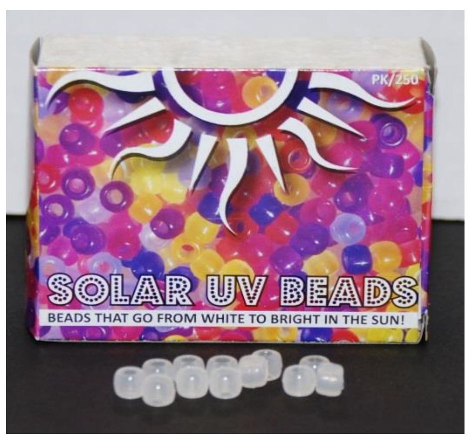


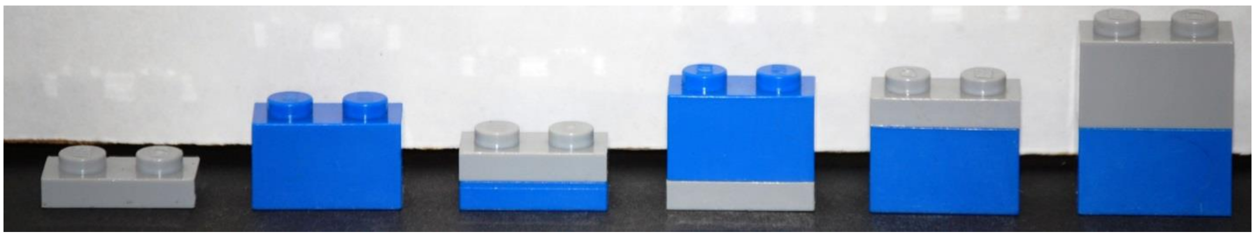
Figure 5: UV beads

Plastics pieces comprised of high density polyethylene (HDPE, D = 0.96 g mL^{-1}) or polypropylene (PP, 0.91 g mL^{-1}) may substitute for LDPE plastic pieces in this activity. Bendable plastic drinking straws cut into pieces tend to be a good source of PP. Pieces cut from plastic gallon milk jugs and laundry detergent bottles (the opaque kind) tend to be a good source of HDPE. (Be careful, because it sometimes gets confusing that HDPE is used as a LOW density plastic in the density bottle). LDPE, HDPE and PP are all good sources of low density plastic in this activity.

Extension Using LEGO Pieces:

LEGO blocks are composed of acrylonitrile butadiene styrene (ABS, D = 1.00 – 1.08 g mL^{-1}). Therefore, LEGO blocks can substitute for higher density plastic pieces in this activity.

It is also fun to experiment with LEGO pieces that are connected to one another. When two LEGO pieces are connected, air is often trapped in between the connected pieces. The trapped air lowers the density of the assembled pieces. As a result, students can experiment with different combinations of LEGO pieces and observe resulting floating and sinking behavior (Figure 6).



A **B** **C** **D** **E** **F**

Figure 6: LEGO pieces. A: 1 x 2 plate (sinks in emulsion). B: 1 x 2 brick (sinks in emulsion). C: connected 1 x 2 plates (floats on emulsion). D: A and B connected brick-on-plate (not used; floats on alcohol). E: A and B connected plate-on-brick (floats on emulsion). F: two connected 1 x 2 bricks (not used, floats on alcohol).

Considerations when using LEGO pieces:

It should be noted that connected LEGO pieces are not completely air tight. If LEGO pieces are left in a density bottle over the course of several weeks, fluid will leak into the trapped air pockets, causing the connected LEGO pieces to increasingly behave like unconnected LEGO pieces. This situation is easily corrected by periodically replacing connected LEGO pieces. (However, it is also fun to have students try to figure out why connected LEGO pieces increasingly behave like unconnected pieces!). Also, some colors of LEGO pieces (I have specifically found that red, green and yellow) contain dyes that will slowly dissolve into the isopropyl alcohol, turning it a slight yellow color. This process occurs over one or two days. Finally, add LEGO minifigure accessories at your own risk! I once added a minifigure scientist holding an Erlenmeyer flask to a Dynamic Density Bottle. The neck of the Erlenmeyer flask disintegrated when left in the bottle much longer than a few hours.

Different recipes:

Three different recipes are provided (see the last three pages of this packet) for constructing Dynamic Density Bottles. This is because isopropyl alcohol is commonly found at three concentrations (70%, 91% and 99%). The student worksheet written to accompany this lesson uses 91% isopropyl alcohol, so be sure to change the student worksheet accordingly if you use a different alcohol concentration. To conserve funds and materials, I have my students make an 8 ounce Dynamic Density Bottle (Figure 7, bottle on the right).

Figure 7: Comparison of Dynamic Density Bottle sizes. L to R: 1 L, 500 mL, 8 ounces. The bottles on the left and right have UV beads as a source of LDPE and Pony beads as a source of PS.

However, I use a large Dynamic Density Bottle for classroom demonstrations. To make larger bottles, the measurements in each recipe need to be converted. Each recipe describes how to make about 8 ounces of fluid. To increase the amount of fluid yielded, all measures in the recipe are multiplied by the following conversion factor:

$$\text{Conversion factor} = \frac{\textit{ounces desired}}{8}$$

Example: Suppose you are using 70% isopropyl alcohol and wish to make a 500 mL Dynamic Density Bottle. Because 500 mL = 17.6 ounces (500 mL / 28.4 mL oz^{-1} = 17.6 ounces), the conversion factor is 2.2:

$$\text{Conversion factor} = \frac{17.6}{8} = 2.2$$

The recipe using 70% isopropyl alcohol calls for 68 mL of water, 24 g of salt, and 172 mL of 70% isopropyl alcohol. Multiplying each of these amounts by the conversion factor, we get 150 mL of water, 53 g of salt and 378 mL of isopropyl alcohol. Thus, 53 grams of salt are dissolved in 150 mL of water, and the salt water is filtered. Next, 378 mL of 70% isopropyl alcohol are added to the filtered salt water.

Try this: How much water, salt, and 91% isopropyl alcohol are necessary to make 500 mL of fluid for a Dynamic Density Bottle?

Answer: 238 mL of water, 53 g of salt, and 290 mL of 91% isopropyl alcohol.

Although I have not tried this particular modification, Lynn Higgins reports that the filtering step can be eliminated by using Kosher salt or canning salt in place of table salt. When using table salt the filtering step is carried out to remove some solids that remain undissolved. These undissolved solids give the fluid layers an undesirably cloudy appearance. I prefer to have students do the filtering step simply to reinforce (or introduce) this technique.

Student Worksheet: Construction of Density Bottle

Introduction In today's experiment, you will be using simple materials to make a Density Bottle. First, be sure to observe how the Density Bottle behaves. Next, use the following worksheet as a guide to study the properties of water, salt water, isopropyl alcohol, and two different types of plastic in order to explain how the Density Bottle works.

Materials 91% isopropyl alcohol, table salt, duct tape, digital balance, 8 oz., clear and colorless water bottle, water, test tubes and stoppers, 10 mL graduated cylinder, 100 mL graduated cylinder, filter paper, funnel, beakers, several colored plastic pieces of different composition.

Procedure *Part A: Densities of the liquids in the density bottle*

1. Place a 10 mL graduated cylinder on the digital balance and tare it.
2. Measure 4 mL of 91% isopropyl alcohol into the graduated cylinder.
3. Record the mass of the 91% isopropyl alcohol.
4. Record the volume of the 91% isopropyl alcohol.
5. Calculate the density of the 91% isopropyl alcohol using the equation:

$$D = m/V \qquad \text{(Equation 1)}$$

Where D is density, m is mass and V is volume.

6. Save the isopropyl alcohol for parts B and D.
7. Clean the graduated cylinder and allow it to dry.
8. Measure 5 mL of water into a test tube.
9. Add 1.1 grams of salt into the test tube.
10. Mix the contents of the test tube until the salt is dissolved.
11. Find the density of the salt water using the same procedure used for the isopropyl alcohol.
12. Save the salt water for later experiments.

Data

Liquid	Isopropyl alcohol	Salt water
Density / g mL^{-1}		

Part B: Miscibility of the liquids in the density bottle

1. Measure 4 mL of water into a test tube.
2. Add 4 mL of isopropyl alcohol into the same test tube. Mix well.
3. Observe the contents of the test tube for 1 – 2 minutes.
4. Are water and alcohol miscible (do they completely mix)? Record your observations.
5. Now add 1.0 g of salt to the test tube containing water and alcohol. Mix well. If the liquids do not separate, dissolve more salt until they do separate. Are alcohol and salt water miscible? Record your observations.
6. Why do you think there is a difference in the behavior of the alcohol/water vs. the alcohol/salt water mixtures?

____

____

7. Save this test tube containing the water/alcohol/salt mixture for Part E.

Observations:

____

____

____

____

Are water and isopropyl alcohol miscible? ______

Are salt water and isopropyl alcohol miscible? ______

Part C: Densities of the plastics in the density bottle relative to water.

1. Obtain 2 – 5 pieces of higher density plastic.
2. Fill a test tube to about 5 mL with water.
3. Place the plastic pieces in the water. Do the beads float or sink? Why do you think this is so? Record your results (see next page).
4. Obtain 2 – 5 pieces of higher density plastic.
5. Fill a test tube to about 5 mL with water.
6. Place these plastic pieces in the water. Do the pieces float or sink? Why do you think this is so? Record your results (see next page).

Data

Plastic	Float or Sink in Water?	Density (greater than or less than 1.0 g mL^{-1})
High density plastic		
Low density plastic		

Part D: Densities of the plastics in the density bottle relative to alcohol, water and salt water.

1. Obtain a single piece of high density plastic.
2. Place the plastic piece in 91% isopropyl alcohol. Does the plastic piece float or sink? Record your observations.
3. Place the plastic piece in water. Does the plastic piece float or sink? Record your observations.
4. Place the plastic piece in salt water. Does the plastic piece float or sink? Record your observations.
5. Repeat steps 1 – 4 with a lower density plastic piece.

	Float or sink in 91% isopropyl alcohol?	Float or sink in water ?	Float or sink in salt water?
High density plastic			
Low density plastic			

6. Review the densities you measured for the 91% isopropyl alcohol and salt water. From these densities, the density of water (D = 1.0 g mL^{-1}) and your observations in the table above, what can you conclude about the relative densities of salt water, water, alcohol and the two plastics?

____

____

Part E: Observation and Characteristics of the Alcohol / Salt Water Emulsion

1. Obtain the test tube from part B containing the water/alcohol/salt mixture.
2. Stopper and vigorously shake the test tube; quickly observe its contents.
3. Notice that the alcohol and salt water take some time to separate.
4. Do you observe a third, cloudy layer that persists for some time before the alcohol and salt water completely separate? Sometimes coloring the mixture with a drop of blue food coloring (added at any time) helps to see this third layer.
5. How long does this third, cloudy layer persist?
6. When two immiscible liquids are vigorously mixed, they can form an emulsion. An emulsion is a transient, heterogeneous mixture of two immiscible liquids (think well-shaken salad dressing). Some emulsions take very long to separate, while others separate quickly.
7. Is the density of the emulsion greater than or less than the density of the alcohol?
8. Is the density of the emulsion greater than or less than the density of the salt water?

Observations:

____

____

Part F: Construction of the density bottle

1. Remove the label from the 8 oz. water bottle.

2. Take the cap off of the bottle. Be sure to keep the cap!

3. Measure out 108 mL of water from the bottle. Pour this water into a beaker. Label this beaker A. Dump out the remaining water in the bottle.

4. Add 24 g of salt to the 108 mL of water you poured into beaker A. Mix the salt and water until the salt is all dissolved. The salt water mixture will look cloudy because there is some undissolved calcium silicate (and perhaps some other solids) in the water.

5. Filter the salt water mixture through a funnel and filter paper. The filtering process takes quite a bit of time, about 10 minutes for every 50 mL of water. To speed up the filtering process, filter the salt water through 2 or 3 separate filtering funnels.

6. Once the salt water mixture has filtered, pour all 108 mL of the filtered salt water back into the original water bottle. The water bottle should be a little less than half full at this point.

7. Now add 132 mL of 91% isopropyl alcohol to the water bottle so that it is almost full.

8. Add about 20 of each type of plastic to your density bottle. Be sure to add pieces of both types of plastic.

9. Tightly place the cap back on the water bottle. Secure the cap with duct tape.

Part G: Density bottle observations and explanations

1. Carefully observe your finished product. Next, shake the bottle well and observe. Describe what happens to the contents of the bottle over the course of 1 – 2 minutes.

Observations:

____

____

____

____

____

2. In the space below, explain your observations in step 1 above. In your explanation, you will need to discuss the relative densities of isopropyl alcohol, salt water, the alcohol/salt water emulsion, and of both of the plastics. Include drawings.

<u>Typical Answers to Questions in Student Worksheet:</u> Answers are given in red.

Part A:

Liquid	Isopropyl alcohol	Salt water
Density / g mL^{-1}	0.7 – 0.9 g mL^{-1}	1.0 – 1.2 g mL^{-1}

Part B:

6. Why do you think there is a difference in the behavior of the alcohol/water vs. the alcohol/salt water mixtures?

Without knowledge of polarity and intermolecular forces, students may have difficulty answering this question. Like dissolves like; the intermolecular forces between water and isopropyl alcohol molecules (dipole-dipole interactions, hydrogen bonding) is not strong enough to displace the ion-dipole forces experienced between water and sodium/chloride ions. Thus, salt water does not mix with isopropyl alcohol. However, the intermolecular forces between water and isopropyl alcohol are sufficiently strong to displace water-water interactions.

Are water and isopropyl alcohol miscible? __Yes____

Are salt water and isopropyl alcohol miscible? __No____

Part C:

The high density beads sink in water, so the high density beads have a density greater than water.

The low density beads float in water, so the low density beads have a density less than water.

Plastic	**Float or Sink in Water?**	**Density (greater than or less than 1.0 g mL^{-1})**
High density plastic	Sink	>
Low density plastic	Float	<

Part D:

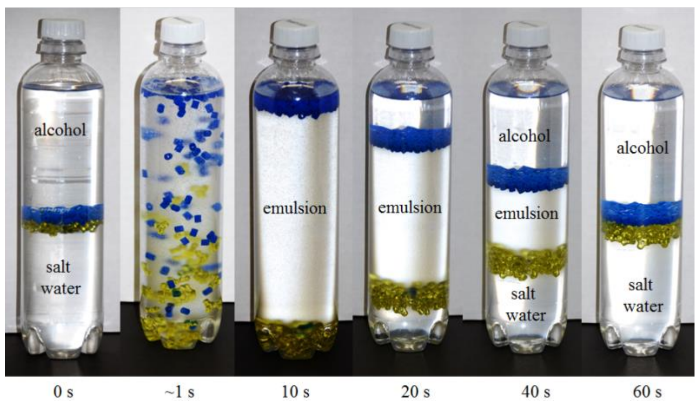
	Float or sink in 91% isopropyl alcohol?	Float or sink in water ?	Float or sink in salt water?
High density plastic	Sink	sink	Float
Low density plastic	Sink	Float	float

Review the densities you measured for the 91% isopropyl alcohol and salt water. From these densities, the density of water (D = 1.0 g mL^{-1}) and your observations in the table above, what can you conclude about the relative densities of salt water, water, alcohol and the two plastics?

Most Dense ⟷ Least Dense

salt water   high density plastic   water   low density plastic   alcohol

Part G:



The position of the liquids and plastics observed are based on their densities. Alcohol (the least dense) is always observed on top, while salt water (the most dense) is always observed on the bottom. At the start, the liquids and solids layer as:

Alcohol
Low density beads
High density beads
Salt water

When the bottle is shaken, an emulsion forms. The emulsion has a density greater than the low density beads but lower than the high density beads. When the emulsion is the only liquid present, the liquids and solids layer as:

Low density beads
Emulsion
High density beads

As the emulsion separates back into alcohol and salt water, three liquids are present. In this case, the liquids and solids layer according to density as:

Alcohol
Low density beads
Emulsion
High density beads
Salt water

Dynamic Density Bottle – 70% isopropyl alcohol recipe

1. Remove the label from the water bottle (for this recipe, use an 8 oz. water bottle).

2. Take the cap off of the bottle. Be sure to keep the cap!

3. Measure out 68 mL of water from the bottle. Pour this water into a plastic cup. Label this cup A. Dump out the remaining water in the bottle.

4. Add 1 ¼ tablespoons (24 g) of salt to the 68 mL of water you poured into cup A. You may have to gently heat the salt water mixture to get the salt to dissolve. Mix the salt and water until the salt is all dissolved. The salt water mixture will look cloudy because there is some undissolved calcium silicate (and perhaps some other solids) in the water.

5. Filter the salt water mixture through a funnel and filter paper. The filtering process takes quite a bit of time, about 10 minutes for every 50 mL of water.

6. Once the salt water mixture has filtered, pour all 68 mL of salt water back into the original water bottle. The water bottle should be about one-third full at this point.

7. Now add 70% isopropyl alcohol to the water bottle so that it is almost full. This will require about 172 mL of isopropyl alcohol.

8. Add a few pieces of plastic to your density bottle. Be sure to add some plastic with a higher density and some plastic with a lower density.

9. Tightly place the cap back on the water bottle. Secure the cap with duct tape.

10. Remember, before the liquids are mixed, the alcohol layer floats on the salt water layer. Both plastics float on the salt water and both sink in the alcohol. When the salt water and alcohol are mixed, a single liquid is formed. Some plastics are more dense than this mixed liquid and sink in it. Other plastics are less dense than this mixed liquid and float in it. Over time, the two liquids will separate and return (along with the plastics) to the original configuration.

ONCE THE CAP IS SECURED WITH DUCT TAPE, DO NOT REMOVE THE CAP!!

To increase the amount of fluid yielded, all measures in the recipe should multiplied by the following conversion factor:

$$\text{Conversion factor} = \frac{\textit{ounces desired}}{8}$$

Suppose you wish to make a 500 mL Dynamic Density Bottle. Because 500 mL = 17.6 ounces (500 mL / 28.4 mL oz^{-1} = 17.6 ounces), the conversion factor is 2.2. Thus, to make about 500 mL, 53 grams of salt (24 g x 2.2) are dissolved in 150 mL water (68 mL x 2.2), and the salt water is filtered. Next, about 378 mL (172 mL x 2.2) of 70% isopropyl alcohol are added to the filtered salt water.

Dynamic Density Bottle – 91% isopropyl alcohol recipe

1. Remove the label from the water bottle (for this recipe, use an 8 oz. water bottle).

2. Take the cap off of the bottle. Be sure to keep the cap!

3. Measure out 108 mL of water from the bottle. Pour this water into a plastic cup. Label this cup A. Dump out the remaining water in the bottle.

4. Add 1 ¼ tablespoons (24 g) of salt to the 108 mL of water you poured into cup A. Mix the salt and water until the salt is all dissolved. The salt water mixture will look cloudy because there is some undissolved calcium silicate (and perhaps some other solids) in the water.

5. Filter the salt water mixture through a funnel and filter paper. The filtering process takes quite a bit of time, about 10 minutes for every 50 mL of water.

6. Once the salt water mixture has filtered, pour all 108 mL of salt water back into the original water bottle. The water bottle should be a little less than half full at this point.

7. Now add 91% isopropyl alcohol to the water bottle so that it is almost full. This will require about 132 mL of isopropyl alcohol.

8. Add a few pieces of plastic to your density bottle. Be sure to add some plastic with a higher density and some plastic with a lower density.

9. Tightly place the cap back on the water bottle. Secure the cap with duct tape.

10. Remember, before the liquids are mixed, the alcohol layer floats on the salt water layer. Both plastics float on the salt water and both sink in the alcohol. When the salt water and alcohol are mixed, a single liquid is formed. Some plastics are more dense than this mixed liquid and sink in it. Other plastics are less dense than this mixed liquid and float in it. Over time, the two liquids will separate and return (along with the plastics) to the original configuration.

ONCE THE CAP IS SECURED WITH DUCT TAPE, DO NOT REMOVE THE CAP!!

To increase the amount of fluid yielded, all measures in the recipe should multiplied by the following conversion factor:

$$\text{Conversion factor} = \frac{\textit{ounces desired}}{8}$$

Suppose you wish to make a 500 mL Dynamic Density Bottle. Because 500 mL = 17.6 ounces (500 mL / 28.4 mL oz^{-1} = 17.6 ounces), the conversion factor is 2.2. Thus, to make about 500 mL, 53 grams of salt (24 g x 2.2) are dissolved in 238 mL (108 mL x 2.2) of water, and the salt water is filtered. Next, about 290 mL (132 mL x 2.2) of 91% isopropyl alcohol are added to the filtered salt water.

Density Bottle – 99% isopropyl alcohol recipe

1. Remove the label from the water bottle (for this recipe, use an 8 oz. water bottle).

2. Take the cap off of the bottle. Be sure to keep the cap!

3. Measure out 120 mL of water from the bottle. Pour this water into a plastic cup. Label this cup A. Dump out the remaining water in the bottle.

4. Add 1 ¼ tablespoons (24 g) of salt to the 120 mL of water you poured into cup A. Mix the salt and water until the salt is all dissolved. The salt water mixture will look cloudy because there is some undissolved calcium silicate (and perhaps some other solids) in the water.

5. Filter the salt water mixture through a funnel and filter paper. The filtering process takes quite a bit of time, about 10 minutes for every 50 mL of water.

6. Once the salt water mixture has filtered, pour all 120 mL of salt water back into the original water bottle. The water bottle should be about half full at this point.

7. Now add 99% isopropyl alcohol to the water bottle so that it is almost full. This will require about 120 mL of isopropyl alcohol.

8. Add a few pieces of plastic to your density bottle. Be sure to add some plastic with a higher density and some plastic with a lower density.

9. Tightly place the cap back on the water bottle. Secure the cap with duct tape.

10. Remember, before the liquids are mixed, the alcohol layer floats on the salt water layer. Both plastics float on the salt water and both sink in the alcohol. When the salt water and alcohol are mixed, a single liquid is formed. Some plastics are more dense than this mixed liquid and sink in it. Other plastics are less dense than this mixed liquid and float in it. Over time, the two liquids will separate and return (along with the plastics) to the original configuration.

ONCE THE CAP IS SECURED WITH DUCT TAPE, DO NOT REMOVE THE CAP!!

To increase the amount of fluid yielded, all measures in the recipe should multiplied by the following conversion factor:

$$\text{Conversion factor} = \frac{\textit{ounces desired}}{8}$$

Suppose you wish to make a 500 mL Dynamic Density Bottle. Because 500 mL = 17.6 ounces (500 mL / 28.4 mL oz^{-1} = 17.6 ounces), the conversion factor is 2.2. Thus, to make about 500 mL, 53 grams of salt (24 g x 2.2) are dissolved in 264 mL (120 mL x 2.2) water, and the salt water is filtered. Next, about 264 mL (120 mL x 2.2) of 91% isopropyl alcohol are added to the filtered salt water.