Density Bottles

Density Demonstrations

FLINN SCIENTIFIC CHEM FAX!

Introduction

Astound students as a blue liquid in a wave bottle "switches" from the bottom layer to the top.

Chemical Concepts

- Density
- Immiscibility
- Polar/nonpolar molecules
- Hydrogen bonding

Materials

Blue food dye solution, 400 mL

Water, distilled or deionized, 400 mL

Bottle, square, plastic, PETG, 1000-mL, 2

Lamp oil, 400 mL

Lamp oil, blue, 400 mL

Safety Precautions

Do not allow students to open the bottles—they contain flammable liquids. Please follow standard laboratory safety guidelines.

Preparation

1. Empty the contents of the bottle containing clear lamp oil into one of the 1000-mL plastic bottles.
2. Pour the entire bottle of blue food dye solution into the same 1000-mL plastic bottle as the clear lamp oil.
3. Tightly cap the bottle.
4. Pour all of the blue lamp oil into the empty 1000-mL plastic bottle.
5. Add 400 mL of distilled or deionzied water to the same bottle with the blue lamp oil. The layers in this bottle should be the reverse of the first bottle. *Note:* Do not use tap water—it tends to be cloudier in appearance than distilled or deionized water.
6. Tightly cap the bottle. The bottles will not need to be reopened once they are prepared.

Procedure

1. Present students with one of the bottles.
2. Encourage students to handle the bottle. Have them shake the bottle, turn it upside down, on its side, etc., observing the layers as they move and separate.
3. Discuss the concepts of density, immiscibility, and polar/nonpolar properties with students.
4. Leave the bottle at a visible location in the classroom, such as a front table, for a few days.
5. Remove the bottle when students are not present and replace it with the other bottle.
6. Students will notice that the layers are reversed. This will initiate questions and discussion on density and other related topics.
7. At this point it may be beneficial to present both bottles to students simultaneously.

Disposal

Bottles may be reused for years.

Tips

- When students first notice that the layers have "switched," do not immediately tell them they are looking at a different bottle. Ask for explanations of how this "switch" may have occurred.
- Ask students whether they believe the bottles contain the same two liquids, and the reasoning behind their answers. Do the layers in both bottles behave in a similar fashion?
- Caps may be glued onto the bottles to prevent opening, spillage, or tampering.

Discussion

The bottles both contain water and lamp oil. Lamp oils are petroleum byproducts primarily composed of liquid paraffin. The density of lamp oil is between 0.8 g/mL and 0.9 g/mL, which is less then that of water which has a density of 1.0-g/mL. The difference in densities results in the more dense water layer on the bottom.

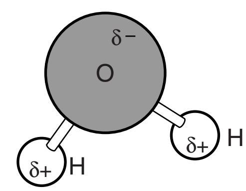


Figure 1. Water molecule with partial charges

The two liquids in each bottle are immiscible, that is they will not intermix to form a solution. Lamp oil is composed of hydrocarbons which have a general chemical formula of $C_NH_{(N \times 2)+2}$. The difference in electronegativity values between carbon and hydrogen is small. When they form molecules, electrons are almost equally shared within the carbon and hydrogen bond. As a result, the carbon hydrogen bond has little change separation or polarity. Hydrocarbon molecules are nonpolar and hydrophobic (water repelling) in nature, since water, H_2O, is a polar molecule. Oxygen and hydrogen have very different electronegativity values causing an uneven distribution of electrical charge resulting in partial charges, a dipole. The geometry of water keeps the partial charges separated and causes water molecules to be polar (see Figure 1).

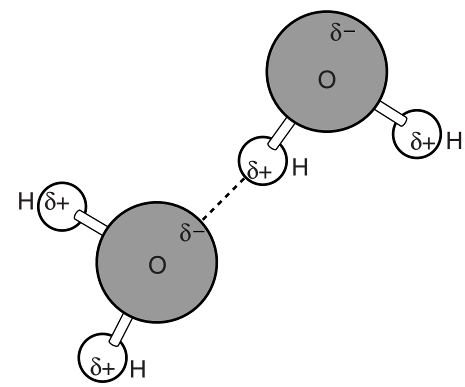


Figure 2. Hydrogen bonding between water molecules

As shown in Figure 1, the electronegative oxygen atoms in water molecules have a partial negative charge. Hydrogen atoms from other water molecules will be drawn to this negativity due to their partial positive charge, resulting in an attractive force called hydrogen bonding. Water molecules have greater attraction to one another due to hydrogen bonding than they do to other nonpolar molecules such as hydrocarbons (see Figure 2). The strong attraction between water molecules causes them to be tightly packed in the liquid state. This means there will be more water molecules (mass) per unit volume of liquid compared to nonpolar liquids.

The blue color in the water comes from food coloring, which is a polar substance, so it mixes readily with water. When the bottle is shaken the oil will not become tinted from contact with the food coloring due to the incompatibility of polarity. The blue coloring in the lamp oil comes from an oil-miscible dye which is nonpolar. Water will not become colored due to the difference in properties between the water and the dye present in the oil.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

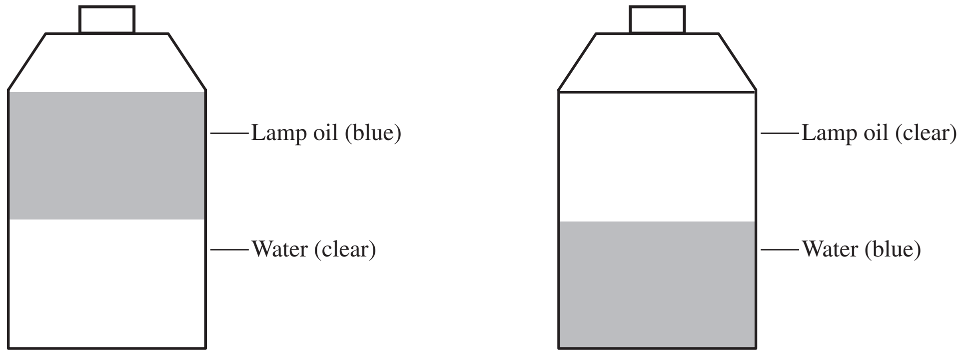
Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter

Answers to Worksheet Questions

1. Draw the two bottles. Label each with chemicals and colors in the correct place.



2. Water has a density of 1.0 g/mL. Approximate what the density of lamp oil might be. Give a reason for your guess.

   The density of lamp oil may be around 0.8 g/mL. It has to have a density lower than that of water, 1.0 g/mL, because the water layer sits below the lamp oil layer in both bottles.

3. The water and lamp oil layers do not mix because lamp oil is a hydrocarbon, which is nonpolar. Water, on the other hand, is a polar molecule. What does this say about the blue dye used in this demonstration? Why do you think that only the water was blue in one bottle, but only the lamp oil was blue in the other?

   The blue dyes used in the demonstration have to be different for each substance. Only a polar substance would bond readily with water, so the dye in water must be polar. The dye in lamp oil, on the other hand, must be a nonpolar substance so that it bonds with the lamp oil but not with the water.

Acknowledgment

Special thanks to Lee Marek, University of Illinois at Chicago; Naperville North High School, Naperville, IL (retired) for providing the idea and the instructions for this activity to Flinn Scientific.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Density Bottles* activity, presented by Lee Marek, is available in *Density Demonstrations* and in *Polar vs. Nonpolar Compounds*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Density Bottles* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Density Demonstration Bottles—Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP6684	Density Demonstration Bottles—Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Density Bottles Worksheet

Discussion Questions

1. Draw the two bottles. Label each with chemicals and colors in the correct place.

2. Water has a density of 1.0 g/mL. Approximate what the density of lamp oil might be. Give a reason for your guess.

3. The water and lamp oil layers do not mix because lamp oil is a hydrocarbon, which is nonpolar. Water, on the other hand, is a polar molecule. What does this say about the blue dye used in this demonstration? Why do you think that only the water was blue in one bottle, but only the lamp oil was blue in the other?