Red, White and Blue Density

Introduction

Create a beautiful, three-layered liquid to demonstrate the salting-out effect, density, and the relative miscibility of organic solvents and water.

Concepts

- Miscible and immiscible liquids
- Salting-out effect
- Density

Materials

Copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, 0.5 g
Distilled or deionized water, 80 mL
Methyl alcohol, CH_3OH, 80 mL
Potassium carbonate, K_2CO_3, 55 g
Sudan III, 0.5 g
Toluene, $C_6H_5CH_3$, 80 mL
Balance
Beakers, 250-mL (1) and 150-mL, 3
Glass bottle, 240 mL
Microspatulas, 2
Pipet, 25- or 50-mL
Stirring rod
Weighing dish or cup, large

Safety Precautions

Methyl alcohol is a flammable solvent and presents a serious fire hazard unless appropriate precautions are observed. It is also toxic by ingestion and may cause blindness. No flames or heat are used in this activity—always keep methyl alcohol away from flames, heat, and all sources of ignition. Replace the cap on the methyl alcohol bottle and return it to a locked, flammables storage cabinet immediately after dispensing the liquid. Toluene is a combustible liquid and is moderately toxic by ingestion. Potassium carbonate is a corrosive solid. Perform this demonstration in a hood or in a well-ventilated lab only. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant apron, and chemical-resistant gloves. Please review current Material Safety Data sheets for additional safety, handling, and disposal information.

Procedure

1. Obtain about 80 mL of distilled water in a 250-mL beaker and add 80 mL of methyl alcohol. There should be one liquid layer because methyl alcohol and water are miscible.
2. Weigh out approximately 55 g of potassium carbonate in the large weighing dish.
3. Gradually add the solid potassium carbonate to the methyl alcohol–water solution. Stir the mixture to dissolve the solid.
4. As potassium carbonate dissolves in the solution, two layers will begin to separate in the liquid. Continue adding potassium carbonate until the lower aqueous layer is saturated (undissolved solid remains).
5. Using a pipet, remove the upper liquid layer of methyl alcohol and add it to a clean 150-mL beaker. Repeat as necessary to remove all the methyl alcohol.
6. Decant the aqueous potassium carbonate solution into a clean 150-mL beaker. (Do not transfer any solid.)
7. Add about 3 microspatulas of copper(II) sulfate pentahydrate crystals to the aqueous potassium carbonate solution. Stir to dissolve—the final solution should be clear and blue. (There may be some undissolved solid in the bottom of the beaker.)
8. Obtain about 80 mL of dry toluene in a 150-mL beaker. Add about 2 microspatulas of solid Sudan III dye and stir to dissolve. The solution should be clear and red.
9. Pour the three solutions into a large gas-collecting bottle in the following order:
   - Blue aqueous solution (contains K_2CO_3 and $CuSO_4$);

- Colorless methyl alcohol solution;
- Red toluene solution (contains Sudan III).

10. The result is a three-layer liquid! The bottom layer is blue (aqueous $CuSO_4$ and K_2CO_3), the middle layer is colorless (methyl alcohol), and the top layer is red (toluene and Sudan III).

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The three-layered liquid may be saved in a sealed glass bottle. The organic layers (toluene and methyl alcohol) may be poured into shallow containers and evaporated according to Flinn Suggested Disposal Method #18b. The remaining liquid layer may be disposed of down the drain with plenty of running water according to Flinn Suggested Disposal Method #26b.

Tips

- The three-layered liquid will keep for many months. Store in a sealed bottle and display in a secure location where the bottle will not accidentally be tipped over. *Note:* The gas collecting bottle available from Flinn Scientific, which is recommended in the *Materials* section, does not come with a cap. Please call or write us and we will send you a polypropylene cap.
- Removing the methyl alcohol from the aqueous solution by pipet rather than simply decanting gives better separation of the aqueous and alcohol layers.
- Additional dyes may be added to achieve a red–yellow–green “traffic-light” density column. Add about one microspatula of methyl red indicator to the methyl alcohol layer after it has been salted out and separated from the aqueous solution. This will give a clear yellow solution. Add about one-half microspatula of potassium ferrocyanide [$K_4Fe(CN)_6$] as needed to the blue aqueous layer to give it a nice green color. The result is red–yellow–green from top to bottom.
- The density of pure methyl alcohol (d = 0.791 g/mL) is less than that of toluene (d = 0.866 g/mL). In this three-layer density column, however, the toluene is the topmost (least dense) layer, because the methyl alcohol layer contains dissolved potassium carbonate, which increases the density of the solution.
- Replacing methyl alcohol with ethyl alcohol does not give a three-layer liquid, because the toluene and ethyl alcohol solutions are miscible (step 9). Ethyl alcohol can be used, however, to demonstrate the “salting out” effect with potassium carbonate (steps 1–4). Two layers will form when solid potassium carbonate is added to 50% ethyl alcohol.
- The separation of 50 percent aqueous methyl alcohol in step 4 into two layers upon addition of potassium carbonate is due to the “salting out” effect. Adding an inorganic salt to water decreases the solubility of organic substances in the aqueous phase. Repeat this demonstration on a small scale with other inorganic salts to see if they have the same effect.

Discussion

Making the red, white, and blue density column demonstrates (1) the miscibility of methyl alcohol and water; (2) the “salting out” effect that results when a salt is added to aqueous methyl alcohol; (3) the immiscibility of toluene and methyl alcohol because toluene is a nonpolar solvent; and (4) the relative densities of the three solutions. Adding suitable dyes or indicators to the different liquid layers makes the phase boundaries more visible.

The ability of an organic compound to dissolve in water is drastically reduced when an inorganic salt (many different salts will work) is added to the water. This effect, called salting out, occurs because the water molecules bind strongly to the inorganic cations and anions in the salt solution, and thus are unavailable to solvate the organic compound. Salting out is used in two different ways to isolate and purify organic compounds from a reaction mixture. If the reaction mixture is an aqueous solution, salt is generally added to remove the organic product into a separate layer. Alternatively, an organic solution obtained by extraction with water may be “washed” with saturated sodium chloride solution to remove water dissolved in the organic solvent.

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 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder

Reference

This activity was adapted from *Chemistry of Organic Compounds*, Volume 19 in the *Flinn ChemTopic*™ *Labs* series, Cesa, I., Editor; Flinn Scientific, Inc., Batavia, IL (2006).

Materials for *Red, White and Blue Density* are available from Flinn Scientific, Inc.

Catalog No.	Description
C0102	Copper(II) Sulfate, 5 g
M0054	Methyl Alcohol, 500 mL
P0038	Potassium Carbonate, 500 g
S0152	Sudan(III), 5 g
T0019	Toluene, 500 mL
GP9148	Gas Collecting Bottle, Flint Glass, 240 mL

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