Soaps, Solvents and Cleaning:

A slippery problem

Objectives

1) Examine the effect of surfactants on solvents.
2) Discuss ways to make cleaning agents environmentally friendly.
3) What role does crystallization play in cleaning?

Green Chemistry Principles

1) Safety first-and last
2) It's midnight. Do you know where your product is?
3) Use safer solvents

IL State Standards (Science)

11.A.3a, 11.A.3b, 11.A.3f, 11.A.4a, 11.A.4b, 11.A.4c, 11.A.4d, 11.A.4f, 11.A.5a, 11.A.5d, 12.B.3a, 12.B.4a, 12.C.5a, 12.E.3c, 13.B.3e, 13.B.3f, 13.B.4c, 13.B.5d, 13.B.5e

Levels

All levels

Vocabulary

Surfactant, perchloroethylene, solvent, polar and non polar molecules, supersaturation

Part 1 Materials (per group of 2)

- 1 small test tube with stopper to fit
- Dropper for water (approximately 30-mL capacity)
- 2 thin stem plastic Beral-style pipets
- 2-3 mL cooking oil
- 2-3 mL liquid dishwashing soap

Part 2 Materials (per group of 2)

- Several clean pennies
- 2 dropping pipets
- Cotton swabs
- Paper towels
- Substances to test: cooking oil or mineral oil, pieces of paraffin wax, sugar, carbonated water, soft lead pencils (as a source of graphite, which is often used as a dry lubricant), liquid dish soap, table salt solution (1.0 M, add 58.5 grams NaCl and enough water make 1.0 L of solution), and any other appropriate substances you wish to use.

Part 3 Materials (per group of 2-4)

- Hotplate
- 100 mL Beaker
- distilled water
- ¼ lb table sugar
- glass rod for stirring
- pencil and string

Time

20 minutes prep.; 10-45 minutes class time

Portions of this material are adapted from the ACS text *Introduction to Green Chemistry.* See the "references" section of the introduction to this manual for additional information on this text.

Background/Overview

Many clothing items are made from fabrics that are not washable in water require a dry-cleaning process. Many dry cleaning processes actually use a *liquid* solvent to remove the dirt and stains. Most dry cleaners use the solvent *perchloroethylene*, or PERC. Disposal of PERC, a suspected carcinogen, can contaminate groundwater, making it unhealthy for humans and animals.

One alternative to this process that has recently been developed uses a detergent and liquid carbon dioxide (CO2) as a solvent. The new method uses an inexpensive, easily recycled solvent and requires less energy overall. The following experiments of solubility and surfactants provide a basis for understanding how the new process works by demonstrating its principles through the familiar process of wet cleaning with water and a soap or detergent.

Part 1-The effect of soap on an oil and water mixture. This activity shows students that oil forms a layer on top of water and that the two do not mix. However, when a soap or detergent is added, the oil dissolves and the original two layers form a single solution. In the part of the module that immediately follows, students will be asked to cite the results they observed in this activity and explain why water (without the aid of a detergent) is not likely to be a good solvent for removing a grease spot from a shirt.

Procedure

1. Place a few milliliters of water in the test tube and add about 1/2 mL of oil.
2. Stopper the tube, mix by inverting the tube several times, and allow the tube to sit undisturbed for several seconds.
3. Record your observations when no further change seems to occur.
4. Add about 1/2 mL of the dishwashing soap to the test tube.
5. Stopper the tube and mix by inverting the tube several times. Try not to create a lot of suds.
6. Allow the tube to sit undisturbed and observe.
7. Record your observations when no further change seems to occur.

Questions & Answers

Suppose a drop of pizza grease falls on your shirt as you are munching down a slice of pepperoni and extra cheese at your favorite Italian restaurant. How can you remove this grease spot from your shirt?

1. Do you decide to try removing the grease spot by soaking the spotted part of the shirt in water. Is this likely to work? Use your results from above to explain why or why not.

   This is unlikely to work. Since the results showed that oil and water do not mix, it is unlikely that water could dissolve and remove a spot on a shirt.

2. Do you consider using soap or detergent along with water to remove the grease spot. Is this likely to work? Use your results from the activity above to explain why or why not.

   This method is likely to work. Since the results showed that oil and water will mix if soap or detergent is added, it is likely that the soap and water will dissolve and remove the grease.

Part 2-The effect of surfactants on solvents

Soaps and detergents belong to a class of substances called *surfactants*. When mixed into water, the molecules of these substances change the surface properties of the water in such a way that the water can spread out or "wet" a surface more effectively. For a solvent to dissolve substances, it has to be in contact with them. If the solvent "beads up" or just sits on the surface, little solute is likely to dissolve.

What effect(s) might possible surfactants have on the surface properties of water? For this activity, you will have available a few clean pennies, thin-stem plastic pipets, cotton swabs, paper towels, and a dropper bottle of water. You will also have some test substances available: liquid soap or detergent, solid soap, cooking oil, a piece of paraffin (solid wax), sugar, seltzer water (water with dissolved CO2), a soft lead pencil (the "lead" is graphite, which is often used as a dry lubricant, especially in cold environments), table salt solution, and possibly other materials you have assembled.

Procedure

Note: Work in groups of two on this activity, so one partner can add the liquid drops and the other can observe closely what is happening.

1) Examine a penny, and rub it between your fingers.
2) Record what the surface feels like in terms of slipperiness, stickiness, or any other characteristic you detect.
3) Place a clean penny on a paper towel.
4) Fill a thin-stem pipet with water, hold it vertically directly above the penny, and carefully add water one drop at a time to the surface of the penny.
5) Count how many drops you can add before the water spills off.
6) Record the number of drops you added.
7) Coat a fresh penny with one of the test substances (oil, soap, etc.)
8) Add drops of water until the water spills off
9) Record your results

Questions & Answers

1) On average, how many drops of pure water could be added to the surface to clean the penny?
2) Which test substance had the largest effect on the number of drops of liquid that could be added to the penny?
3) Discuss how the surfactant (liquid dish soap), a nonpolar liquid (mineral oil), and an ionic solution (the table salt solution) affect the number of drops of water added when using it.
4) Characterize the surfactant effects of the various test substances.
5) Explain in your own words how soap works as a cleaning agent.

Much of the grime that soils our clothing can be removed by washing in water. Water is a solvent that can dissolve many substances. To remove greasy or oily stains, we must use soaps or detergents. Soap works by having a molecular structure so that one end can dissolve in the greasy/oily stain and the other dissolves in water.

Part 3-Removing dirt with crystallization

Using crystallization, we can remove any dirt or oil we have "dissolved" in a cleaning solution. Crystallization refers to the formation of solid crystals from a homogeneous solution. It is essentially a solid-liquid separation technique and a very important one at that.

Example of Crystallization

1. Water freezing
2. Removing sucrose from beet solutions
3. Removing KCl from an aqueous solution

Crystals are grown in many shapes, which are dependent upon downstream processing or final product requirements. Crystal shapes can include cubic, tetragonal, orthorhombic, hexagonal, monoclinic, triclinic, and trigonal. In order for crystallization to take place a solution must be "supersaturated". Supersaturation refers to a state in which the liquid (solvent) contains more dissolved solids (solute) than can ordinarily be accommodated at that temperature.

The experiment below will demonstrate how crystallization removes dirt, using sugar as the dirt. In the experiment, the first part of the sugar (dirt) that does not dissolve will help the first part of crystallization. Simply defined, it's the growth of a new crystal. This first step is called nucleation or primary nucleation

In order to demonstrate crystallization - Let's grow crystals!

Procedure

1) Fill beaker halfway and bring water to boiling using hotplate.
2) Add sugar while stirring to make a water-sugar solution.
3) Continue adding sugar until no more sugar will dissolve in the solution (this is a saturated solution).
4) Now add one final teaspoon of sugar.
5) The sugar that will not dissolve will help the first step in crystallization begin. This first step is called "nucleation" or primary nucleation. The sugar resting at the bottom of the pot will provide a site for nucleation to occur.

Primary nucleation is the first step in crystallization. Simply defined, it's the growth of a new crystal

Questions for Discussion

1) How does crystallization effect the removal of dirt?