A Salty Separation

It can be difficult to separate a solid from a liquid. Sometimes other chemicals can be added to aid in separation. You can imagine how difficult it would be to separate soap and water once they have been mixed. How well can you do it? Try the following activity and see.

Materials

- bar of soap (do not use detergent)
- cheese or carrot grater
- water
- 1 of the following heat sources:
  - stove
  - hot plate
  - microwave
- heat-safe container (appropriate for use with chosen heat source)
- 8 clear plastic cups or glasses
- 2 clear plastic cups or glasses for each additional optional solid used
- masking tape
- marker or pen
- coffee filters (fluted, basket-style filters are recommended, but any will do)
- 8 rubber bands
- teaspoon measure
- cup measure
- 5–7 stir sticks
- table salt
- sugar
- optional solids (use at least one):
  - Epsom salt
  - alum (aluminum potassium sulfate—used in canning and as an astringent)
  - MSG (monosodium glutamate—used as a seasoning)
  - crushed chalk (composed of $CaCO_3$)

Getting Ready

Grate 1/2 cup of soap using a cheese or carrot grater. Place the grated soap in the heat-safe container, add 2 cups of water, and stir for several minutes. Heat the mixture using the stove, hot plate, or microwave, stirring occasionally until all of the soap shavings are dissolved. It is not necessary to boil the solution. Remove the solution from the heat and allow it to cool to room temperature.

Exploration

Step 1 Use the masking tape and pen to label two of the empty cups “control,” two others as “table salt,” and two as “sugar.” Pour 1/4 cup of the prepared soap-water solution into one cup of each labeled pair. Place a coffee filter in the other cup of each labeled pair. Fold the edge of the filter over the rim of the cup and secure it with a rubber band.

Step 2 Add 2 teaspoons table salt to the cup of soap-water solution labeled “table salt.” Add 2 teaspoons sugar to the cup of soap-water solution labeled “sugar.” Stir each solution for several minutes. Compare them to the control cup with nothing added.

Step 3 Pour each mixture into the corresponding cup with filter. Record the appearance of the filtrate that passed through the filter. How does the material in each of the filters look and feel? What is the purpose of the control cup?

Step 4 Predict which of the optional solids on the materials list will do a good job of separating the soap from water. Repeat Steps 1 through 3 with at least one of the optional solids.

Challenge

What type of common compounds will separate soap from water?

A Salty Separation

This activity can be used to show two mechanisms of intermolecular attraction: polarity and charge.

Concepts

covalent and ionic compounds

Expected Student Responses to Exploration

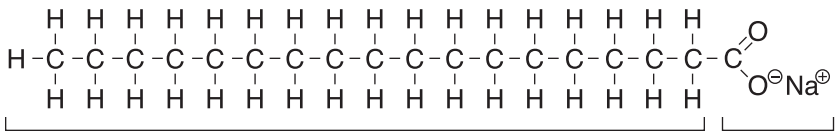
Step 2 The solution containing table salt (an ionic compound) seems thicker than the control solution. The one containing sugar (a molecular compound) appears the same as the control solution.

Step 3 See table below.

solid	filtrate	residue
none	$\frac{1}{4}$ cup cloudy filtrate	none
table salt (NaCl)	$\frac{1}{4}$ cup clear filtrate	fine-grained white powder
Epsom salt ($MgSO_4$)	1 tablespoon clear filtrate	thick white slurry
alum [$(AlK(SO_4)_2$]	1 tablespoon semi-cloudy filtrate	white slurry
crushed chalk ($CaCO_3$)	1 tablespoon semi-cloudy filtrate	thin white slurry
MSG*	$\frac{1}{4}$ cup cloudy filtrate	small amount white powder
* If the MSG filtrate is allowed to sit long enough, it will form two layers; one clear and one cloudy.		

(c) The purpose of the control cup is to provide a basis for comparison.

Note: The mechanism of reaction with soap for each of these salts is not the same. The reaction of the monovalent salts with the soap occurs through a process called "salting out." When a high concentration of an ionic compound (such as NaCl, Alum, or MSG) is added to an aqueous solution, the soap becomes less soluble. The two divalent cations used in this activity, Mg^{2+} and Ca^{2+}, are what give water hardness and form insoluble salts with the fatty acid anions in the soap, resulting in a curd-like precipitate. The sugar, not being ionic at all, does not affect the ionic strength of the soap solution and has no apparent effect on its solubility. The structure of sodium stearate (a soap) is:



Step 4 (See Step 3.)

Expected Student Answer to Challenge

Ionic compounds can be used to separate soap and water.

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