# Soap, Slime, and Creative Chromatography

**Strand** Phases of Matter and Kinetic Molecular Theory

**Topic** Investigating kinetic theory

**Primary SOL** CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

a) nomenclature;
b) balancing chemical equations;
c) writing chemical formulas;
d) bonding types;
e) reaction types; and
f) reaction rates, kinetics, and equilibrium.

CH.5 The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

f) specific heat capacity.

**Background Information**

Fats and oils are members of the class of compounds referred to as "lipids." Fats and oils may be hydrolyzed by the action of a strong base. Hydrolysis of a fat or oil with NaOH results in the sodium salt of the fatty acids. Such salts are more commonly called "soaps," and the reaction is commonly referred to as "saponification." Hence, soaps are metallic salts of fatty acids. When common NaCl is added, the soap will precipitate. When soap is used in hard water, insoluble calcium salts of the fatty acid and other precipitates are formed. These precipitates are often referred to as "soap scum" or "bathtub ring."

In Experiment 1, cottonseed oil will be hydrolyzed with NaOH to form a soap, and the properties of the soap will be investigated briefly.

A *polymer* is a large molecule formed by joining together repeating units of small molecules. The individual molecules forming the polymer are called "monomers." The monomers link together like chains. Chemists usually represent a polymer with notation that shows the simplest repeating unit and the total number of repeating units (*n*): for example, $(C_6H_{12})_n$. A typical polymer, Styrofoam, may have about 25,000 carbon atoms in its chain and would have a molar mass of about 350,000 grams. The molecules in a polymer can bend and twist and often tangle like a plate of spaghetti. Polymers can be made stiffer by introducing chemical bonds between the polymer chains, a process called "crosslinking." The greater the number of crosslinks in a polymer, the more rigid the material will be.

*Chromatography* uses differences in the molecular structure and polarity of molecules to separate the components of a mixture. Chromatography uses a stationary phase and a mobile phase. Some compounds will be attracted to the stationary phase and will not travel or spread very much. Other compounds will be attracted to the mobile phase and will be carried along with it. Whether a compound is attracted to the stationary phase or to the mobile phase depends on the intermolecular attractions between the compound and the different phases.

In this experiment, students will use inks made of water-soluble, colored pigments. The cellulose of the filter paper is the stationary phase, and water and isopropyl alcohol are the mobile phases. As the mobile phase travels up the paper, it carries the different pigments along with it. Different-colored pigments are carried along at different rates, some traveling farther and faster than others. The speed of the pigment depends on the size of the pigment molecule and on how strongly the pigment is attracted to the paper. Since the mobile phase carries the different pigments at different rates, the colored inks will separate to reveal the colors that were mixed to make them.

**Materials**

- Cottonseed oil
- Ethanol
- 20% NaOH solution
- Plastic pipettes
- Watch glasses
- 250-mL beakers
- Saturated NaCl solution
- Paper towels
- Scoop
- Vegetable oil
- 1% $CaCl_2$ solution
- 4% polyvinyl alcohol solution
- Food coloring
- Plastic medicine cups
- Wooden splints
- 4% sodium tetraborate
- White glue
- Filter paper
- Markers with water-soluble ink in black, purple, green, yellow, red, orange, blue, and brown
- Isopropyl alcohol
- Distilled water

**Student/Teacher Actions (what students and teachers should be doing to facilitate learning)**

*Procedure*

Experiment 1: Saponification (Soap Making)

1. Obtain a plastic pipette, the tip of which has been cut to approximately 1 inch in length.
2. On a watch glass, combine 15 drops of cottonseed oil, 10 drops of ethanol, and 10 drops of 20% NaOH solution. Stir the reagents to mix completely.
3. Carefully suck the mixture on the watch glass into the cut-off pipette. Invert the pipette, and place it into a small beaker. Allow the pipette to stand for a few minutes. After this

time, the liquid in the pipette will have separated into two layers—a yellow oil layer and a colorless water layer.

4. Put a 250-mL beaker half full of water on a ring stand, and heat the water to about 85–90°C. This water will be used to heat the oil/NaOH/ethanol mixture gently.
5. Transfer the pipette containing the mixture, *stem end up*, to the hot water bath. Heat the mixture in the water bath, occasionally shaking the pipette, until the two layers coalesce into a single layer. This typically takes 5–10 minutes, depending on the temperature of the water and the amount of shaking done.
6. Obtain approximately 25 mL of a saturated NaCl solution. When the mixture in the pipette has formed a single layer, remove the pipette from the water bath, and squirt its contents into the saturated NaCl solution. Stir the mixture. This should cause a small quantity of white soap to form at the surface of the solution.
7. Using a clean scoop, skim the flakes of soap from the surface of the NaCl solution, and transfer them to a paper towel. Allow the soap to dry briefly on the paper towel.
8. Place about 100 mL of distilled water in a clean Erlenmeyer flask. Scrape the soap flakes from the paper towel into the water in the flask. Stopper the flask, and shake to dissolve the soap. Record what happens regarding an important property of the soap.
9. Add 2 drops of vegetable oil to a test tube containing about 5 mL of water. Note that the oil forms a separate layer. Stopper the test tube and shake. Allow the test tube to stand for a few minutes: the water and oil will separate into layers again. Repeat the test, using 5 mL of your soap solution in place of the water. The soap allows an emulsion to form between oil and water. Record your observations.
10. Place about 5 mL of your soap solution in a test tube. Add 10–15 drops of 1% $CaCl_2$ solution to the soap solution. ($Ca^{2+}$ is one of the ions found in hard water; it forms a precipitate [soap scum] with common soaps. $Mg^{2+}$ ions also result in hard water.) Record your observations.

Experiment 2: Polymerization (Formation of a Polymer)

*Procedure A: Slime*

1. Mix 10 mL of 4% polyvinyl alcohol solution with 2 drops of food coloring in a small plastic medicine cup. Stir to mix completely.
2. Add 2 mL of 4% sodium tetraborate solution *slowly* while stirring vigorously with a wooden splint. Stir until the mixture has “gelled.”
3. Take the mixture out of the container, and test some of its properties. (The more crosslinking chemical [sodium tetraborate] you add, the stiffer the polymer will be.)

*Procedure B: Silly Putty*

1. Combine 5 mL of white glue and 2 drops of food coloring in a plastic cup. Stir to mix completely.
2. Add an equal amount of 4% sodium tetraborate solution *slowly* while stirring vigorously with a wooden splint. Stir the mixture until it has begun to thicken.
3. Wash the lump under running water while squeezing it with your hands to remove any excess glue. Keep working the lump under running water until it is clean and smooth.

4. Test some of the properties of this polymer.

Experiment 3: Creative Chromatography
In this experiment, you will make designs with different colored markers on a piece of filter paper. The colors will spread and overlap as they react with the different mobile phases. Experimenting with different mobile phases will show which gives a better separation of pigments. You may use pure water or pure isopropyl alcohol, or you may make a mixture of each in any ratio that you wish.

1. Take a piece of filter paper, and draw a design on it (dots, lines, squiggles, swirls, or whatever you want), using a variety of colored markers.
2. Place the filter paper on top of a beaker to catch any excess liquid that is not absorbed by the filter paper.
3. Use a pipette to drop your solvent of choice slowly, drop by drop, in the middle of the filter paper. Observe what happens to your design as the solvent moves outward from the center of the filter paper.
4. Repeat your experiment several times with other designs and other mixtures of mobile phases. Feel free to be creative. You may experiment with dropping the solvent in locations other than the middle of the paper. Do not use too much solvent, as excess solvent will tend to wash away your design.
5. Explain which mobile phases you decided to use and the reasons for your choices.

*Observations and Conclusions*

1. Explain how soap allows an emulsion to form between oil and water.
2. Explain how the $Ca^{2+}$ ions react with the soap to form soap scum.
3. Describe some of the common properties of the “slime” and the Silly Putty.
4. Which mobile phase did you decide to use for the first chromatography lab? Why?
5. Explain some differences between water and isopropyl alcohol that led to different interactions with the inks.

**Extensions and Connections (for all students)**

- Have students research advanced chromatographic procedures and the uses of these procedures in industry.
- Have students research the advanced chemical reactions that occur during saponification.