Activity 8  Making Soap Functional and Appealing

GOALS
In this activity you will:
• Compare a store-bought soap to soaps made by classmates using a variety of measures, including a quantitative test of cleaning effectiveness.
• Evaluate the pros and cons of different fats as foundations for a soap product.
• Make a decision about other additives to your soap, after considering four broad classes of additives.
• Produce the soap you have designed.

What Do You Think?
When you change the fat in the starting materials for soap, you have control over the lathering ability and hardness of a soap. When you change the base, you have control over whether the soap is a solid or liquid. Many soaps on the market claim to be moisturizing soaps.

• How can you develop a soap that has a moisturizer?

Record your ideas about this question in your Active Chemistry log. Be prepared to discuss your responses with your small group and the class.

Investigate
In this activity, you will need to decide what other chemicals you might add to your soap to give it additional appealing properties that the fat and base do not create. Then, you will invent your recipe for your soap, and you’ll make it.

1. Obtain a sample of the store-bought soap that you are trying to compete against. Perform the soap effectiveness tests that you used on all the other soaps on the store-bought soap. Compare the results from the store-bought soap to your results from testing the six soaps you made before beginning this chapter.

   a) What special qualities does the store-bought soap have that you are going to improve?
b) What features do the six soaps have that are improvements on the commercially available soaps? What features are worse?

c) Write notes in your Active Chemistry log to help you decide on how to build your recipe for the Chapter Challenge.

2. Discuss with your group the data you collected over the chapter. Decide on the fat(s) and base you will use to make your soap.

a) Write down in your Active Chemistry log your rationale for using the fats and base you decide on.

3. Once you know what your ingredients will be, submit them in writing to your teacher.

4. Decide on any additives to use. You can learn about what different additives do in the Chem Talk section for this activity. Your teacher can give you an idea of how much to use of different additives and at what point in the procedure to add them.

5. Make the soap you propose. Use the basic recipe that you used when making the soaps before you began the chapter.

**Chem Talk**

**SOAP APPEAL**

**Additives**

There are many factors that can increase the appeal of a soap. We will focus on four additives:

- moisturizers like lanolin or cetyl alcohol
- thickeners (usually waxes)
- ingredients to adjust pH, such as citric acid or extra fatty acids
- foaming agents that enhance lathering (like sodium lauryl sulfate or sodium laureth sulfate).

Other additives you might consider could include:

- dyes (must be FDA-approved) to alter the color
- fragrances such as essential oils or esters
- preservatives and antioxidants, such as EDTA or vitamin E.

You could probably extend this list. You can find out more information about what the other additives do in books about soap-making in the library and by searching on the Internet.

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**Chem Words**

additives: substances that are added to alter the characteristics of the material. An example in soaps would be the addition of a foaming agent to increase the lather of the soap.

essential oils: in soaps, oils or esters that are added to give it desirable fragrance.

ester: the reaction product when an organic acid and an alcohol combine and eliminate a water molecule.
FUNCTIONAL AND APPEAL OF SOAPS

Moisturizers

There are two ways to moisturize skin: add molecules to the skin that draw water vapor in from the air, or coat the surface of the skin with molecules that prevent the skin’s own water from escaping into the air. The first kind of moisturizers are called **humectants**, and the second kind are called **emollients**.

A humectant must be a molecule that attracts water. The most common humectants are glycerin (already a product of the saponification reaction), propylene glycol, sorbitol, and cetyl alcohol. All of these molecules have alcohol (—OH) groups. The O—H bond is very polar, so it helps the molecule to be polar. Water molecules are also very polar. The attraction of polar molecules for each other is a crucial chemistry concept. The process you are using to make soap leaves the glycerin produced by saponification in the soap, although many commercial soap-making processes do not. You could consider adding more glycerin or other humectants to your soap to increase its ability to attract water.

An emollient must be a molecule that sticks to the skin but repels water. Emollients act by trapping water within the skin, preventing its evaporation. They form a thin layer of molecules that the water molecules cannot cross. Skin produces its own emollient, called **sebum**. Unfortunately, the more frequently and thoroughly you wash your skin, the more of it you wash away. So, emollients are added to soaps to replace what is being removed. Lanolin is a typical emollient. It is a naturally occurring animal oil that is a mixture of molecules made of cholesterol and various fatty acids. Lanolin is often removed from sheep’s wool in the process of cleaning it. Its function in the sheep’s wool is to protect and waterproof the wool. Other animal oils can be used as emollients (such as mink oil). Plant and vegetable oils are also used — avocado, sesame, and aloe vera oils are common ingredients in moisturizers.

Fats can also act as emollients. In order for this to happen, of course, the fats must not be saponified. This is arranged by using less than the amount of base needed to completely saponify all of the fat used in the soap recipe. With more chemistry knowledge, it is possible to calculate exactly the amount of a particular base needed to completely saponify the amounts of the specific fats used in a soap recipe. Then, in order to
leave some of the fat intact, the calculated amount of base is reduced by some small percentage, which will be the percentage of fat left in the soap. The six soaps you made had a base reduction of about 6%. Some soap makers reduce the base by as much as 15%, but this can sometimes result in a soap that feels somewhat greasy.

**Thickeners**

Waxes are sometimes added to soaps to thicken or harden them. A thicker, harder soap preparation will dissolve more slowly in water, and last longer as a bar of soap. Most waxes such as beeswax, a commonly used natural soap ingredient, are complex mixtures of many chemicals. The major component is a mixture of chemicals in which a saturated fatty acid is linked to a saturated fatty alcohol. A fatty alcohol has an —OH group at the end of a long hydrocarbon chain. The linkage is like that in a fat molecule, but there is only a single —OH group in the fatty alcohol instead of the three —OH groups found in glycerol. This results in a molecule with properties somewhat similar to those of a fat, but which can take a more or less straight shape (much less complicated than the shape of a fat, with those three fatty acid chains all attached to the same molecule). This straight shape allows the molecules to pack together more closely, so it is harder and melts at a higher temperature.

Many waxes are solids at room temperature, but melt at relatively low temperatures, so they are easy to work with and easy to add to soap. When soaps are made from fats that are liquids at room temperature, the soaps tend to be softer. It is helpful to add wax to thicken and harden them (so the bar lasts longer). As you learned in Activities 5 and 6, attractive dispersion forces (van der Waals interactions) are stronger when hydrocarbon chains are longer and more saturated, and when molecules stack more neatly, the substance becomes solid and hard. Stronger attractive dispersion forces require more energy to break and send the molecules from the solid phase into the liquid phase. Therefore, longer saturated-chain molecules melt at higher temperatures. Paraffin, for example, consists of hydrocarbon chains containing at least 26 carbon atoms. (Paraffin is a wax sometimes used in home canning or candle-making as well as soap-making.)
Adjusting pH

When you dissolve soap in water, some of it reacts with water and produces a somewhat basic solution (pH > 7). The negatively charged carboxylate group, \( R–COO^- \), is a weak base and will increase the concentration of \( OH^- \) ions according to the equilibrium equation below. Typically, only 1 in 100,000 soap molecules react at any given time.

\[
\text{soap} + H_2O \rightleftharpoons \text{fatty acid} + Na^+ \text{base}
\]

This basic solution can be harsh on your skin. One way to counteract this is to add an acid (to neutralize the base). Typically, citric acid is added because it occurs naturally (so people will be less likely to react to it) and it has a pH of 4 to 4.5, so it can lower the pH but not to a dangerous level. If you combine an acid at pH 4 with a base at pH 9, the pH of the resulting solution will have to be somewhere in between 4 and 9.

Foaming Agents

Foaming agents increase the lathering in soaps. They do this by lowering the surface tension of water. (Look back at Activity 4 to see more details about the surface tension of water.) Lather is not necessarily related to cleaning ability, but most consumers think it is because of heavy advertising that pushes this idea. Laundry detergents for washing machines, for example, are carefully designed to clean with a minimum of suds, because suds interfere with the operation of the machine. But many people like lots of lather in their personal care products, so products like hand soaps and shampoos are often designed to produce extra bubbles. Fats that are used to increase lather are primarily coconut oil and palm kernel oil. These two oils contain nearly 50% lauric acid,
a very short (12 carbon atoms) saturated fatty acid, as well as large amounts of myristic acid, a slightly larger (14 carbon atoms) saturated fatty acid. Soaps are rarely made from these oils alone, but they are often added to the mixture of fats to increase lather.

Bubbles (lather) can form more easily if the surface tension is reduced further. Soap is not the only molecule that can break the surface tension of water. Foaming agents also do this. Typical foaming agents are sodium lauryl sulfate and sodium laureth sulfate. Both are derived from coconuts.

**Checking Up**

1. List four additives that you could include in making a soap.
2. Explain the difference between a humectant and an emollient.
3. Give three examples of emollients you could use in your soap.
4. What additive can be used to thicken a soap?
5. In your own words, explain how a thickening agent works.

**What Do You Think Now?**

At the beginning of this activity you were asked:

- How can you develop a soap that has a moisturizer?

What additives have you now decided to add to your soap recipe? Be sure to consider your marketing target group when choosing your additives. Will some of your chosen ingredients appeal to all soap users?

**Chem Essential Questions**

**What does it mean?**

Chemistry explains a macroscopic phenomenon (what you observe) with a description of what happens at the nanoscopic level (atoms and molecules) using symbolic structures as a way to communicate. Complete the chart below in your Active Chemistry log.

<table>
<thead>
<tr>
<th>MACRO</th>
<th>NANO</th>
<th>SYMBOLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>The look, feel, and odor of your soap must appeal to your target group. Make a list of the properties your soap will have.</td>
<td>At the molecular level, what is responsible for the desired macroscopic properties of your soap? For example, the smell of your product might be due to an added chemical fragrance, often essential oils or ester compounds.</td>
<td>Be sure you know the structures of the chemical ingredients you are adding to your soap. Look them up and record them in your Active Chemistry log.</td>
</tr>
</tbody>
</table>
**How do you know?**

Which chemical ingredients in the commercial soap are responsible for the desired properties that you will want in your soap?

**Why do you believe?**

There are many soap products designed specifically for hair, face, dry skin, oily skin, dandruff, laundry, dishes, etc. Would it be smart to use facial soap to remove tough automobile grease from your hands? Make sure that your soap’s ingredients are chosen not only for marketing, but also the chemicals you add will get the job done.

**Why should you care?**

You want your soap to be commercially successful, so choosing your ingredients to satisfy your corporate executives, marketing department, and the target group must be done carefully. Explain why the ingredients you have chosen will do the job that the soap was intended to do.

**Reflecting on the Activity and the Challenge**

You now have compared the soap you are improving upon for your challenge, and the six soaps you made from different animal and vegetable fats. You also know what some different additives will do to your soap. You designed your final soap recipe and made the soap. A month from now, after the reaction is nearly complete, you can find out how well it worked. Now it’s time to turn your attention to the fun part of completing the *Chapter Challenge* and marketing your soap.

**Chem to Go**

1. Look at the ingredients in a bottle of shampoo that you have at home. List all the ingredients and identify the functions of as many of the ingredients as you can. (See the *Chem Talk* section.)

2. What advantages would a soap made from two different fats have if one fat was a liquid at room temperature and the other was a solid at room temperature? Which additive(s) could help fix the problems arising from a bar soap made from a fat containing a single kind of fatty acid (one that was a liquid)?

3. What is the difference between a humectant and an emollient? List two examples of each.
4. Preparing for the Chapter Challenge

Devise several recipes for soap that you could try. Figure out which one will be the best one to try. Write down the reasons why you chose the one you did, and also the reasons why you rejected the others. Write down in your *Active Chemistry* log a detailed recipe for the soap you will make for your Chapter Challenge.

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**Inquiring Further**

**Esters**

Research techniques for the synthesis of specific esters to add fragrance to your soap. (Your teacher may have procedures for producing esters in chemistry lab manuals that come with college chemistry books or other high school chemistry textbooks.) Identify an ester with a fragrance appropriate for a soap and develop a plan to synthesize it. After approval by and under the supervision of your teacher, make the ester.