Module 8 Lab

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CHEM 1814 Organic Chemistry I
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The **Module 8 Lab** should have been set up after the completion of Module 7's lab. Sometimes these reactions take 3-4 days to complete. If you prepared the base correctly, your soap curds should be solid after a few days. If you have decided to test other oils, those results are welcome to be displayed as well. When analyzing this lab, it is tempting to be short with the analysis. You have to be able to describe your observations and weave the course material into this analysis. These are saponified fatty acids. That means that they have ester functional groups that are ionized on one end and long chains (or medium, depends on the acid) on the other end. Describe how that removes soil. Use the intermolecular forces you learned in Chem 1 & 2 to discuss this mechanism and include the physical and chemical properties of organic chemistry as well.

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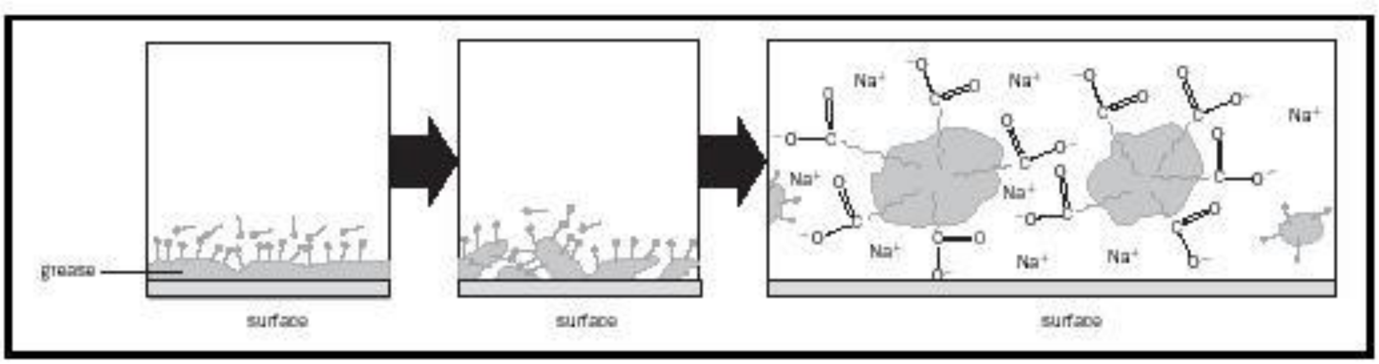
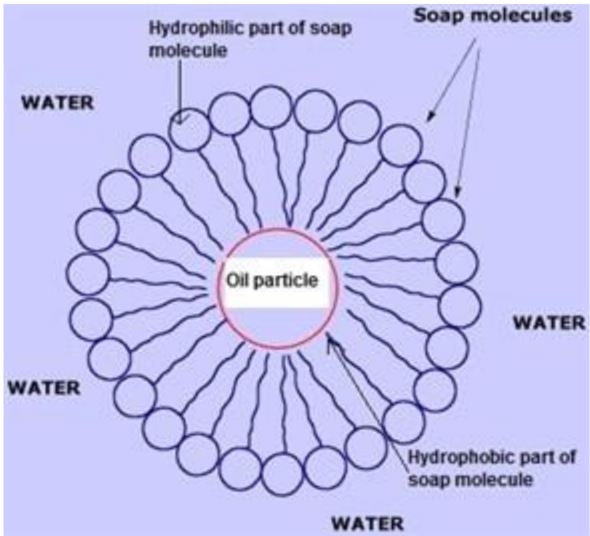
1) **Explain scientifically how soap can remove grease from a surface (whether hands, dishes, or other surface). Use your own words. (10pts)**

First, a brief look at the history of how soap came into existence. According to David Dobberpuhl, the discovery of soap goes back perhaps as far as six thousand years, predating recorded history. During excavations of ancient Babylon, cylinders with inscriptions for making soap were discovered around 2800 B.C.E. Later records from ancient Egypt (c. 1500 B.C.E.) were found describing how animal and vegetable oils were combined with alkaline salts to make soap.

Dobberpuhl also reports, soap got its name, according to Roman legend, from Mount Sapo, where animals were often sacrificed. Wood ashes from the sacrificial fires would mix with rain, washing the fat from the sacrificed animals along with alkaline, into the Tiber River where people found the mixture helped clean clothes. This recipe for making soap was relatively unchanged for centuries, with American colonists collecting and cooking down animal tallow (rendered fat) and then mixing it with an alkali potash solution obtained from the accumulated hardwood ashes of their winter fires (save your wood ashes and you can try this yourself). Similarly, Europeans made something known as castile soap using olive oil. Only since the mid-nineteenth century has the process become commercialized and soap become widely available at the local market.

So how does soap remove grease from a surface? This drawing provides a good visual while I explain.





How soap works: The hydrophobic tails of soap molecules embed in grease and oil, breaking it up into particles called micelles that lift off the surface and disperse into water.http://www.chemistryexplained.com/Ru-Sp/Soap.html#ixzz4MENkKh8q

So now we understand soaps are sodium or potassium fatty acids salts, produced from the hydrolysis (the breaking of a bond in a molecule using water) of fats in a chemical reaction called saponification (alkaline hydrolysis of the fatty acid esters) (Helmenstine, A. , 2015). But what does this mean?

Let's take a look at the role water plays in removing dirt (ever tried to clean your hands without it?) You might think water gets you wet, which it does. But not nearly as wet as you might

http://www.planet-science.com/categories/under-11s/chemistry-chaos/2011/06/soap---how-does-it-get-things-clean.aspx

think. This is because it has surface tension. Water molecules prefer their own kind and tend to stick together in drops. To make water wash better, the surface tension has to be reduced so it wets things more uniformly. This is what a surfactant does.

The surfactants in detergents improve water's ability to spread over surfaces and wet things evenly, including seeping into dirty clothes fibers (to see this in action, try placing a drop of plain water on a dish towel and a drop of soapy water on a dish towel – which one soaked in first?). Surfactants have another function too. One end of their molecule is attracted to water, while the other end is attracted to dirt and grease. So the surfactant molecules help water bind to grease, break it up, and wash it away.

Likewise, each soap molecule has a long hydrocarbon chain, often referred to as the 'tail', with a carboxylate 'head'. In water, the sodium or potassium ions float free, leaving a negatively-charged head. Soap, because of its chemical make-up, is a highly effective cleanser because of its ability to act as an emulsifying agent, meaning soap has the ability to disperse one liquid into another immiscible liquid. So oil, which attracts dirt, will not naturally mix with water, but soap can suspend oil and dirt so that it can be removed in rinse water.

Dr. Ann Marie Helmenstine explains it this way, "The organic part of a natural soap is a negatively-charged, polar molecule. Its hydrophilic (water-loving) carboxylate group (-CO2) interacts with water molecules via ion-dipole interactions and hydrogen bonding. The hydrophobic (water-fearing) part of a soap molecule, its long, nonpolar hydrocarbon chain, does not interact with water molecules.

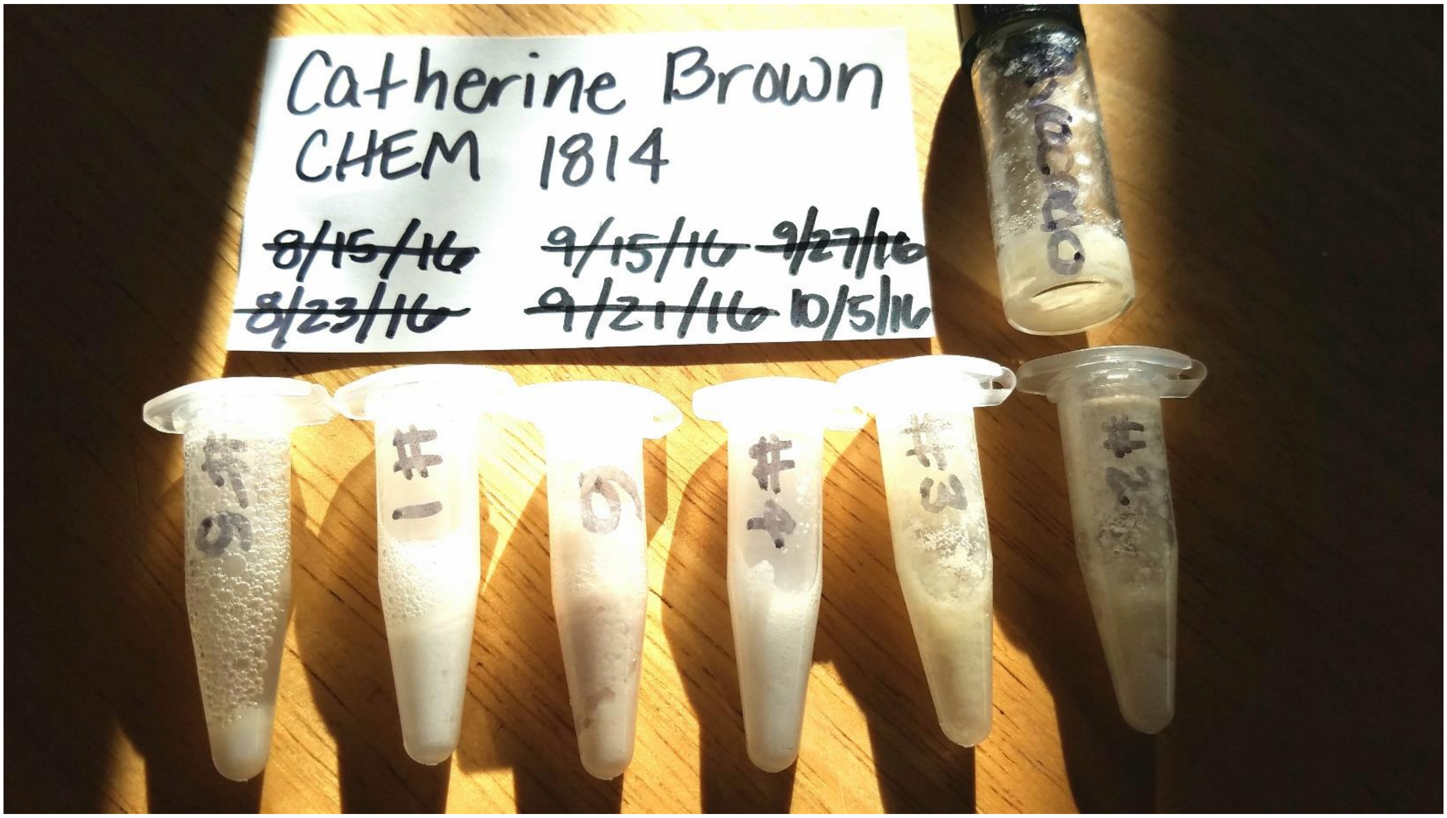
The hydrocarbon chains are attracted to each other by dispersion forces and cluster together, forming structures called micelles. In these micelles, the carboxylate groups form a negatively-charged spherical surface, with the hydrocarbon chains inside the sphere. Because they are negatively charged, soap micelles repel each other and remain dispersed in water.

Grease and oil are nonpolar and insoluble in water. When soap and soiling oils are mixed, the nonpolar hydrocarbon portion of the micelles break up the nonpolar oil molecules. A different type of micelle then forms, with nonpolar soiling molecules in the center. Thus, grease and oil and the 'dirt' attached to them are caught inside the micelle and can be rinsed away" (Helmenstine, A., 2015).

As excellent as soaps are, they do have some disadvantages. For example, they do not work well in hard water containing calcium and magnesium. This is because the calcium and magnesium salts of soap are insoluble, as such they tend to bind to the calcium and magnesium ions, eventually precipitating and falling out of solution. Which might look something like this: $2\ CH_3(CH_2)_{16}CO_2^-Na^+ + Mg^{2+} \rightarrow [CH_3(CH_2)_{16}CO_2^-]_2Mg^{2+} + 2\ Na^+$. This is also why soap will not lather as well in hard water.

When this happens, soaps actually dirty the surfaces they were intended to clean only in a different way. We can see this as the whitish scummy build-up on bathtub surfaces (and sometimes on our skin). For this reason, soaps have mostly been largely replaced in modern/commercial cleaning solutions by synthetic detergents that have a sulfonate ($R\text{-}SO_3^-$) group instead of the carboxylate head ($R\text{-}COO^-$). These sulfonate detergents tend not to precipitate with calcium or magnesium ions and are generally more soluble in water.

2) **Discuss your results here. Discuss the ranking of the soap sudsing ability in distilled water and compare to the level of unsaturation observed in Unit 7. Explain why this does or does not make sense. Use the properties of the molecules you investigated in Lab 7 to weave into this discussion. Include a picture of your sudsy vials with bottled water. (20pts)**



Here's my line-up after the addition of bottled water. I decided to test the liquid commercial soap sample separately from this initial test. I tested seven oils: 1-sunflower, 2-olive, 3-grapeseed, 4-coconut, 5-castor, 6-macadamia nut, and 7-avocado (glass vial).

From the sudsing ranking noted below the photo above, it would appear the greater the level of unsaturation and especially those in the trans (as opposed to cis) formation, the better the sudsying ability. This would make sense because saponification would occur more readily. Once magnesium sulfate was added, the heavily saturated trans-fat coconut oil, became much sudsier, while the others were less so. This is a great website to explore, and is also where the saponification chart on the next page came from:

http://www.soap-making-resource.com/saponification-table.html

oil or fat (acid)	*SAP*	*Hard/Soft*	*cleansing*	*fluffy lather*	*stable lather*	*skin care*
avocado oil	133.7	soft	fair	yes	no	amazing!
coconut oil	191.1	hard	great	yes	no	fair
castor oil	128.6	soft	fair	yes	yes	great
olive oil	135.3	soft	good	no	no	great
palm oil	142	hard	great	no	yes	fair
peanut oil	137	soft	fair	no	yes	great
soybean oil	135.9	soft	good	no	yes	fair
sweet almond oil	137.3	soft	good	no	yes	amazing!
jojoba oil	69.5	soft	fair	no	yes	great
kukui nut oil	135.5	soft	good	no	yes	great
lard	138.7	hard	good	no	yes	fair
tallow	140.5	hard	good	no	yes	fair

1. *Hard/Soft* - This column will tell you if a specific acid will produce a hard or soft bar of soap. If a bar of soap is too soft it will dissolve prematurely and become a mushy mess; so make sure that your soap has a certain level of hardness by combining hard oils with soft oils.
2. *Cleansing* - This column will tell you how well an acid cleans. Keep in mind that all soaps clean relatively well, but some oils produce a soap that is more harsh then others. For the best results, try to combine oils that are mild when saponified with oils that are more harsh when saponified for a balance between a cleansing and conditioning bar.
3. *Fluffy Lather* - This column will tell you whether or not a specific acid will produce a fluffy lather. A fluffy lather is thick and bubbly but washes away easily.
4. *Stable Lather* - This column will tell you whether or not an acid will produce a stable lather. A stable lather has very little substance but is harder to wash away. In general, you want a combination of ingredients that produce both fluffiness and stability to your soap's lather. Again, your goal here is balance.
5. *Skin care* - This column will tell you how beneficial a soap produced by a specific acid is to the skin. It depends mostly on the presence of nourishing vitamins, its mildness and moisturizing abilities.

The line-up including the liquid soap sample (the sudsiest one!).

The new line-up after the addition of five drops of magnesium sulfate solution to simulate hard water. Note the new position of coconut oil to number 1 in sudsiness. It is the most highly saturated fat out of all of these.

3) **Find the chemical make-up of some sort of organic "dirt". Identify the functional groups of that dirt and explain how the soap you have created would or would not remove that dirt from a chosen substrate. (You choose – countertop? Cloth? Skin? Whatever) You'll have to dig into the polarity of the surface, the polarity and properties of the "dirt" and the ability of the soap … discuss the fatty acid origins of the soap … to remove the dirt from the surface. Expand on your knowledge gained throughout the course and previous chemistry courses. (10pts)**

For this, I will use a real-time scenario of potassium derived from wood potash as my form of organic **"dirt"** and my hands as the **"surface"** in need of cleaning (we have had a continuous brush-burn going for the past several days as we are clearing more area for agricultural space and spreading the ashes from the burn pile over the newly cleared areas to improve soil fertility, which necessitates the frequent need to wash my hands). The functional groups of potassium are methyl, dioxothiazole, ketone and an esther group. The surface of the skin on my hands will mostly be lipids with a few proteins (possible some bacteria as well, but I'll focus on the lipid/protein combination). Functional groups here would likely be the carboxylic acid with long hydrocarbon chains and amino groups. The carboxyl group will be polar and hydrophilic (water loving) whereas the potassium in the potash will need to be attached to another molecule to gain polarity. Carbon is a good bet, so let's say I'm dealing with potassium carbonate, K_2CO_3, which actually IS potash, and we'll say no other substances are involved. My soap, with its hydrocarbon chains, will be attracted to each other by dispersion forces and cluster together, again, forming the micelles mentioned above. Within these micelles, the carboxylate groups will form a negatively-charged spherical surface, with the hydrocarbon chains inside the sphere. Because they are negatively charged, soap micelles repel each other and remain dispersed in water. This will allow the water to create the necessary surface tension to evenly wet my skin, the hydrophobic and hydrophilic ends of the soap molecules will emulsify and suspend the lipid, potassium carbonate and amino acid molecules until I rinse them away. I am left with clean hands!

References

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