EXPERIMENT
SOAP SYNTHESIS

PURPOSE

To synthesize soap by reaction between an alkaline and a fatty acid.

THEORY

A soap is a salt of a fatty acid. Fatty acids are carboxylic acids with a long unbranched hydrocarbon (aliphatic) chains.

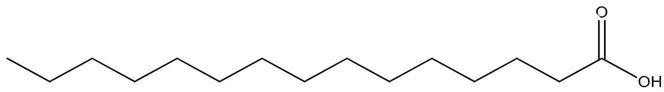
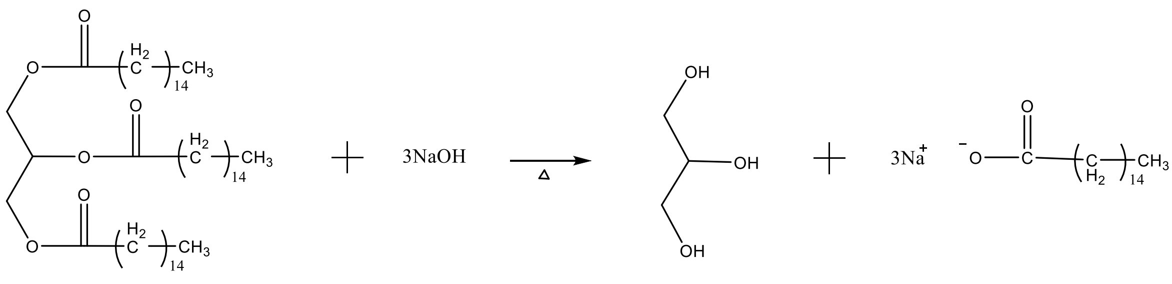


Figure 1. A typical fatty acid

Soap can be prepared from certain esters by a process known as saponification. The reaction in making soap (saponification) is a base (usually NaOH or KOH) hydrolysis of triglycerides to make three salts (soap) and glycerol. The molecules crystallize differently depending on the base used. NaOH produces a harder bar while KOH is used more frequently for liquid soaps.



Scheme 1. General synthesis of soap

Sodium palmitate $CH_3(CH_2)_{14}COO^-Na^+$ is the salt of palmitic acid $CH_3(CH_2)_{14}COOH$, a fatty acid with a 16 carbon chain. Fatty acids are straight-chain monocarboxylic acids with a general formula $CH_3(CH_2)_nCOOH$ where n usually varies between 8 and 18. In nature, most fatty acids are present as triglycerides. Natural fats and oils usually include different fatty acids. For example, the saponification reaction of a component of olive oil would produce the salts of palmitic acid and stearic acid.

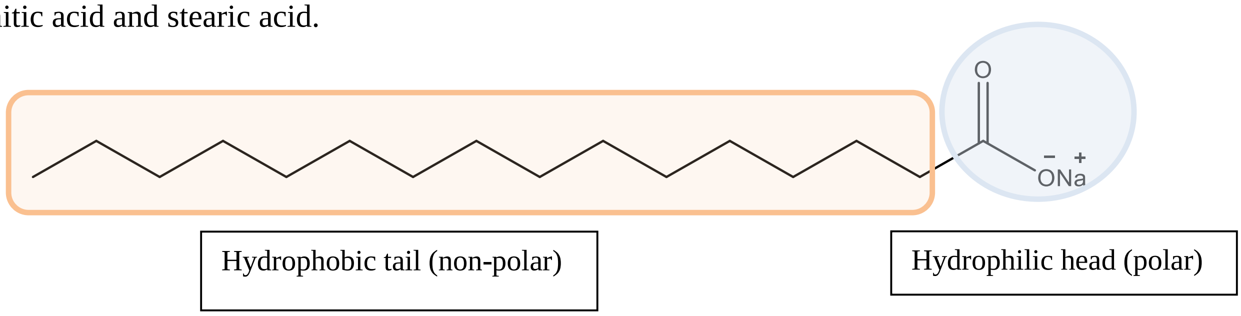


Figure 2. Hydrophobic and hydrophilic part of soap

Notice the particular structure of the soap molecule: it has a long nonpolar tail (the hydrocarbon chain of the fatty acid) and a highly polar end (the ionic group COO^-) (**Figure 2**). The non-polar or hydrophobic tail can dissolve the grease and dirt whereas the polar or hydrophylic end is attracted to water molecules.

Adjacent negatively charged heads repel each other forcing the soap molecules into a spherical shape, a micelle. The soap molecules orient themselves with the nonpolar tails towards the center of the micelle and the COO^- groups facing the water. In the presence of oil (or dirt), the nonpolar tails interact with the oil that ends up at the center of the micelle. This is how soap cleans: the dirt and the grease stay at the center of the micelles which repel each other due to the negatively charged outer surface. Rinsing with water washes the micelles (and the dirt) away. Soap is acting as an emulsifying agent. Recall that an emulsion is the dispersion of a liquid in a second immiscible liquid.

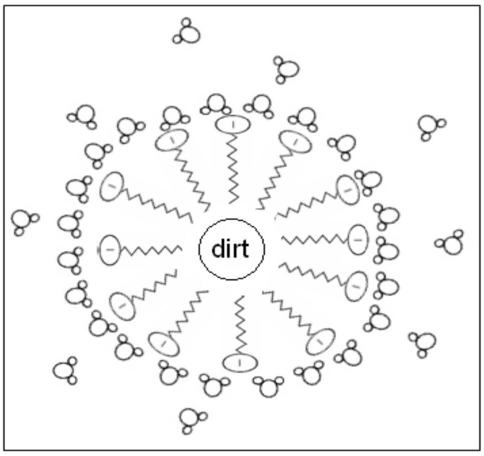
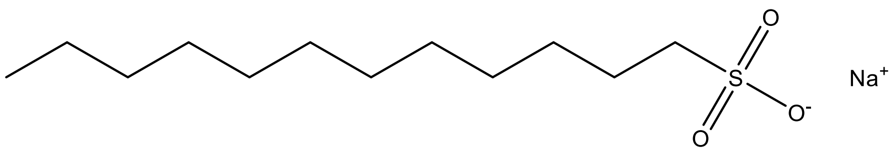


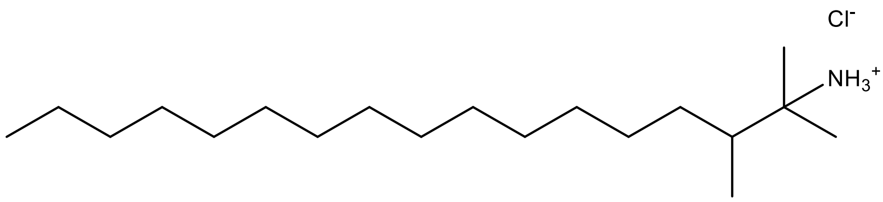
Figure 3. Diagram of a soap micelle

The nonpolar tails of the soap molecules attract dirt and the polar heads attract water molecules. The cleaning properties of soap are intimately related to the fact that there is a highly polar head and a nonpolar tail in each soap molecule. If the ionic charge of the polar head were to disappear, the soap molecules would not be able to interact with water, micelles would not form, and soap would not clean. This is what happens in acidic or hard water. In acidic water, the COO^- group gets protonated and the fatty acid precipitates, being now water insoluble.

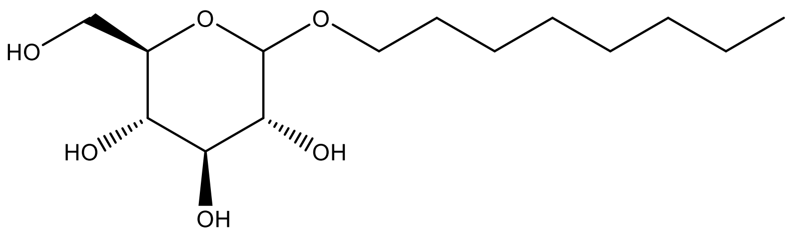
Today there are a variety of detergents, which in general contain a surfactant, a builder, and other additives (such as bleaching agents and enzymes). The surfactants are the chemical equivalent of the soap and they are responsible for the cleaning properties of the detergent. Some of them are anionic, some of them are cationic and some of them are non-ionic. For example:



sodium dodecyl sulfonate



trimethylhexadecyl ammonium chloride



octyl glucoside

Notes:

1. NaOH is corrosive to skin and clothing. Avoid contact. Wash hands before leaving the laboratory. Ethanol is flammable so be sure that there are no open flames in the laboratory.
2. **Important:** as it is heating, some of the solution will evaporate. You must make sure that the volume does not decrease too much, so you will need to add moreliquid as the reaction progresses.
3. **Caution:** the mixture of oil and ethanol will be very hot, and may splatter or catch fire. Have a watch glass nearby to smother any flames. Wear goggles at all times, because NaOH can cause permanent eye damage!

PROCEDURE

- Add 5 mL of olive oil and 10 mL ethanol in 100 mL beaker and this mixture is stirred.
- Slowly add 20 mL of 5 M NaOH to the solution. Stir and keep hot for 30 minutes.
- To warm solution, add 25 mL of saturated NaCl solution.
- Remove the beaker and allow the solution to cool to room temperature
- The soap will precipitate out of solution.
- Collect the soap by vacuum filtration.

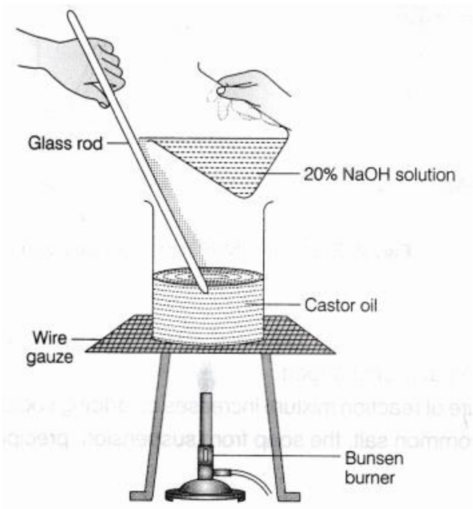


Fig. 1 Mixture of castor oil and NaOH solution

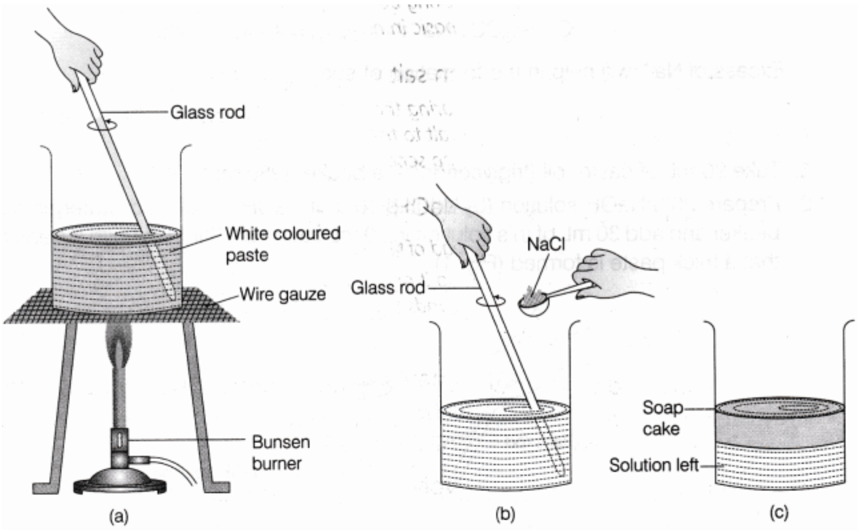


Fig. 2 Steps involved in the preparation of soap