Soaps and detergents: The chemistry which keeps us clean

Soaps *and* ***detergents*** are very essential for our personal hygiene. We use them in order to wash our hands, our faces and our bodies but also to wash our dishes, our clothes and all the surfaces we come in contact with. Alternatively, children (and also some adults) use soaps and detergents to generate beautiful ***bubbles****,* just for fun! But what is the difference between a detergent and a soap and where do they attribute their exceptional cleaning properties? Moreover, what is really a bubble and how does it form? All the answers to these questions can be given by **science** and more specifically by **chemistry**. Before we answer these questions let's see first when was soap introduced to humanity for the first time.

A hand dish-washing detergent. Bubbles are formed because of the detergent's presence inside water

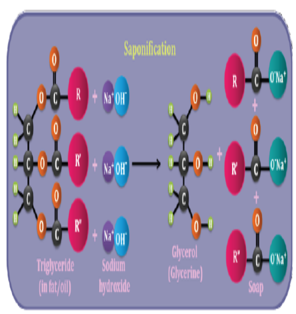
Historical facts

The *prehistoric people* did not have soaps. They were just removing the mud from their hands by washing them in the river. The first evidences of soap were documented in *1500 B.C* in ancient Egypt. Egyptians were using a mixture of animal or vegetable oils and some salts for treating skin diseases and for washing. The *ancient Greeks* were also using a mixture of oil and ashes for their baths, unlike their clothes which were only washed with water. At around *300B.C* a *Roman legend* says that in the Mount Sapo in Italy where animals were getting sacrificed, women discovered that the animals fat in the soil in combination with wood ashes rendered their clothes cleaner with much less effort. Thereafter, the soap took its name from the location, Mount Sapo. Soap was especially popular during the *Roman civilization* advancement and it was used in Roman baths. After *Roman empire fell*, bathing habits in Europe were forgotten; **plagues** and **black Death** epidemics gave rise due to **serious lack of personal cleanliness and unsanitary living conditions**. In the *17th century,* soap appeared again and different varieties of animal/vegetable oils and ash were available for shaving, shampooing, bathing and laundering. Soap production was significantly up-scaled in the *18th and 19th century* with the research advancements of French and Belgian scientists. In the *20th century* synthetic detergents were first fabricated, a need that arose from World War I and the subsequent lack of natural fats. This new class of cleaning agents was comprised by other compounds than regular soaps and had better cleaning properties. The research in detergent technology is still going on until today and many different kinds of soaps and detergents can be found in the supermarkets such as liquid hand soaps, beauty soaps, dishwasher powders, liquids or gels, powdery and liquid laundry, hand dish washing, fabric softeners, detergents with oxygen and chlorine bleach, prewash soil and stain removers etc.

How soaps are formed?

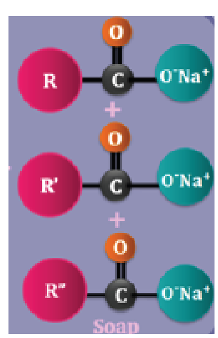
From the previous section, it is evident that in old times the basic ingredients for soaps were **fats** from animals or vegetables and **ash**.

Fat is a large category of chemical compounds whose main building units are called **triglycerides**.



A triglyceride is the building unit of fats. It consists of hydrogen (H), carbon (C) and oxygen (O) atoms. R, R', RR'' depict different lengths of carbon-hydrogen atoms

In order to obtain soap, triglycerides react with a compound which contains sodium (Na^+). Eventually, triglycerides break into smaller compounds which give the soapy characteristics. In old years, ashes were the source of sodium and that was the reason why fats and ashes appeared to be a good cleaning mixture. Potassium (K^+) is also frequently used in place of sodium.

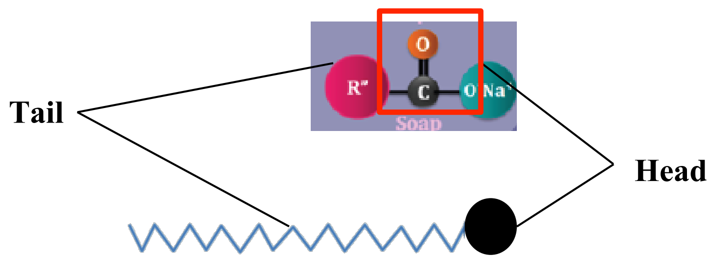


Three different soap compounds deriving from the breaking of a triglyceride from a sodium (Na^+) source

Soap's cleaning properties

In order to understand the cleaning properties of the soap, we need to know first that water cannot be mixed with oil and grease. If we try to do so, one repels the other and eventually we get two separate phases. That is the reason why water itself cannot remove the stains, since most of them have oily and greasy nature. Moreover, water has the tendency to adopt a spherical geometry on the different surfaces (for example on our bodies or our clothes) and it doesn't fully spread in order to wet the surfaces. Soap agents reduce this tendency and help water to entirely spread. It is said that compounds like soap *make water ''wetter''*.

Soap's compound has two parts. One part is called the **''head''** and it is fond of being in contact with water while the other part is called the **''tail''** which unlike the head hates water and prefers to be around oily and greasy substances.



The soap substance is generally illustrated with a head and a tail. The head is friendly to water but not to grease and the tail is friendly to grease but not to water

In water, soap compounds come together and form a spherical entity called **micelle**. All the oil friendly tails are gathered in the center, to protect themselves from water and all the head groups are located on the outside in order to be closer to water. In the presence of a stain, all the grease reacts and resides in the center of the micelle. Subsequently, the stain is ''captured'' and taken away from the surfaces and clothes as the micelle flows in the water.

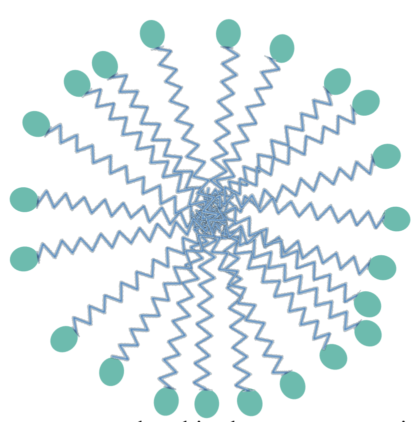
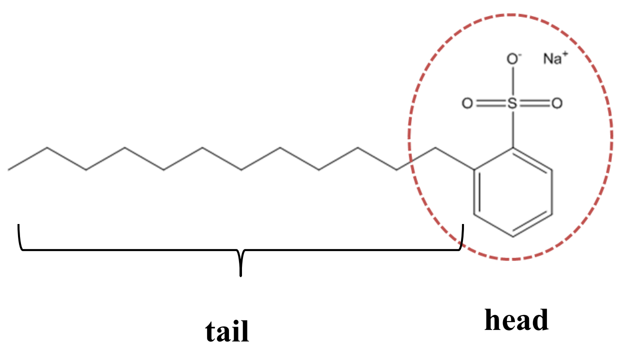


Illustration of a micelle. All the tail groups are accumulated in the center to avoid water, while the head groups are located in the outside close to water.

Soaps against detergents

Soaps have an important disadvantage. Their cleaning performance is influenced by the *composition of water*. Water possesses sometimes significant amounts of other components such as calcium (Ca^{2+}) and magnesium (Mg^{2+}). In these cases, water is called **''hard water''** and depending on the portions of these components, water **hardness** can be low or high. These components, substitute sodium or potassium in the soap's head groups and they force it to precipitate as a stain or as a soap film which is known as a **scum**. The scum sometimes is visible in our clothes, in our bathtubs or sinks and is very difficult to be removed.

In the 20th century, a new category of cleaning agents was developed called **detergents**. Detergents follow the same micelle principle as soaps, with the difference that instead of naturally occurring triglycerides, they contain compounds with a versatile number of head groups and tails**.** In detergents, the compounds tails are stemming from petrochemicals (derivatives of petroleum) and oleochemicals (fats and oils). The head groups can vary depending on the detergent, unlike soaps in which the head group is always the same. In detergents, the nature of the head groups reduces the possibilities of sodium or any kind of substitution by water calcium and magnesium and therefore their performance is not dependent on the hardness of water. Moreover, the bigger variety of detergent compounds, generated cleaning agents with very strong cleaning power, capable of eliminating persisting stains which could have been impossible to remove with regular soaps.



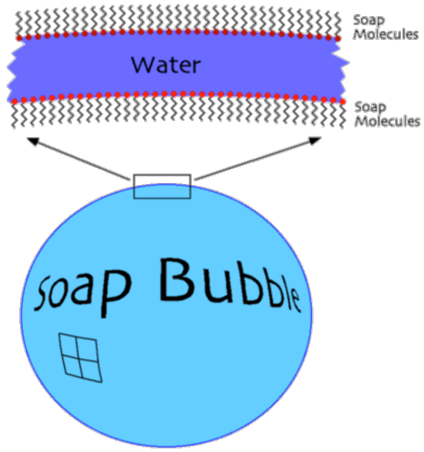
One of detergent's active compound. The head group is different than the head group of a soap

However, detergents are not the ''**good**'' cleaning agents and the soaps the ''**bad**'' ones. Despite the limited performance of soaps, they contain only natural components with additional antibacterial properties and therefore they are environmentally friendly. On the contrary, detergents contain a number of preservatives, industrial substances and synthetic antibacterial agents along with synthetic fragrances, in order to remove the unpleasant odor of the different chemicals. All these, could cause a number of unpleasant reactions and allergies when using detergents.

Bubbles

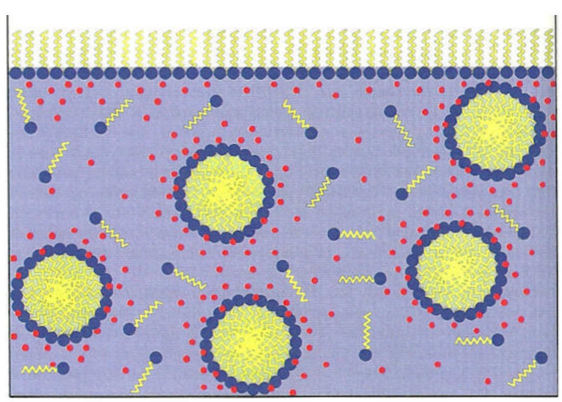
We all noticed that each time we use soaps and detergents many bubbles pop and splash in a few instants! But how do these bubbles form? Why do they live that shortly and why do they form in the presence of a soap or a detergent only?

Bubbles can fly freely around because they consist mostly of air. The air is captured in a spherical film of *soapy water*. The ''soapy water'' on the surface of the bubble is comprised by three layers: a thin layer of soap/detergent surrounded by a layer of water and another soap layer on the outside of the surface. The water-friendly head groups of the soap compounds are oriented towards the water layer and the water-hating tail groups are oriented towards the air, in order to avoid any contact with water.



An illustration of a bubble surface

The bubbles in a soap solution are formed because of the tendency of soap compounds to locate primarily on the surface of the water and therefore they interact with the air.



Some soap or detergent compounds are located on the surface of the water and they come into contact with air

However, it's not always evident that water and soap will create bubbles. For instance the hardness of water is affecting the formation of bubbles. Because of that, a mixture of soap and *hard* tap water is not as a strong bubble making solution as a detergent solution. Detergents are not severely affected by the hardness of water and therefore they form more bubbles than a soap.

Unfortunately, bubbles have a very short lifetime. As soon as they form, they burst almost immediately. Normally the bubbles should live as long as it takes for the captured air to go away. However, gravity and evaporation is dragging water layer away too, and eventually the layered surface becomes too thin to sustain bubbles weight and the bubble splashes.

So finally, if we want to make an efficient bubble solution three things need to be taken into consideration: 1) we need to select a detergent over a soap. 2) We need to use soft water without any interfering elements or demineralized water (like the one we use to iron) and 3) in order to increase the duration of our bubbles we could add a thickener, for example a little bit of sugar, in order to increase the thickness and the weight of our soapy surface.