Chem Factsheet

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Detergents

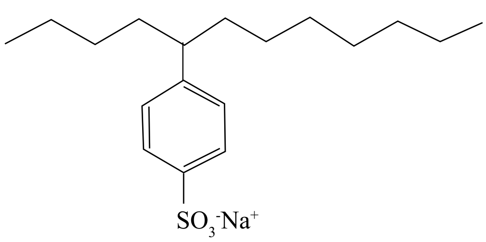
Soaps and detergents are common materials associated with washing and cleaning. There is a key distinction between the two. Soaps are made from natural fats and oils, while detergents are made from synthetic chemicals, usually petro-chemicals. Many household cleaning agents, from shampoo to washing powder, should be classed as detergents.

The actions of soaps and detergents are similar in that they both reduce the surface tension of water. These materials are called surfactants. They decrease the strength of the intermolecular forces of attraction between water molecules. This means water molecules on the surface are not so strongly pulled into the main body of the liquid, which allows the formation of water bubbles and foam.

Action of detergents

Many detergents are surfactants from a family of compounds called alkylbenzenesulphates. The most commonly used is sodium dodecylbenzenesulphonate, $C_{12}H_{25}C_6H_4SO_3Na$ (see Fig. 1). This molecule consists of a straight-chained alkyl group attached to the 4-position of a benzenesulphate group. The straight-chained structures are preferred over branched structures because the latter biodegrade too slowly.

Fig. 1



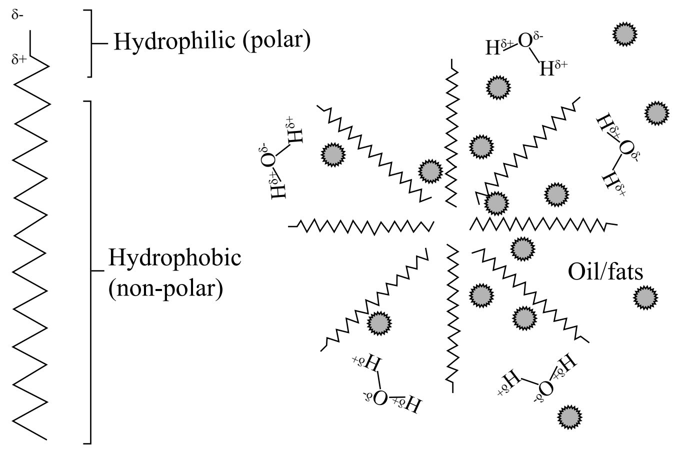
4-(5-dodecyl) benzenesulfonate

Detergents are good cleaning agents due to their amphipathic [see key point] properties. The addition of detergents allows non-polar oils and fats to mix with polar water molecules.

> Amphipathic substances are partly hydrophilic (polar) and partly hydrophobic (non-polar). This property allows amphipathic substances to interact with <u>both</u> components in a mixture of hydrophobic compounds (e.g.oil or grease) and water (see Fig. 2).

During major oil spills, powerful detergents are used to break up the oil pooled on the surface of a body of water. Tiny droplets of oil interact with the oil-soluble component (hydrophobic end) of the detergent molecule, while the water-soluble component (hydrophilic end) mixes with the water (see Fig 2). The oil does not dissolve, instead it forms an emulsion suspended in the main body of water. Eventually the oil is dispersed over a wider area. Because detergents may be made from toxic chemicals care is taken deploying detergents as these too may cause environmental damage.

Fig. 2



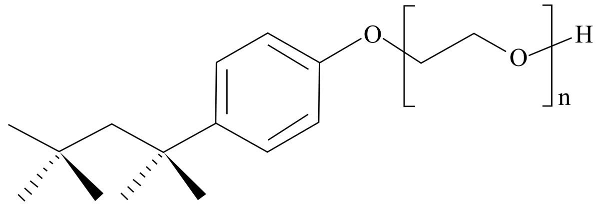
Types of detergents

Alkylbenzenesulponates are classed as anionic detergents because of the negatively charged sulphonate group. The alkylbenzene section is hydrophobic (or lipophilic), which readily interacts with non-polar molecules, e.g. fats and oils. The sulphonate ion, $-SO_3^-$, is hydrophilic, which interacts with polar water molecules.

Cationic detergents work similarly to anionic detergents. Instead of the anionic sulphonate group acting as the hydrophilic component, cationic detergents have a positively charged ammonium ion, $-NH_3^+$.

Non-ionic detergents have uncharged, hydrophilic groups, e.g. sugars or polyethylene oxide, connected to an aromatic hydrocarbon hydrophobic group. An example of a non-ionic detergent is *Triton X-100*, $C_{14}H_{22}O(C_2H_4O)_{9(or10)}$, see Fig. 3.

Fig. 3



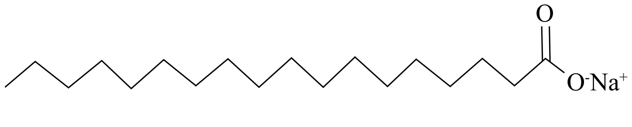
Triton X-100, $C_{14}H_{22}O(C_2H_4O)_{9(or10)}$

Zwitterionic detergents possess a net zero charge arising from the presence of equal numbers of +1 and −1 charged chemical groups. Examples include CHAPS (abbreviated from 3-[(3-cholamidopropyl) dimethylammonio]-1-propanesulfonate), which is used in laboratories as a non-denaturing solvent in the purification of proteins.

Saponification

Soaps are salts of fatty acids (long chain carboxylic acids). A typical soap is sodium stearate ($C_{17}H_{35}COONa$), which is the sodium salt of stearic acid ($C_{17}H_{35}COOH$). See Fig 4.

Fig. 4

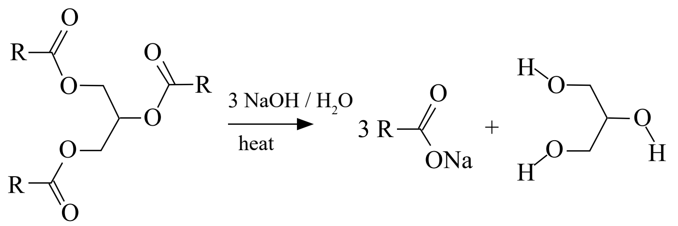


Sodium stearate

Other soaps are formed from other naturally occurring oils. For example, sodium palmitate, $CH_3(CH_2)_{14}COONa$, is made from palmitic acid (hexadecanoic acid, $CH_3(CH_2)_{14}COOH$), which is obtained from palm oil. The process for manufacturing soaps from fats or oils is called saponification.

To make soap, vegetable oils and animal fats undergo saponification. These materials are called triglycerides –triesters of one molecule of glycerol (propane-1,2,3-triol) with three fatty acid molecules. These are derived from diverse fats and oils. Soaps are formed by treating triglycerides with a strong base, for example, sodium hydroxide, NaOH. The reaction requires the cleaving of the ester bonds to form the fatty acid salt (the soap) and glycerol (propan-1,2,3-triol, $C_3H_8O_3$) as shown in Fig. 5.

Fig. 5

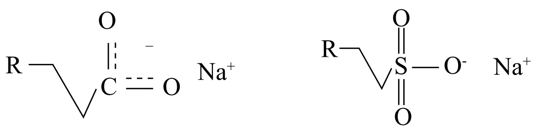


Saponification is the process used to produce soap. It involves the alkaline hydrolysis of an ester to form the sodium or potassium salt of a carboxylate.

Action of soaps and detergents

Both soaps and detergents are amphipathic. Soaps characteristically are naturally made by the formation of salts from fatty acids. When soaps come into contact with hard water, calcium ions and magnesium ions will react with the soap producing insoluble calcium and magnesium salts. This is described as soap scum. This greatly reduces the efficiency of the soap. In detergents, any resulting calcium or magnesium salts formed in the cleaning process are soluble. Therefore, using detergents will not produce a similar scum, making detergents more efficient. Detergents are more soluble in hard water due to the addition of a sulphonate group, which is less likely to bind with any magnesium or calcium ions found in hard water (see Fig. 6). Detergents may be deactivated by the calcium ions in hard water, which is why softeners are added.

Fig. 6



Soap Detergent

Early detergents included phosphates as water softening agents. Unfortunately, the release of phosphates can lead to major environmental issues, primarily with eutrophication. Eutrophication promotes an increase in phytoplankton in natural waters, which may cause hypoxia, (the depletion of oxygen), affecting aquatic animals.

Phosphates have now been largely replaced in detergents by zeolites, which are naturally occurring microporous, aluminosilicate minerals.

Applications

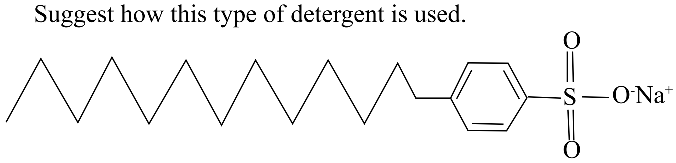
Soaps and detergents are used in the cleaning of grease from different materials and in the dispersal of oils. Lithium soaps are similarly derived from fatty acids. An example, lithium 12-hydroxystearate, $C_{18}H_{35}O_3Li$, is an important constituent of lubricating greases.

A common application of detergents is in laundry for washing clothes. Laundry detergents are complex materials designed to meet the high diversity and expectations required by consumers. These include; surfactants (typically an anionic surfactant), bleach, agents to soften water, fragrancies, with some formulas including enzymes and brighteners. The components of manufactured detergents will reflect its targeted use, for example, types of fabrics, local water quality and temperature of the cleaning water.

Fire extinguishers developed for combating cooking oil fires do so through saponification, converting the burning oil into a non-combustible soap. The process is endothermic, thus decreasing the temperature of the surroundings, which helps fire-fighters inhibit the fire.

Questions

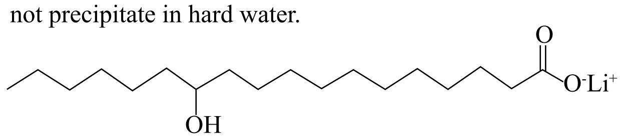
1. How does a detergent differ from a soap? Suggest one advantage detergents have over soaps.
2. Draw the skeletal formula for lithium 12-hydroxystearate, $C_{18}H_{35}O_3Li$, a key component in lubricating greases.
3. Identify the hydrophilic section and hydrophobic sections of a detergent molecule and describe their relative interactions with water and oils.
4. What type of detergent is this (sodium 4-dodecylbenzenesulphonate)? Suggest how this type of detergent is used.



5. Sodium stearate, $CH_3(CH_2)_{16}COONa$, is a soap. If it is added to hard water a precipitate (a soap scum) forms. Suggest a formula for this precipitate.
6. Phosphates have largely been replaced in detergents by zeolites, due to their impact on the environment. Describe how the use of phosphates in detergents have affected aquatic life.

Answers

1. Soaps are produced from natural products and detergents are synthetic. A major advantage of using detergents is that they do not precipitate in hard water.
2.



3. Hydrophilic section (associated charges) interact strongly with polar water molecules. Hydrophobic section (hydrocarbon tails) interacts strongly with non-polar oil molecules.
4. An anionic surfactant/detergent. These attract dirt and are used in laundry detergents, dishwashing liquids, hand soap and toothpastes.
5. $(CH_3(CH_2)_{16}COO)_2Ca$. (or Mg in place of Ca).
6. Eutrophication. Phosphates contribute to an increase of nutrients in natural water bodies leading to an increase in plants/algae leading to hypoxia, the depletion of oxygen in the water. This may result in declines in aquatic animal populations.

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