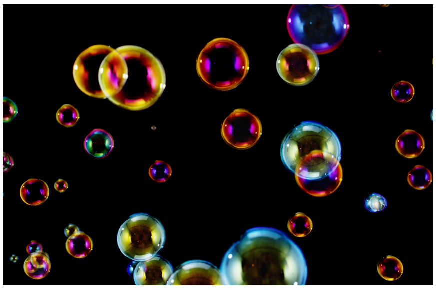
Bathroom Surfactants



What is it about soaps that make them good at cleaning? What about how they make bubbles? Did you know it is the same physical effect as being able to make mayonnaise without it splitting into oil and vinegar again when you stop stirring? The molecules that have these effects are called surfactants and are present in things you use at home and at school every day.

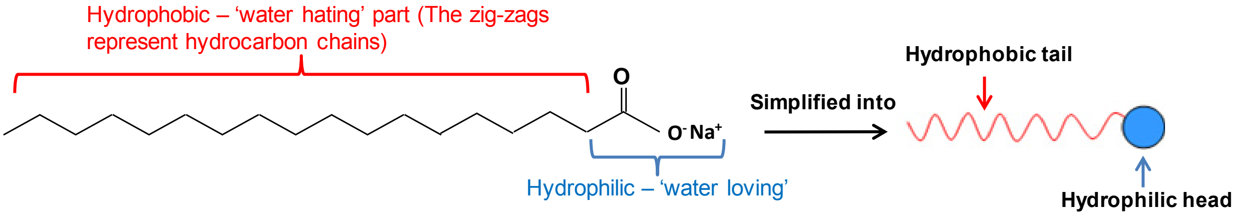
Surfactants in the bathroom

You will certainly have surfactants in your bathroom. Find some shampoo and conditioner. The shampoo forms bubbles, called lather, when you mix it with water. The ability to form bubbles is called foaming and is the result of having excess surfactant in your shampoo. The ability of the shampoo to remove dirt and grease from your hair is also the result of the surfactant. The conditioner is a little different – it doesn't form bubbles when you mix it with water but it does still contain surfactants. Conditioner is an emulsion, a mixture of two substances that don't mix easily. Surfactants help the conditioner stay as an emulsion rather than separate out into its component parts.

What is a surfactant?

Surfactants are usually organic compounds which have a particular structure which is different at one end of the molecule to the other. One end of the molecule is hydrophobic (or water hating), the other end is hydrophilic (water liking). Having both of these properties in one molecule means the molecule is 'amphiphilic'.

Surfactant molecules are usually long chains so that there is a separation between the hydrophilic end and the hydrophobic end of the molecule. An example of a common surfactant is sodium stearate (shown in the figure below), look out for it on detergents and soaps at home.



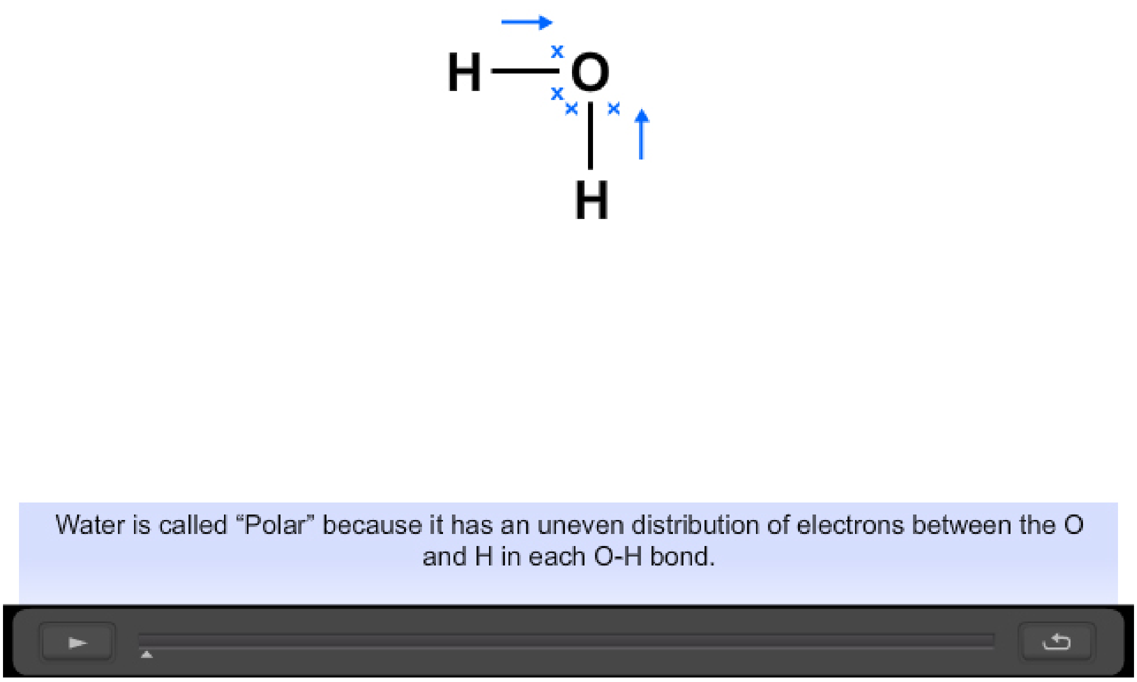
How do surfactants work?

Surfactants are molecules that have two parts to them, one that can interact with oils, and the other which can interact with water-like liquids (aqueous). This means that one molecule can effectively be dissolved in two different types of liquid at once.

When two immiscible liquids are added together they just sit one of top of the other in two layers. This is because the forces between the molecules in one liquid are different from the forces between the molecules in the other liquid. It is as if the liquids speak different languages and cannot communicate with each other so they don't mix.

A surfactant can act like a translator between the two liquids. One end of the molecule can interact with the water layer and the other end of the molecule can interact with the oil layer. This allows the surfactant to interact with both layers at once and means it is usually found at the interface or surface between the two liquids – hence the name surfactant being short for "surface active agent".

Animation: How Surfactants Work

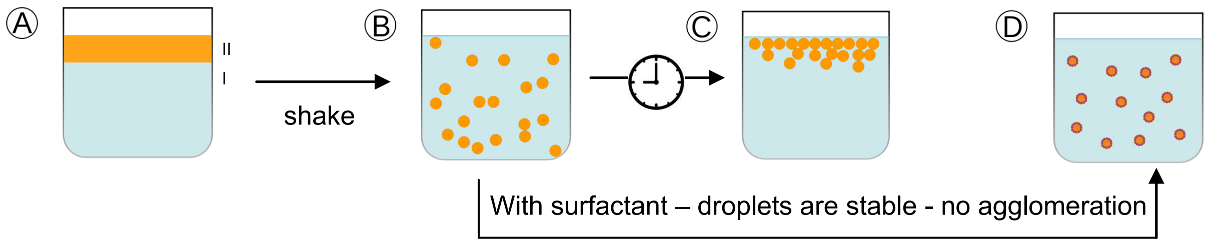


What can surfactants do?

There are a wide range of applications for surfactants. Which surfactant you use depends on the structure and the properties required:

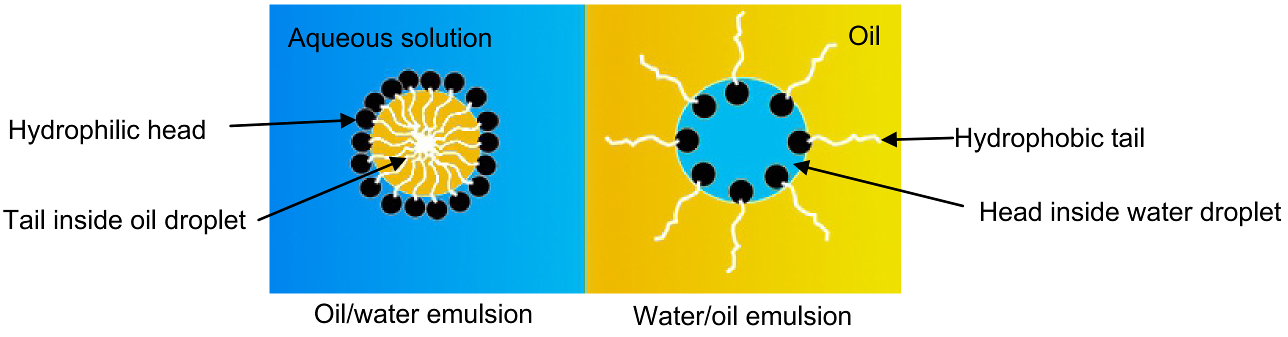
Croda emulsifying agents

An emulsifying agent is a surfactant that enables two immiscible liquids to mix together and remain mixed instead of separating out over time. The liquid formed is called an emulsion and is made up of microscopic droplets of one of the liquids dispersed in the other liquid. Without an emulsifying agent, these small droplets “agglomerate” again (stick together) and the liquids separate into two layers. The emulsifying agent stabilises the droplets and stops them from sticking together.



A. Two immiscible liquids, not yet emulsified
B. An emulsion of Phase II dispersed in Phase I
C. The unstable emulsion progressively separates
D. The surfactant positions itself on the interfaces between Phase II and Phase I, stabilising the emulsion

But how do surfactants stabilise the tiny droplets of liquid? In an emulsion of oil in water, the hydrophobic part of the molecule enters the oil droplet and the hydrophilic part stays in the water. This means that the droplet is stable and if it were to come across another droplet, they would not stick together because the surfactant is in the way.



Emulsions appear all over the bathroom and kitchen – in moisturising creams, hair conditioners and shower gels as well as in mayonnaise and mustard.

Making the emulsion in the first place is relatively straight forward but keeping it stable for months or years of shelf life can be difficult. Moisturising creams have to survive storage in warehouses for up to several months and then last between 12 and 24 months once the consumer has opened the packaging. It must also survive a wide range of temperatures, such as temperatures between 0°C and 60°C in a shipping container.

Croda use NatraGem E145 which is derived from natural sources and is a nonionic surfactant. It is a combination of polyglyceryl-4-laurate and polyglyceryl-4-succinate and produces oil in water emulsions.

Surfactants classified

Surfactants are classified according to their structures and what charges if any are present on the molecules. Different types do different jobs and there is often a mixture. Look at the back of your washing up liquid bottle, what does it contain?

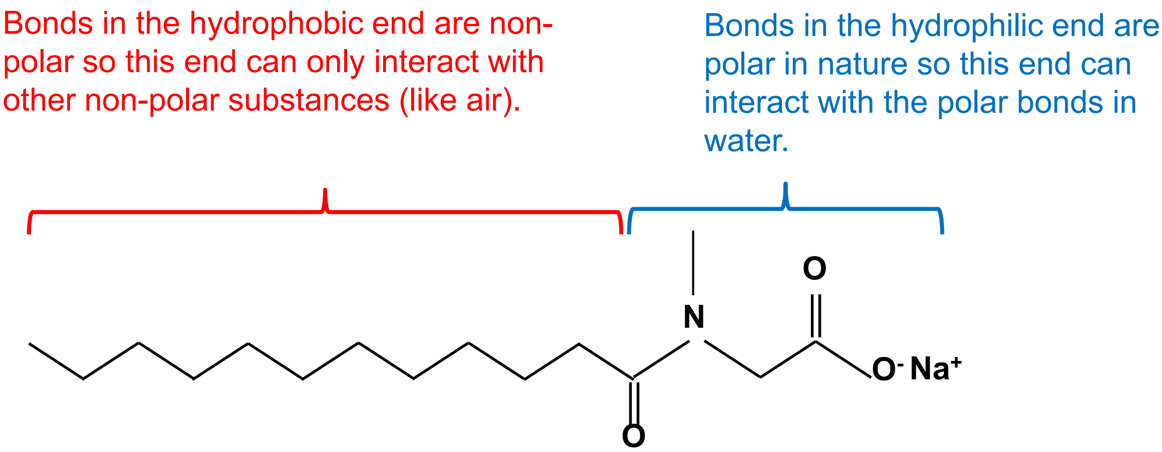
	Hydrophilic	Hydrophobic
Non-ionic		
Anionic (negative)	-	
Cationic (positive)	+	
Amphoteric (both)	- +	

Click this **Do Something** button to try out some surfactant chemistry

Croda Foaming Agents

If you were having a shower and you used a shower gel that cleaned your skin but did not appear to produce any bubbles it would feel quite strange. This is because we are used to foam being part of the cleaning process and probably feel that the cleaning has not been completed if there is little or no foaming. The Croda foaming agent Crodasinic LS30 is a surfactant used in personal care products to cleanse the skin and hair and produce luxurious foam.

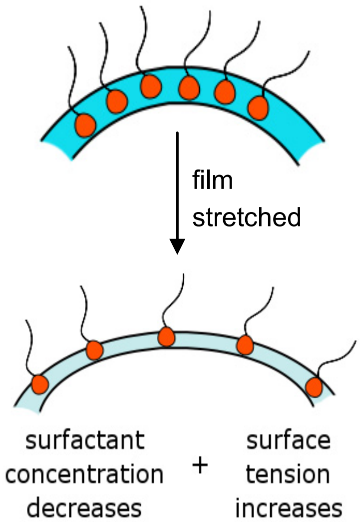
It is made from the surfactant sodium lauroyl sarcosinate (see figure below).



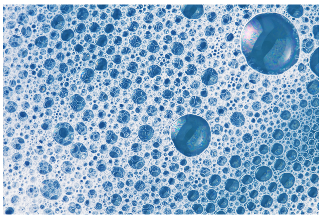
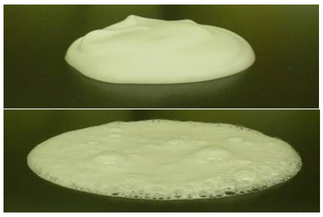
Bubbles are very thin films of liquid around some gas. The surfactant would have the hydrophilic section in the water-based liquid and the hydrophobic section sticking out into the air.

Surface tension is a measure of how strong the surface of a liquid is. Surfactants reduce surface tension, making a surface weaker. When a liquid film is stretched over some gas, the surfactant gets more spread out, making the spaces between the surfactant molecules stronger because they have higher surface tension. This is called the Marangoni Effect and it strengthens the parts of the bubble that are most stretched. This means a bubble can flex without breaking the film of liquid.

Foams are essentially just a pile of bubbles. If the bubbles are strong then the foam will last a long time and if the bubbles are weak then the foam is short lived. Foams usually break down because the liquid that makes the bubbles drains away, bursting the bubbles. Surfactants can be designed to produce bubbles with the right combination of properties so that the foam has the right feel and look for that product.

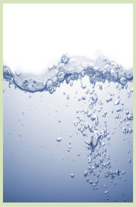


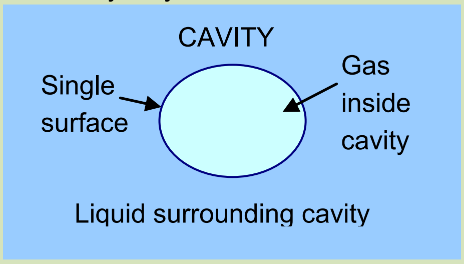
There are two main types of foam – wet and dry. The names indicate how much liquid the foams carry and this has a significant effect on their properties. The table shows the comparison between normal wet and dry foams with Crodasinic LS30 foam.

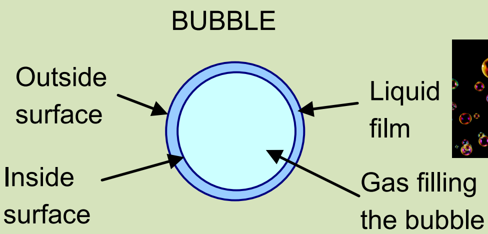
	Wet Foams	Dry Foams	Crodasinic LS30
Characteristic Feature	Small bubbles, low gas volume	Large bubbles with strong surfaces	Small bubbles with strong surfaces
Advantages	Feels soft to the touch and high foam volume	Low drainage – long lifetime	Feels soft, good volume, low drainage
Disadvantages	High level of drainage – short lifetime	Does not feel soft, low foam volume	None
Appearance (Crodasinic LS30 (top) is in comparison to a looser, drier competitor foam.)			

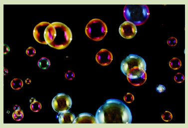
When is a bubble not a bubble?

Bubbles are films of liquid encasing a gas. They have two surfaces, an inside, in contact with the gas and an outside surface, in contact with the atmosphere. Bubbles in liquids are not actually bubbles but cavities because they only have one surface, the one on the inside of the cavity.







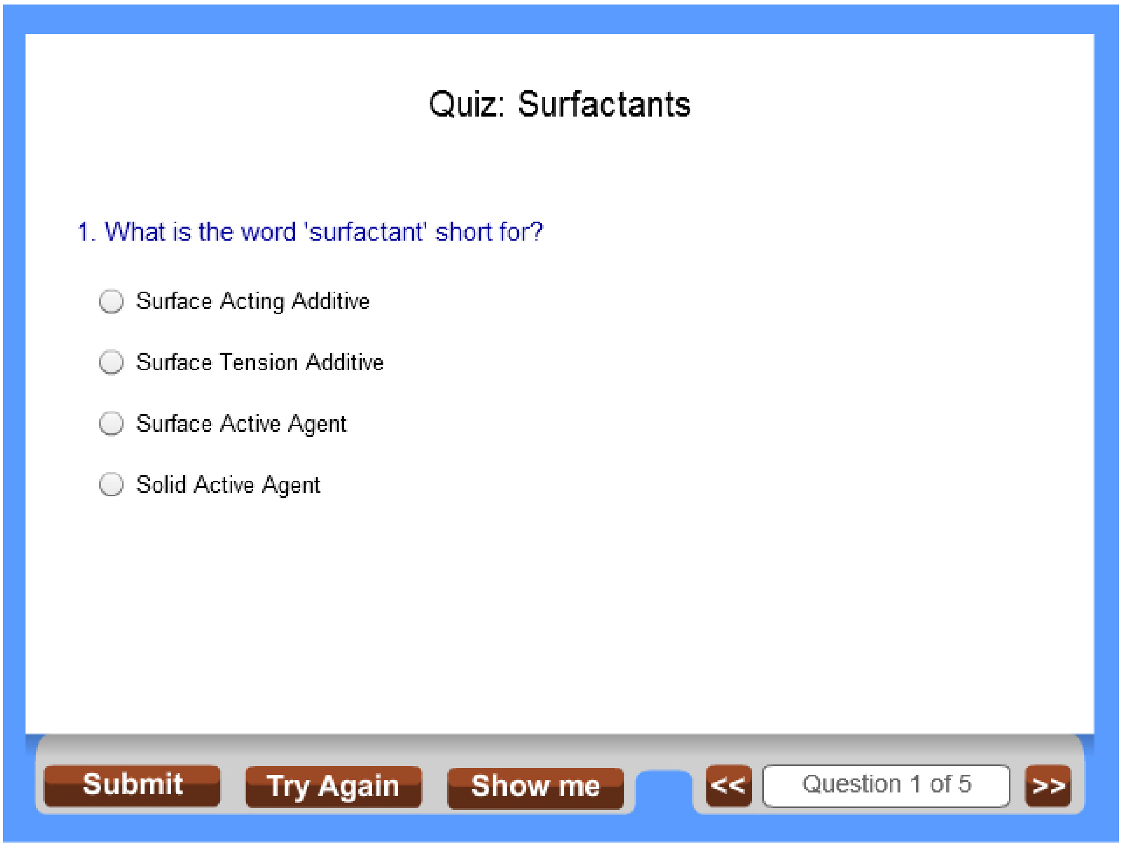


Conclusions

Surfactants are chemicals which can interact with two different immiscible liquids at the same time. It enables us to make bubbles where we want them, to clean dirt from objects and people and to stabilise some of the most commonly used materials today. Without them we would be dirty, un-moisturised and have no mayonnaise!

Test your knowledge

Take the short quiz below to test your understanding of surfactants.



Become a Surfactant Chemist – Practical Activities for School or Home

Disclaimer:

Before carrying out any experiment or demonstration (or preparation work for these), teachers and technicians are responsible for complying with any of their employer's risk assessment requirements making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.

Immiscible liquids and emulsions – ages 14-16

This is a short experiment to show the effect of differing surfactant concentration.

Health and safety note:

Make sure the students wear appropriate eye protection.

Apparatus:

- Small sealable bottles
- Washing up liquid
- Vegetable oil
- Water
- Food colouring (optional)
- Dropping pipettes
- Stopwatch

1) Colour the water with the food colouring so that it is possible to see it when it is mixed with the oil.
2) In each bottle place an equal amount of water and oil. Note how they form two layers and don't mix – this is because they are immiscible. Up to five per experiment works well although you can make as many test bottles as you like. Number the bottles so you can identify them.
3) Carefully add different amounts of washing up liquid to each bottle using the pipette. Keep one bottle with no washing up liquid as a control. Suggestion: Add a small amount of washing up liquid to one bottle, and then double that for the next bottle etc.

Tip: Less is more – you can always add more washing up liquid but you can't take it away again, if you are unsure, add less now then top it up later.

4) Shake each bottle for the same amount of time or with the same amount of force (make sure they are sealed properly before you do this!). This will mix the two liquids and in some cases form an emulsion.
5) Time each bottle and see how long it takes for the two liquids to form two layers again. How does this correlate with the amount of washing up liquid you added? What are the limitations of this experiment – is it a good way to see differing amount of surfactant in a solution?

Surface tension – ages 14-16

Surface tension can be modified by the addition of a surfactant. This short experiment illustrates this and can be applicable to chemistry or physics lessons.

Health and safety note:

Make sure the students wear appropriate eye protection.

Apparatus:

- Beaker
- Distilled water
- Clean sewing needle
- Talcum powder (talc) or other lightweight powder such as carbon or cornstarch
- Liquid detergent (washing up liquid or Teepol)
- Dropping pipette

1. Fill the beaker with water and carefully sprinkle talc onto the surface of the water. What happens to the talc?
2. Now place a drop of liquid detergent into the centre of the talc. What happens? Does the talc continue to float or does it sink? Why does this happen?
3. Repeat the experiment with a clean beaker and the needle in place of the talc. Do you need more or less detergent to sink the needle? Why does detergent have this effect?

Saponification and emulsification – making cold cream – ages 16-18

This is a practical experiment taken from the paper "Laboratory Preparation of Cold Cream to Show saponification and Emulsification" by George W. Hunter[1], published in 1944. At the time this paper was published, there was a major problem for the cosmetics industry – school pupils were taught to make their own simple moisturising cream, called "cold cream" during home economics lessons. These students had started to sell their home made cream, undercutting the bulk manufacturers.

In this experiment you will make a cold cream in the same way although it is not advisable to use it as a moisturiser as the experiment produces the hydroxide NaOH which may cause skin irritation. This version of the experiment is scaled down for school laboratories. For the original amounts and extra activities with the completed cream, see the original publication.

Health and safety note:

Make sure the students wear appropriate eye protection.

Apparatus (for one experiment):

- 4 g white beeswax
- 12.5 cm^3 mineral oil
- 0.25 g borax powder (toxic)

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[1] Laboratory Preparation of Cold Cream to Show saponification and Emulsification Hunter G.W. J. Chem Ed, 1944, 21 (4), p145

- Distilled water
- A measuring cylinder
- Bunsen burner, tripod and gauze x2
- Large beaker (to act as a water bath)
- Clamp stand, clamp and boss
- Small beaker x2
- Thermometers x2

1) Combine the beeswax and mineral oil in one small beaker.
2) Fill the large beaker ¾ full with distilled water and place on a Bunsen flame to heat.
3) Clamp the small beaker with beeswax/oil mixture into the large beaker with the contents under the water line. Continue to heat the water bath until the wax melts.
4) Take the temperature of the wax/oil solution.
5) Place the borax powder (toxic) with 8.25 cm^3 of water in the second small beaker.
6) Heat this over the second Bunsen until it is at the same temperature as the wax/oil solution.
7) Take the oil/wax solution out of the water bath when you are ready to do step 8.
8) Carefully pour the hot borax solution (toxic) into the wax/oil solution. The solution with become cloudy which is the saponification process between the cerotic acid in the beeswax and the alkali in the borax solution (toxic). Stir the mixture while it cools.
9) When the mixture is cooled, it will have formed a water in oil emulsion of the components used – this is cold cream.