Soap

Colloids and Polar Molecules

Lesson Plan

Guiding Question: How are stains removed from your clothing?

Overview: Learn the chemistry that explains how soap molecules can remove stains from clothing and visualise the amphipathic nature of soap molecules.

Learning Goals:

- Explain how soap molecules clump together to form micelle structures when added to water because of their distinct hydrophilic and hydrophobic regions.
- Recognize that solutions can form between solids and liquids.
- Identify the relationship between the polarity of a substance and its ability to form a solution with another substance—substances with similar polarity (i.e. polar & polar) will dissolve in one another.
- Observe that emulsifiers contain both hydrophobic and hydrophilic groups.
- Describe how soap's dual functionality (it can dissolve in both oil and water) allows it to create emulsions.

Key Concepts: Bond Polarity, Polar Molecules, Colloids, Solute and Solvent, Dissolving Process, Liquid-Liquid Solutions, Structure of Water

Link to Simulation: https://interactives.ck12.org/simulations/chemistry/soap/app/

Background Video

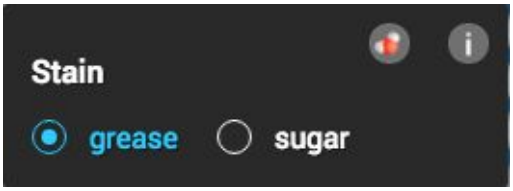
Ever wonder how stains get removed from your clothing? Let's see what happens inside the washing machine. Let's zoom in on the stain on these shorts! Because of the unequal sharing of electrons within each water molecule, water molecules act like little magnets with other polar molecules. The positive end of one polar molecule is attracted to the negative end of another polar molecule. Many stains are nonpolar. Nonpolar molecules do not have any partial charges because their electrons are distributed evenly. Nonpolar molecules are not attracted to polar molecules, so the water and stain do not mix. So how does soap help water get stains out? Let's explore the science behind this …

Soap molecules have two different ends. The head of a soap molecule is polar. The tail of a soap molecule is nonpolar. Having both polar and nonpolar parts allows the soap to interact with both water and grease molecules. The nonpolar ends of the soap molecules cluster around the grease stain to form a micelle. Let's explore all the ways you can get stains out of clothing!

Simulation Overview

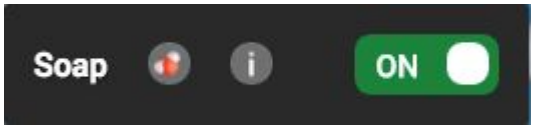
Stain

This control changes the stain on the clothing to a non-polar grease stain or a polar sugar stain.



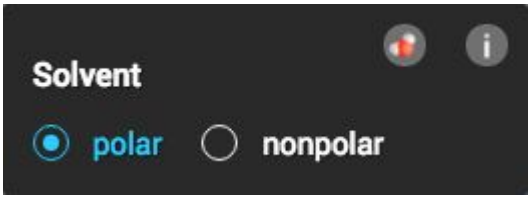
Soap

This toggle adds or removes soap from the cleaning solvent.

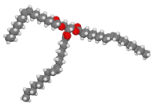


Solvent

This control changes the solvent being used to wash clothes to water, a polar solvent, or a dry-cleaning fluid, a mix of non-polar alkanes.

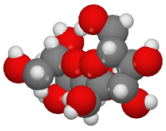


Molecule Explorer



Grease Stain - Triolein - $C_{57}H_{104}O_6$

The grease stain in this sim comes from a chemical called triolein, which is a type of triglyceride. In plants and animals, fats are stored as large molecules called triglycerides. These greasy molecules have long nonpolar hydrocarbon tails which prevent them from dissolving in water. This is why you can't wash butter off your hands with just water!

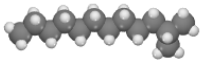


Sugar Stain - Sucrose - $C_{12}H_{22}O_{11}$

The sugar stain in this sim comes from sucrose. Sucrose is a sugar found in most sweet foods. It is often preferred to other sugars because it has an intense sweetness that stays on the tongue for a long time. Sucrose is polar because the electrons are not evenly shared across the molecule. Because of its polar nature, sucrose can dissolve in water.

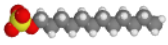
Polar Solvent - Water - H_2O

Water dissolves so many other substances we sometimes call it "the universal solvent." However, it can't dissolve everything! The electrons in water spend most of their time around the oxygen atom, giving it a permanent dipole. This unbalanced charge makes water polar, which means it is great for dissolving polar compounds, but causes water to repel from nonpolar molecules.



Non-Polar Solvent - Isotridecane - $C_{13}H_{28}$

Isotridecane is a nonpolar dry cleaning solvent. Dry cleaning solvents primarily consist of nonpolar molecules that are liquid at room temperature. The term "dry cleaning" refers to the absence of water when these solvents are used to clean clothes. Since these solvents will not interact with water-soluble molecules, they are perfect for washing clothes with water-soluble dyes without damaging them.



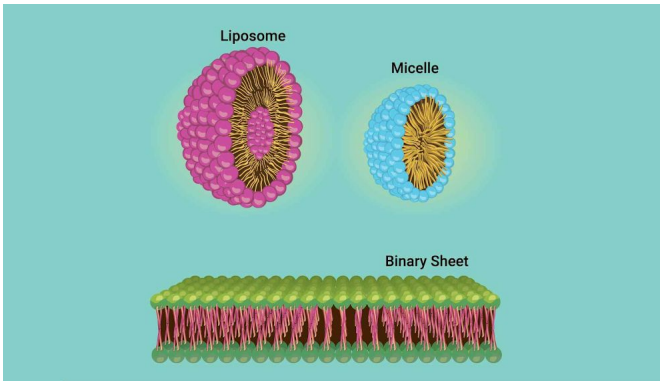
Soap - Sodium Lauryl Sulfate - $NaC_{12}H_{25}O_4S$

The soap molecule acts like a bridge between polar and nonpolar substances. Its hydrophilic head is polar so it sticks to other polar molecules like water. Its hydrophobic tail is nonpolar, so it sticks to other nonpolar substances. Sodium lauryl sulfate is a specific type of soap molecule called a detergent. Detergents are typically made from sulfonates because the sulfate head will not bind with ions like calcium found in hard water. In solution, sodium dissociates from the lauryl sulfate. For simplicity, the sodium ions were not shown in the simulation.

Real-World Connections

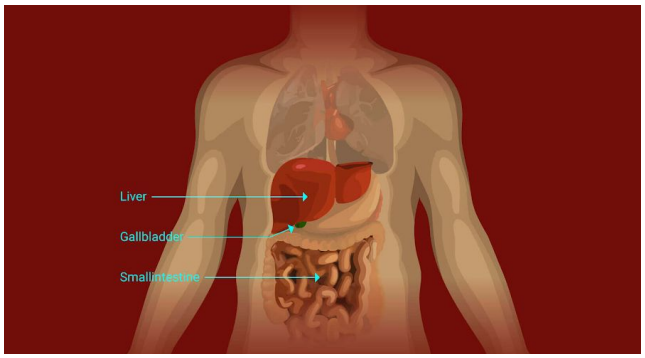
Can soap be used to clean up an oil spill?

Soap micelles can be used to break down the oil residue after an oil spill. The micelles enclose the oil in small droplets and these droplets dissolve into the water, where they can be broken down by bacteria. The advantage of this strategy is that the oil can be removed from the sea's surface, thereby reducing some of its dangers to birds and other near-surface creatures. In contrast, this approach threatens the underwater environment, where fish and marine creatures live.



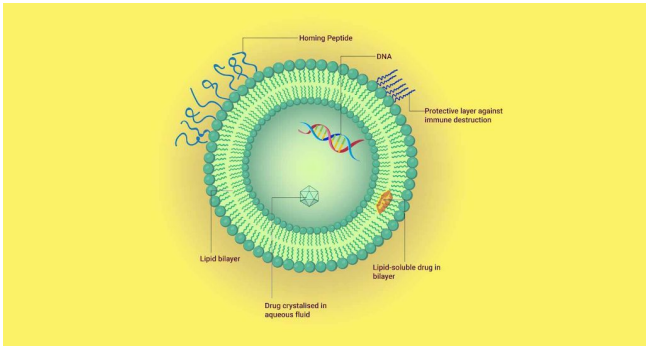
What is the relationship between form and function?

Liposomes, micelles and bilayers are similar in nature. The formation of these structures is a response to the amphipathic nature of the molecules that they are made of. Fatty acids that form micelles usually have a single hydrocarbon chain as opposed to two hydrocarbon tails. This allows them to conform into a spherical shape. Other fatty acids have two hydrophobic chains. These structures are too bulky to fit into a spherical shape as micelles do. Thus, they prefer to form as bilayer sheets or liposomes.



Are there micelles in our bodies?

Micelles play an important role in the human body. Micelles help the small intestine to absorb essential lipids and vitamins from the liver and gallbladder. They also carry vitamins (A, D, E and K) to the small intestine. Without micelles, these vitamins would not be able to be absorbed into the body, causing serious complications.



How are micelles used to deliver medicine?

Usually when we take a medication it is absorbed across a biological membrane like your stomach wall. The drug doesn't just go to the exact area that is needed, it is released to your entire body. Micelles can be used to target specific areas and release medical drugs in specific dosages. The advantages are the reduction in the frequency of the dosages taken by the patient, having a more uniform effect of the drug, reduction of drug side-effects, and reduced fluctuation in circulating drug levels. The disadvantage of the system is high cost, which makes productivity more difficult and the reduced ability to adjust the dosages.

Answer Keys

Exploration Questions #1-6:

1. Soap can dissolve in both nonpolar and polar solvents because each soap molecule has a polar and nonpolar end. In polar solvents the soap molecules form a sphere with the nonpolar ends in the middle and the polar ends toward the solvent. In nonpolar solvents, soap molecules form spheres with the polar ends in the middle and the nonpolar ends toward the solvent.

2. **Hydrophilic**: This part of the molecule is polar, meaning it interacts with other polar molecules. It is likely made up of elements like oxygen or sulfur that have high electronegativity compared to carbon. **Hydrophobic**: This part of the molecule is nonpolar, meaning it interacts with other nonpolar molecules. It is likely made up of carbon chains with elements like hydrogen and carbon that have similar electronegativity.

3. In cases where the solvent polarity matches the polarity of the stain the solvent primarily helps remove the stain, while the soap does not interact much with the stain. This is because there is a larger concentration of solvent than soap in solution, so it is much more likely to interact. The formation of a micelle is also unfavorable in this situation because the soap molecules are competing with the solvent to interact with the stain

   For example, given a polar solvent and a polar stain the soap would not interact with the stain. If this were to happen the soap's polar end would surround the stain but would also interact with the polar solvent, preventing the soap molecules from surrounding the stain.

4. One solvent/soap combination could be a polar solvent with soap. In this case the nonpolar region of the soap molecules would interact with the stain while the solvent would surround the soap-stain micelle. Another combination would be a nonpolar solvent with no soap. In this case the solvent would interact with the stain.

5. Without solvent the stain-soap micelle would not be carried away from the cloth fibers. Solvent is needed because the outside of the soap molecules interact with the solvent, which causes the soap micelle to flow away from the cloth fibers and be replaced by more soap molecules to carry away more stain.

6. Soap is able to dissolve the stain because it surrounds it and "hides" it from solvent. If a single molecule of soap interacts with the stain it also has to interact with all the solvent that still surrounds it, making the interaction less stable. When many soap molecules aggregate together they interact with each other and push the solvent away from the stain and the regions of the soap molecule that have less stable interactions with the solvent.

Check My Understanding #8-14

7. d
8. a
9. b
10. a
11. c
12. b
13. d
14. a

Name: _____ Date: _____

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Colloids and Polar Molecules

Guiding Questions

How are stains removed from your clothing?

Exploration Questions

Challenge Me Questions 1-6: As you explore the simulation, answer the following questions.

1. Why can soap dissolve in both polar and nonpolar solvents?

2. Describe the interactions of each part of a soap molecule, as well as listing possible elements that would make up that portion of the molecule.

    a. Hydrophilic

    b. Hydrophobic

3. How is the effectiveness of the soap impacted by the solvent?

4. A stain is made up of molecules that do not have charged regions. What soap/solvent combination should I use? Are there multiple?

5. Why is a solvent necessary even if it does not remove the actual stain?

6. Why do soap molecules completely surround the stain as opposed to just one molecule removing stain at a time like the solvent?

Name: _____ Date: _____

Check My Understanding

Questions 8-14: Circle the choice that best answers each question.

7. A hydrocarbon chain makes up _____ of a soap molecule
    a. The whole part
    b. None
    c. The hydrophilic part
    d. The hydrophobic part

8. In a solution of soap and water used to wash clothes, _____ is the solvent, _____ is the solute.
    a. Water, soap
    b. Soap, water
    c. Stain, water
    d. Water, stain

9. Why will soap not remove polar stains when in polar solvents?
    a. The soap is not attracted to the polar stain.
    b. The soap competes with the polar solvent to interact with the stain and doesn't play a significant role in removing it..
    c. If the soap surrounded the stain with the polar end, the nonpolar end would come in contact with the polar solvent, which is more stable.
    d. The polar solvent is too attracted to the tails of the soap molecules.

10. To remove a stain using a solvent, the stain has to become dissolved in the solvent.
    a. True
    b. False

11. Stains can be removed without soap provided that they _____.
    a. Are polar
    b. Are in a polar solvent
    c. Match the polarity of the solvent
    d. Do not match the polarity of the solvent

12. The polarity of the clothing fibers determines the effectiveness of the solvent.
    a. True
    b. False

13. In solutions, soap molecules will be _____.
    a. Very far from each other
    b. Evenly spread out
    c. Near each other
    d. Forming micelle structures with many soap molecules

14. Substances with _____ polarities will dissolve in one another.
    a. Similar
    b. Different
    c. Multiple