BASF
We create chemistry

Kids' Lab
Creating Fun with Chemistry!

Experiment Guide

Emulsions, Surface Tension and Surfactants

Objective

You may not realize it but you may be using emulsions and surfactants every day. This activity illustrates the properties of certain molecules and how these molecules act as emulsions or surfactants.

Introduction to Kids' Lab

Welcome to the BASF Kids' Lab. BASF is the world's largest chemical company and run Kids' Lab programs like this all around the world. Can anyone think why? BASF wants children all over the world to understand and enjoy experimenting with chemistry!

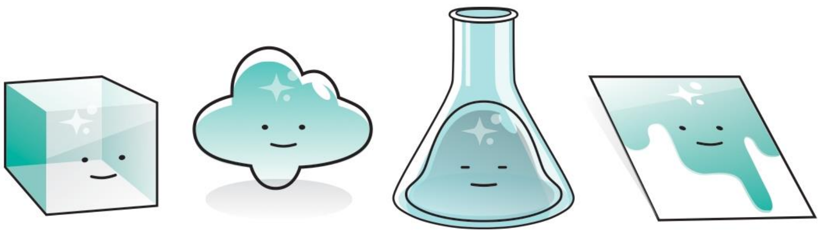
Has anyone heard that word before: Chemistry? What do you think it means?

Chemistry is the science of matter. Have you heard the word "matter" before? What is matter? Matter is anything that takes up space and has a weight here on earth. So basically, matter is a scientific word for stuff.
Chemistry is a science that explores the composition of substances and their properties and reactions. In other words, Chemistry is a science that explores how different stuff behaves.

Matter comes in a few different forms or states: Solids, Liquids and Gases are the most common.

Chemistry is all around us. For example:
Who takes a vitamin? How do vitamins help you? (Grow big and strong, boost immunity) BASF makes chemicals that go into vitamins.
Raise your hand if you play a sport or ride a bike. What should you do to be safe? (Wear a helmet, pads, etc.) What materials make up the helmets that you wear? (Plastics and foam) BASF makes chemicals that go into the plastics and foams in helmets and padding.
Besides helping you grow strong and keeping you safe when you are playing your favorite sport, BASF chemistry keeps farmers crops safe, cleans water for those in need and keeps babies clean and dry.

Let me introduce you to morpH, the face of Kids' Lab. morpH can move through the three states of matter with ease. Is there a substance that you know of, like morpH that can easily shift from solid to liquid to gas (and back again)? Water! That's right! You know that water is usually liquid but what happens when you freeze water? Water becomes a solid ice cube. When you boil water, it becomes a gas. Water is one of the most important substances on earth. Water is essential for all living things and has some very unique properties compared to other molecules.

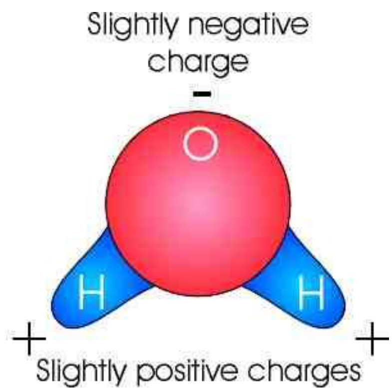


morpH and I would like you to explore some basic properties of molecules and explore emulsions and surfactants.

Experiment Introduction

One of the interesting features of a water molecule is that it is a **polar molecule**. This means that the water molecule has both positively and negatively charged ends. Since only opposites attract, the positive and negative ends of the water molecules stick together. This attraction between water molecules make it very cohesive which gives water another unique feature called surface tension. **Surface tension** is the molecular force that causes different molecules to temporarily bond together to reduce the surface area. Surface tension explains why water droplets are more rounded than flat because the molecules are attracted inwardly towards each other.

Below is a representation of the water molecule (H_2O) which has one oxygen atom (O) and two hydrogen atoms (H). Because of the slight charge on opposite sides of the molecule, the water molecule is a polar molecule. The positively charged hydrogen atoms from other water molecules are attracted to the negatively charged oxygen atoms of other water molecules and visa-versa such that these molecules “stick” together very cohesively.



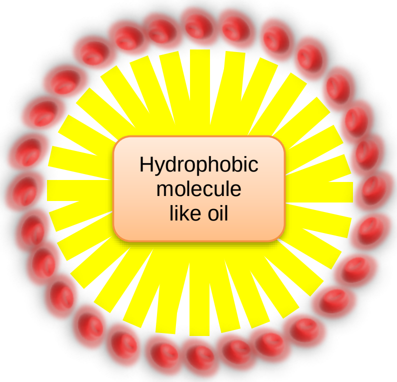
http://www.marinebiology.org/images/watermolecule.jpg

Substances like oil and water do not mix because water is a polar molecule and oil is a non-polar molecule. Oil is actually **hydrophobic** (water repelling), meaning it does not readily mix with polar or charged substances. Hydrophobic molecules like oil prefer to bond with other oil molecules or with other hydrophobic molecules. Similarly, polar molecules are **hydrophilic** (water attracting) and prefer to mix in polar solvents. Water is a polar solvent.

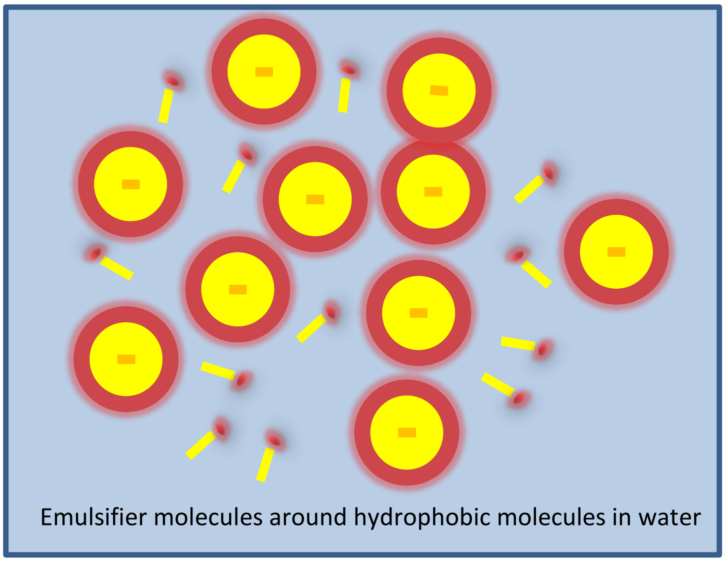
Emulsions are created when a compound called an emulsifier is added to substances that normally wouldn’t mix. Oil and water can be combined to create an emulsion when soap is added. Soap acts as an **emulsifier** because it has both hydrophobic (water repelling) and hydrophilic (water attracting) ends on the molecule. Each end will attract either polar or non-polar molecules, creating an emulsion.

<u>Illustration of an emulsifier molecule</u>

In a solution with polar molecules and non-polar molecules, the hydrophobic part of the emulsifier molecule avoids the polar molecules but will combine with the non-polar or hydrophobic molecules. The hydrophilic part of an emulsifier readily mixes with the polar molecules in the solution. The emulsion is stabilized because the emulsifier has an affinity for both polar and non-polar molecules.

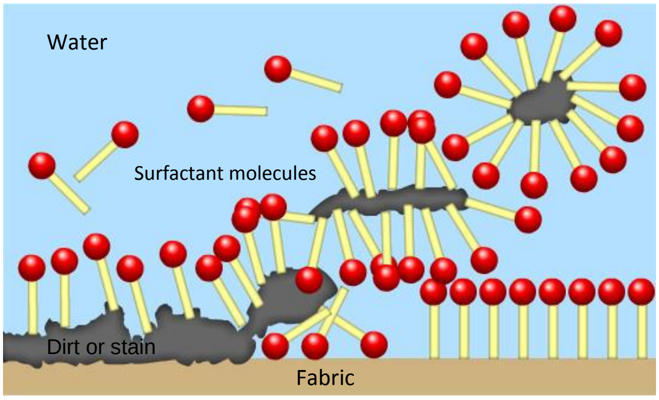


In a solution with water which is a polar molecule, the hydrophobic part of the emulsifier is attracted to the non-polar molecules like oil and the hydrophilic region is attracted to the water.



Interestingly, soap can also be used as a surfactant. A **surfactant** is an agent that lowers the surface tension of a liquid to allow for easier mixing, spreading or sticking. Because surfactants also have both hydrophobic and hydrophilic ends they work very similarly to emulsifiers in weakening the surface tension of other molecules. Surfactants are often used in cleaning solutions to reduce the surface tension between water and the dirt you are trying to remove.

Illustration of how the hydrophobic portion of a surfactant attaches to an oily fabric stain. Because the surfactant molecule also has a hydrophilic end, the oily stain is drawn out of the fabric and into the liquid laundry water.



http://www.rsc.org/learn-chemistry/resources/chemistry-in-your-cupboard/images/finish/figure8.jpg

Make sure you are familiar with the following terms:

Molecule*:* a group of atoms that are bonded together and represent the smallest fundamental unit of a chemical compound.

Polar molecule*:* a molecule that has a slightly positive end and a slightly negative end due to a covalent bond between two atoms where the electrons that form the bond are unequally distributed. Water is an example of a polar molecule.

Non-polar molecule*:* a molecule that has no separation of charge. This means that there are no positive or negative poles. Oil is an example of a non-polar molecule.

Emulsion*:* a mixture of two liquids or substances that normally wouldn't mix.

Emulsifier*:* a compound or substance that creates an emulsion by acting as a stabilizer and preventing liquids or substances from separating.

Surfactant*:* an agent that lowers the surface tension of a substance to allow easier spreading.

Surface tension*:* the force that causes molecules to be pushed together to minimize the surface area.

Hydrophilic*:* water-loving or water attracting.

Hydrophobic*:* water-fearing or water repelling.

Additional Background Information

Substances like oil and water normally do not mix because their molecular structures are arranged differently. Water's molecules are packed very densely and are attracted to other water molecules. Because of this density, water is also heavier than oil and will sink to the bottom of a container of oil and water. Also, water and oil do not mix because of polarity. Water molecules are polar molecules meaning the molecules are positively charged on one end and negatively charged on the other end. Oil is non-polar and has no electrical charge across the molecule, thus it is not attracted to the charge in a water molecule. In fact, oil is hydrophobic and repelled from water.

Emulsions are made when an emulsifier is added to different substances that normally wouldn't mix. An emulsion of water and oil can be made when soap is added because the soap is amphiphilic, which means the soap molecule has water attracting and oil attracting atoms. In this case, the soap is the emulsifier because it is the agent that stabilizes the liquids and allows them to mix.

Mayonnaise is an example of an emulsion and is made from mixing oil and vinegar, two substances that would normally not mix together. Vinegar is made of acetic acid and water so it is a polar substance. Egg yolk contains a molecule called lecithin, which has a polar end and a non-polar end, so it is attracted to both the vinegar and the oil. Thus, egg yolk is considered an emulsifier, or emulsifying agent, because it is what helps stabilize the mixture and combine the oil and vinegar.

Milk is actually an emulsion made up of water and fat (and sugars, proteins, vitamins and minerals). However, milk not does not contain an emulsifier. Usually milk is homogenized, meaning the fat particles are reduced in size such that they are suspended in the water. Have you ever seen raw milk separate into whey and cream?

A surfactant is an agent that lowers the surface tension of a substance to allow for easier spreading. Like an emulsifier, a surfactant has a water-attracting end (hydrophilic) and a water-repelling end (hydrophobic). Surface tension is the force that causes molecules to be pushed together in order to reduce surface area. In the milk experiment, when the food coloring is added, it does not disperse in the milk because the food coloring has a lower density than the milk.

When you initially add the drops of soap to the milk, the hydrophobic portion of the soap molecule quickly attracts the fat portion of the milk. This interaction between the soap and milk fat molecules immediately reduces the surface tension of the milk as the soap spreads out over the surface of the milk. As the surfactant spreads, it pushes the food coloring across the milk surface and the colors churn through the mixture as it slowly equilibrates. Simultaneously, the hydrophilic portion of the soap's molecules dissolve in the water portion of milk. The surfactants in the soap are too close together when they are first added, so they bend, roll and twist away from each other. The molecules in the food coloring get shoved during this process, which is why it is easy to see.

The surfactants will eventually move apart in different directions. The reaction that occurs during this experiment is the same reaction that is used to remove grease off of dirty dishes with the use of many cleaning products.

Safety Guidelines

Lab safety is a must! In order to safely explore Chemistry, we need to follow proper lab safety. How do you think we are going to do this? Chemists follow very strict procedures to protect themselves and they include:

- Gloves
- Safety glasses
- Lab aprons or lab coats

Before we get started:

- Be sure everyone including instructors and helpers are wearing safety glasses and gloves. An apron or lab coat are also recommended for this activity.
- Point out any safety features in the classroom (ie. Eyewash or emergency shower; emergency exits).
- Mention housekeeping rules – NO EATING OR DRINKING.
- Mention location of bathrooms.

Experiment 1: Making an Emulsion

This activity can be a demonstration or a hands-on activity. There are two primary experiments and you can choose to do one or both depending on the time. Participants can work in teams of 2-4.

Materials
- Clear jar or bottle with a lid
- Wooden stirrer or plastic spoon
- 1 cup water
- Food coloring
- 1 cup vegetable oil
- Dish soap
- Plate or shallow dish
- Whole or 2% milk
- Q-tips
- Measuring tool for cups (1 per instructor)
- Measuring tool for teaspoons

Step 1: Start with water
Add 1 cup of water to the jar or until the jar is 1/3 full. Add 2-3 drops of food coloring to the water and stir until the water and food coloring combine.

Step 2: Add oil
Add 1 cup of oil into the jar or until the is 2/3 full (including the water you poured in step 1).

Step 3: Shake it
Securely tighten the lid on the jar or bottle and lightly shake it for 20 seconds. Set the jar down and watch the liquid for a minute. Observe what happens to the oil and the water. Do they mix together or do they separate? Which liquid is at the bottom of the jar and which is at the top?

Step 4: Add an emulsifier

Take the lid off the jar or bottle and add 1-2 teaspoons of dish soap into the jar.

Step 5: Shake it again
Tighten the lid back on the jar and shake again for another 20 seconds. Set the jar or bottle down and watch the liquid for a minute. Observe what happens to the oil and the water now that the dish soap has been added to the mixture. Do they mix together or do they separate?

Experiment 2: Using a Surfactant

Materials
- Plate or shallow dish
- Whole or 2% milk
- Food coloring
- Dish soap
- Q-tips

Step 1: Start with milk
Pour milk into the shallow dish. Fil it to a depth of about 1 inch. Make sure the entire bottom of the dish is covered with milk.

Step 2: Add food coloring
Using four different food colorings, add one drop of each color of food coloring near the center of the dish. Make sure the food coloring drops are close to each other but not touching. Observe what happens to these drops of food coloring on the surface of the milk. Can you see how the density of milk affects these drops of food coloring?

Step 3: See what soap does

Place a few drops of dish soap on the end of the Q-tip. Place the Q-tip with soap in the center of the dish of milk between all of the different colors of food coloring and observe what happens to the food coloring and the milk. What do you think adding the soap did to the surface tension of the milk?

After a while, the soap, milk and food coloring equilibrate and the molecules are less reactive as more soap is added. Dispose of this mixture (do not consume).

Summary:

Emulsions and surfactants are seen in everyday life. Foods like butter, salad dressing, ice cream, milk, mayonnaise and sausage are all emulsions. When you mix up cake or cookie batter, you are making an emulsion of water, oil and flour. Emulsions can also be found in medicines, lotions, and paints. Every time you use shampoo, dish detergent or laundry detergent, a surfactant ingredient reduces surface tension so that water can get to the dirt. Chemists must use molecular concepts like polarity, density and surface tension all the time to separate chemicals, mix chemicals or create new substances.