Formulate and Understand Notebook

Formulation Science & Technology Group

RSC | Advancing the Chemical Sciences

Preface

This FUN pack is all about engaging the general public and raising the awareness of formulation science and technology.

This FUN pack gives special attention to young people with the activities designed to be both educational and fun!

This FUN pack is designed to stimulate creative thinking and lead to a better understanding of formulation science.

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Formulation

- The science and technology of formulation is about making products from raw materials.

- Formulation is all about designing the everyday products we use: detergents, paints, cosmetics, pharmaceuticals, food and fuel additives.

- This FUN pack will introduce you to the world of formulation through fun, interactive activities.

Your Formulation Tool Box

- Objects that float
- Oil and Water
- Bubbles & Foam
- Apples and Oranges
- Formulating with colour
- Sand castles
- Polymers

Objects that float

Metal doesn't float on water, right? It's heavier (has a higher density) than water and so we expect it to sink.

LET'S FORMULATE!
Drop a metal paperclip in water.
Does it sink / swim?

Carefully place the paperclip on water.
Does it sink / swim?

WHAT'S GOING ON?!
If we break the surface tension of the water the paperclip sinks as it's denser than water.
If the surface tension stays intact then the paperclip floats.

LET'S FORMULATE FURTHER!
Add a few drops of liquid soap to the water with the floating paperclip.
What happens and why?

Paper Test

You need: Newspaper & Scissors
Water
Liquid soap
Two bowls
Stopwatch

Cut two identical shapes from your newspaper.
Fill both bowls with water to the same level (about one inch from the top).
Add a squirt (about a tablespoon) of liquid soap to one of the bowls and mix.
Drop your shapes into the bowls simultaneously and time how long it takes each of them to sink.

IN DEPTH:
Discuss formulations: is more always better?

Is it better to use more laundry detergent to wash your cloths than what is recommended? Think about how detergents are formulated!

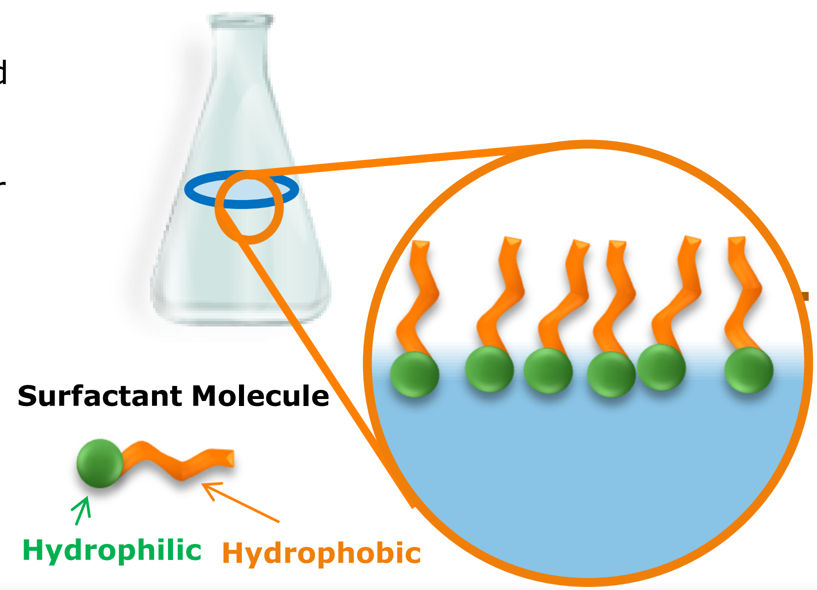
Surface tension is a property of the surface of a liquid that allows it to resist an external force. It is revealed, for example, in floating of some objects on the surface of water, even though they are denser than water, and in the ability of some insects (e.g. water striders) and even reptiles (basilisk) to run on the water surface. This property is caused by cohesion of like molecules, and is responsible for many of the behaviors of liquids.

Additives can change the surface tension of a liquid. The most common class of substances used to modify the surface tension is called surfactant.

Surfactants are molecules that concentrate at the interface between water and air, or between water and oil. These molecules have a water loving part, called the surfactant head, and a water hating part, called the surfactant tail. The insoluble hydrophobic group may extend out of the bulk water phase, into the air or into the oil phase, while the water soluble head group remains in the water phase. This alignment of surfactant molecules at the surface modifies the surface properties of water at the water/air or water/oil interface.

The surface tension of a liquid is closely related to the ability of the liquid to wet a solid. A property known as the contact angle measures how effectively a liquid can wet a solid. If the contact angle is large, the liquid does not wet the solid (like a drop of water in a new teflon coated pan), but if the contact angle is small, then the liquid can wet the solid. In general, the lower the sufrace tension of a liquid, the better its ability to wet a surface.

How Surfactants Work



Detergents, paints and other formulated products use surfactants to facilitate wetting of surfaces.

Oil and Water

Oil & water … do they mix?

You need: Two identical glasses
Water
Cooking oil
Food colouring

LET'S FORMULATE:
Fill one glass with cold water, leaving a couple of inches at the top.
Pour an inch of cooking oil into the other glass. Add a couple of drops of food colouring to the oil.
What do you see?

WHAT'S GOING ON?
This is a coating. The food colouring form balls as it coats with oil.

LET'S FORMULATE FURTHER:
Pour the oil slowly into the water.
Look carefully as the oil rises – where are the oil-coated food colouring balls?
Now stick a pencil through the oil layer and pierce the balls.
What happens? How colourful can you be?

Formulation challenge: Mix oil & water!

To mix oil & water you will need to add an emulsifier. This is called an EMULSION!

Examples of emulsifiers can be egg yolk (yellow bit!) or soap.

Try it … Take your oil and coloured water mixture, add a egg yolk and stir!

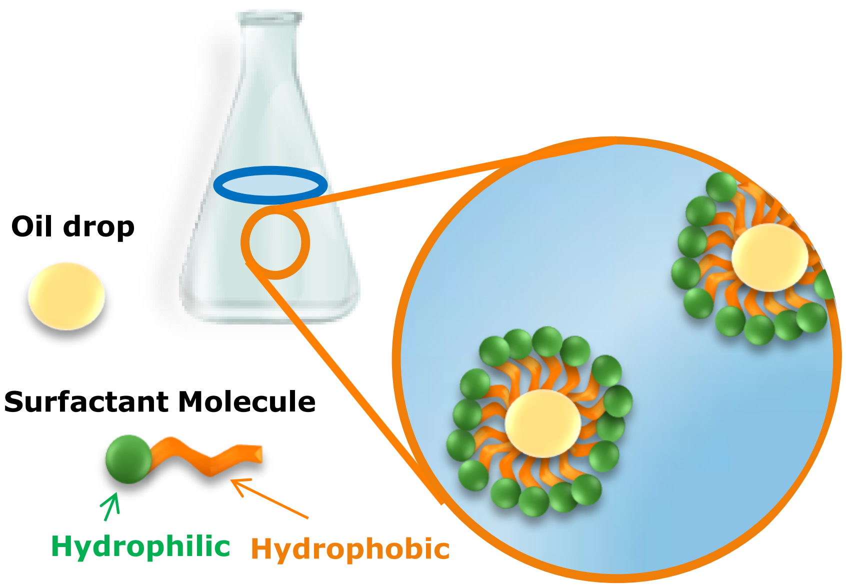
Can you think of a food which uses this formulation?

While water often mixes with other liquids to form solutions, oil and water does not. Water molecules are strongly attracted to each other, this is the same for oil, because they are more attracted to their own molecules they just don't mix together. They separate and the oil floats above the water because it has a lower density.

Immiscible liquids can be mixed with the aid of an emulsifier to form an emulsion. An emulsion is a mixture of two or more liquids that are normally immiscible (un-blendable). The word "emulsion" comes from the Latin word for "to milk", milk being (among other things) an emulsion of milk fat and water.

Emulsions are part of a more general class of two-phase systems of matter called colloids. In an emulsion, one liquid (the dispersed phase) is dispersed in the other (the continuous phase). Examples of emulsions include vinaigrettes, milk, and some cutting fluids for metal working. The photo-sensitive side of photographic film is an example of a colloid.

How Emulsions Work



Whether an emulsion turns into a water-in-oil emulsion or an oil-in-water emulsion depends on the volume fraction of both phases and on the type of emulsifier (surfactant).

Formulated products not only use surfactants as additives to maintain water and oil well mixed, but also to control the drop size and other properties.

FUN Fact

When two liquids do not mix, they are said to be immiscible. Chemicals that act like lecithin to mix immiscible liquids are called emulsifiers. Detergents are emulsifiers; they break up oil into smaller sizes so it can be more easily washed from clothes or dishes.

Bubbles & Foam

FOAM – What you need:
Tall glasses
Carbonated soda
Ice cream

LET'S FORMULATE:
Add a scoop of ice cream to your glass then pour over the soda.
Congratulations – You have formulated a foam!

LET'S THINK:
What does the foam look like? How long does the foam last?
You can now try your formulation – it tastes rather good!

LET'S FORMULATE FURTHER:
Pour the soda into the glass and then add the ice-cream.
Do you still get foam? What has happened?

The formulation method is very important
– adding materials in the wrong order can lead to big differences!

BUBBLES – What you need:
250ml washing-up liquid
250ml glycerine
4 L of water

LET'S FORMULATE:
Mix together ingredients in a shallow, wide container. Make a bubble wand by twisting a metal coat hanger into a circle – dip into your formulation and make some bubbles!

LET'S FORMULATE FURTHER:
How long can you make the bubbles last?

If you vary the amount of glycerine in the bubble solution then the lifetime of the bubble will change … what is the optimum formulation for the longest lasting bubbles?

Apples and Oranges

Oxidation – What you need:
Apples
Oranges
Lemon Juice

LET'S FORMULATE:
Wash your apple and slice into eight pieces.
Take 2 pieces.
Add a few drops of lemon juice to one of the slices.
What happens over time? Is there a difference between the slice with the lemon juice and that without?

LET'S THINK:
Why does the lemon juice stop the oxidation process?

LET'S FORMULATE FURTHER:
What happens if you add orange juice instead of lemon juice?

Corrosion – Looking New again!

What you need:
1p pieces
White vinegar
Salt
Lemon juice

LET'S FORMULATE:
Mix 1/4 cup of white vinegar with one teaspoon of salt.
Stir until the salt dissolves.
Add your 1p into the solution.
What do you see?

LET'S FORMULATE FURTHER:
What happens if you add a dull 1p to lemon juice instead of vinegar-and-salt?

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Oxidation is caused by an interaction of oxygen molecules with the substances they come in contact with, such as when an apple that has been cut turns brown or a metal object sitting outside gets rusty. There are many types of oxidation, and they occur through various processes. These heat and water can be factors in this. The one common tie in all forms of oxidation is the presence of oxygen, without which oxidation could not occur.

Corrosion is in general the oxidization by chemical reaction of a clean metal surface. This can cause pitting, "rust" or even the disolving of the metal being attacked by the chemical reaction. Examples of this are red rust on iron or steel where the oxygen in the air reacts with the free iron in the metal and it forms rust. Or white rust on zinc or aluminum where, again the oxygen attack the metal and leaves a white film or white rust.

A corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material. The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water, and flow regime.

The nature of the corrosive agent depends on the material being protected and on the corrosive agent(s) to be neutralized. The corrosive agents are generally oxygen, hydrogen sulfide, and carbon dioxide. Oxygen is generally removed by reductive inhibitors such as amines and hydrazines:

$$O_2 + N_2H_4 \rightarrow 2\ H_2O + N_2$$

In this example, hydrazine converts oxygen, a common corrosive agent, to water. Related inhibitors of oxygen corrosion are hexamine, phenylenediamine, and dimethylethanolamine, and their derivatives. Antioxidants such as sulfite and ascorbic acid are sometimes used.

FUN DISCUSSION

A formulation to prevent corrosion requires a good active ingredient and a number of additives. Discuss the function of these additives.

Formulating with colour

Paints – What you need:
1/4 cup flour
1 cup water
Small jars or plastic containers
3 tablespoons powdered tempera paint per container (red, yellow, blue)
2 tablespoons water per container
1/2 teaspoon liquid starch or liquid detergent per container

LET'S FORMULATE:
Slowly add the flour to the water – stir continuously until mixed.
Heat gently and stir until thick.
Allow to cool.
Divide the mixture into 5 portions.
Add 2 tablespoons of water and 3 tablespoons of powdered paint to each portion and stir. (Add more water if too thick!)
Add liquid starch for a glossy finish OR add liquid detergent for a matte finish.

LET'S FORMULATE FURTHER:
Think about the 3 primary colours – red, yellow & blue.
How many different colours can you make from the three primary colours?

Mix together different ratios of the paints – write down the amounts of each colour used and the colour you got

IN DEPTH: water or oil based paints?

In stores you can find water and oil based paints. When would you use a water based paints? When would you use a oil based paint? How can you tell the difference between them?

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What is colour?

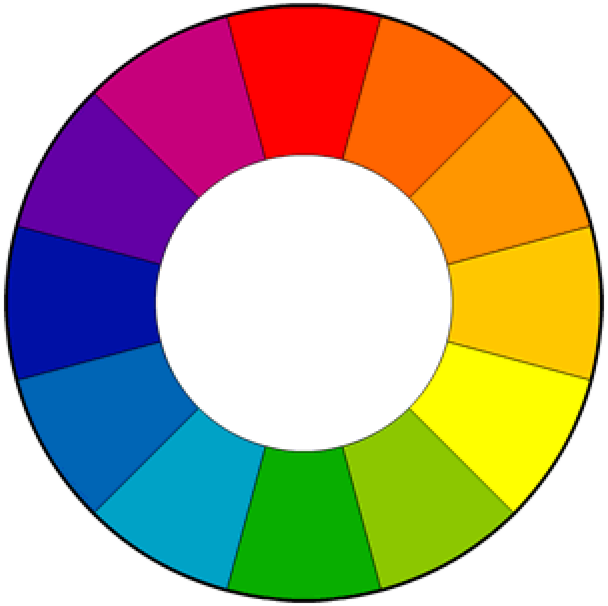
Colour is the light that reaches our eyes after being reflected or refracted by a material – we do not see the light that is absorbed. We can form a range of colours by careful combinations of existing colours. By mixing primary colours secondary colours can be formed, and further mixing can create tertiary colours

What types of material are used for colour?

There are two types of material we can use to create colour. Dyes are soluble materials, for example tartrazine or cochineal, which are used to make foodstuffs yellow or red. Colour-providing materials that are not soluble are called pigments. An example of a pigment is titanium dioxide, which is used to whiten toothpaste.

Colour is important for industry:

- Paints
- Cosmetics
- Foods
- Plastic packaging



Sand castles

Formulation challenge:
Make sand castles with magic sand!

Sand Castles – What you need:
Magic sand
Regular sand
Water
Liquid detergent

LET'S FORMULATE:
Fill a cup 3/4 full with water.
Slowly pour Magic Sand into the water – look closely … is there a coating on the sand?
Touch the sand – is it wet / dry?
What happens if you add liquid detergent and stir?

LET'S FORMULATE FURTHER:
Fill 2 cups 3/4 full with water.
Sprinkle a thin layer of regular sand into one of the cups and magic sand into the other.
Does the sand sink or swim?

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The surface of sand grains is made wet by water, which means that water molecules are attracted to sand grains. Remember, this water-loving property of sand is called a hydrophilic property.

Magic Sand is regular sand that has been coated with an oil-like substance that is water-hating or hydrophobic. Soap breaks down the oil coating on the sand and lowers its hydrophobic properties. Adding soap removes the “magic” from Magic Sand and causes it to behave like regular sand. The secret is revealed!

The coating on Magic Sand is like Scotchguard, which is sprayed on fabric to protect it from stains. Magic Sand was originally developed as a way to trap oil spilled from oil tankers near the shore. The idea was that when Magic Sand was sprinkled on floating petroleum, it would mix with the oil and make it heavy enough to sink. This would prevent the oil from contaminating beaches. However, it is not being used for this purpose, perhaps because of the expense of making Magic Sand. Another potential use of Magic Sand is to bury junction boxes for electric and telephone wires in the Arctic in order to protect the utilities from the extreme cold temperatures but make it easy to dig up for repairs. Normal earth is frozen so hard because of moisture content and it is difficult to dig. However, Magic Sand remains dry and is easy to dig, regardless of how cold it is.

Polymers

Secret Messages – What you need:
Teflon Tape (PTFE thread seal tape)
Scissors
Pen

LET'S FORMULATE:
Cut a piece of tape and write a message on it.
Increase the WIDTH of the tape by pulling gently (be careful not to tear the tape!)
Look at the message – what do you notice? Can you read it?
Pull on the ends of the tape to return the tape to its original width and length - can you reveal the message?

LET'S FORMULATE FURTHER:
What you need:
Lemon, Bowl, Knife, Cotton swab
White paper, Lamp

Cut the lemon in half.
Squeeze the lemon juice into the bowl
Remove any seeds
Add a few drops of water to the lemon juice. Mix.
Dip the cotton swab in the mixture and write a message on the white paper.
Allow to dry.
What do you see on the paper?
What happens if you since a light over the paper?
What happens if you hold the paper close to the bulb?
(Take care: Do not touch the bulb as paper burns)

Snow in summer – What you need:
Instant Snow Powder
Distilled water
Ziptop bags / plastic cups

LET'S FORMULATE:
Add one teaspoon of snow powder to the bag/cup
Add 50ml of water to powder
What happens?
What does it feel like?

LET'S FORMULATE FURTHER:
What happens if you add salt to your snow?
What happens if you add water to your snow?
What happens if you use tap water instead of distilled water?
Can you freeze your snow?

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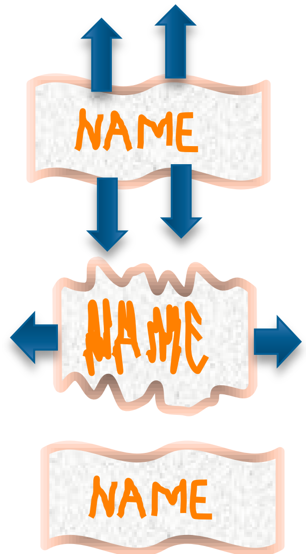
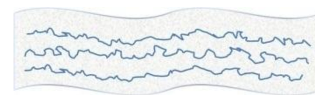
A lot of everyday items are made from polymers.



PTFE stands for polytetrafluoroethylene or Teflon. The polymer stands in the Teflon tape are parallel in alignment to the "long" sides



When you pull, as in step 2, the strands slip longitudinally over one another and your name appears distorted. If the strands are pulled too far apart, the chains spread out and the attraction between the chains breaks so the tape is torn. If you have not torn the tape, when you pull the two short ends of the tape in step 4, the polymer chains return to their original parallel orientation.

A polymer can be thought of as resembling numerous beads on a string. Each monomer, or bead, is linked (bonded) to the next to form chains composed of thousands of atoms in a row. It is the huge size of polymer chains that gives the molecules many of their special properties.

Instant Snow Polymer is made by cross-linking molecules of the sodium polyacrylate polymer. When water is added, the individual clusters internally hydrate and expand, forming small, fluffy clusters that do not cling to surrounding clusters. This appears as a powdery snow. When more water is added, the water molecules hydrate the external surface of these clusters, and the clusters begin to adhere to one another. This appears as slush.