14-16s LESSON 2

HOW CAN WE CONTROL VISCOSITY?

In this lesson students explore how surfactants (the active compounds in detergents) can be made to have different viscosities or thickness, depending on use. Students learn how surfactant molecules can form 'micelles', small spherical groups of surfactant molecules. They add salt solution to change the ionic concentration of a sample solution and discover how the salt concentration changes how closely together these micelles can pack together. Students test the viscosity of a sample solution at different salt concentrations and identify the concentration at which the micelle structures break down and the viscosity rapidly reduces.

TOPIC AREAS

- Ionic molecules
- Detergents / surfactants
- Practical skills
- Applications of science

LEARNING OUTCOMES

Students will be able to:

- Recall and explain how surfactant molecules work in terms of ions and charged molecules.
- Explain viscosity in terms of molecular structures that are closely or loosely packed together.
- Complete a simple practical to alter and measure viscosity.

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RESOURCES

FROM THIS PROGRAMME

14-16s lesson 2: activity sheets 1 and 2
(one per student)

14-16s lesson 2: PPT presentation
(one each per student)

To complete this activity you will need to order a **free** surfactant solution from SCS.

Each school is entitled to two 5L containers of the surfactant, whilst stocks last. This will be enough solution to complete the experiment three times with a class of 30 students.

To order your solution email:
edcoms@education.co.uk

Please detail your request, including your name and school address. Postage and handling is also completely free.

You will also need a range of sample surfactant-based products - see 'preparation' details below.

FROM YOUR LAB

Per pair of students:

- 200ml surfactant solution
- Salt solution
  (batch production and quantities detailed below)
- Water (ideally distilled)
- Electronic scales accurate to 0.1g
- Spatula
- Stirring rod
- 200ml and 400ml beakers
- 100ml measuring cylinder
- Lead shot or ball bearing with mass of 0.05 to 0.1g
- Tweezers
- Stopwatch

PPE as required by your school, eg eye protection.

PREPARATION

Order your surfactant solution from
edcoms@education.co.uk

It's also helpful to have a range of surfactant-based toiletries for students to sample to see how their viscosity varies. These could include:

- A runny liquid soap or shampoo
- A standard liquid soap
- Shower gel
- 'Swarfega' original solid gel hand cleaner – recommended!

Carefully review the instructions. You will need to make up a salt solution large enough to cater to all the pairs of students who are completing the experiment. For a class of 30 students, we would suggest making a solution of 2250ml. Add 750g of salt to 2250ml of water (ideally distilled) and stir until the salt has dissolved. Students will need to collect a quantity of salt solution from this main batch using a measuring cylinder. Quantities are listed further down.

Students should mix the salt and surfactant solutions together gently in the beaker to avoid adding air and creating foam.

You will need to source a suitable small, ball bearing or lead shot for each group to drop through their solution. The suggested mass range is 0.05-0.1g and will ensure times are slow enough to allow accurate measurement.

You may want to complete a test run to optimise how students will measure the time taken for the ball bearing or lead shot to fall through the surfactant solution using your equipment. Students may benefit from lamps or torches to light up their measuring cylinder.

It is helpful if students have already covered the basics of how surfactants (which you may refer to as detergents) work thanks to long, polarised molecules with a hydrophilic and hydrophobic end.

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SAFETY

We recommend students wear eye protection. Follow your school's risk assessment and safety procedures for this activity.

The surfactant solution contains water, sodium laureth sulfate and cocamidopropyl betaine, plus preservative.

Ensure students do not look directly into strong light sources when timing their experiment.

STARTER

1. Explain that students are going to explore how to change an important property of surfactants – the everyday, or sometimes specialised, products that help us clean ourselves, our homes and more.
2. Explain that first, students need to review their understanding of how surfactant molecules work, because this is related to what students will do in this lesson.
3. Invite students to share their ideas verbally or by using sketches to illustrate how they think surfactant molecules work.
4. Show **slide 1**. Review how surfactants work by using polar molecules, with hydrophilic (water-loving) and hydrophobic (water-hating) ends, to overcome water and oil's natural reluctance to mix.
5. Ask students to name some toiletry products that contain surfactants (eg soap, hand wash, shampoo etc).
6. Hand round samples of surfactant-based products that range from the very runny to almost solid. Share ideas on how cosmetic scientists might vary the viscosity of these solutions.

MAIN ACTIVITY

1. Explain that cosmetic scientists can make shower gels and other cleaning products the right viscosity by taking advantage of a remarkable property of surfactant molecules.
2. Ask students to recall that surfactant molecules have one end that is attracted to water, and another that is repelled from it. Now ask them to recall that cleaning toiletries usually have water as their first ingredient – so these molecules, with their water-hating ends, are surrounded by water in the product!
3. Ask students to discuss in small groups or pairs how these surfactant molecules might arrange themselves in water in a way that overcomes this issue. How can the water-hating ends of the surfactant molecules 'hide' from the water?
   - One metaphor for this is to imagine a surfactant molecule as being made up of a pair of people holding hands, one brave and one timid. If a group of these pairs of people were to be surrounded by wild animals, how might they arrange themselves?
   - The timid people could cluster in the middle, each holding hands with a brave person on the outside.

   Show slide 2. Review how surfactant molecules group themselves to form structures called 'micelles' – spheres of molecules with the water-loving ends outwards (facing the water molecules) and their water-hating ends inwards (hidden from the water molecules). Students can sketch a micelle on **activity sheet 1**.
4. Briefly consider how some cleaning products are thin, and some are much more viscous (such as the samples you shared). Why might customers prefer toiletries or cleaners that are thicker? Share ideas and review **slide 3**.
5. Explain that the viscosity of products depends on how closely these micelles can pack together.

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Ask students to suggest how the micelles might be packed in a highly viscous (thick) product, versus a less viscous (runny) one.

6. Share ideas and explore **slide 4**, to determine that viscous products contain micelles that can't move around each other. Adding salt to the product enables this by adding ions to the water. These Na+ ions are attracted to the outside of the micelles, swelling their diameter and making them less mobile. The Na+ ions also mask the micelles charge to some degree so they can pack together more tightly.
7. Review the briefing on **slide 5**: students must find out how thick they can make a new surfactant product by adding salt.
8. Review how to add salt to their sample surfactant solution using **slide 6 (animated)** and **activity sheet 2**.
9. Share ideas on how students might measure the viscosity of each sample in a simple way. Review how students will measure viscosity by timing how long it takes for a miniature ball bearing or lead shot to sink through their sample, using **slide 7 (animated)** and **activity sheet 2**. Make sure students understand the correlation between increased time and increased viscosity – it's an indirect measurement.
10. Students make their sample solutions, carefully adding the required amount of salt to their surfactant and mixing as instructed.
11. Students test their sample(s) and record their time(s).

PLENARY

1. Share results and plot a chart as a class. There is an example on **slide 8** to help you.
2. Discuss the shape of the chart.
   - Did the viscosity keep on increasing or did something else happen?
   - How much salt could students add before this happened?
3. Ask if students can explain why this happened, using what they understand about how the ions from the salt 'mask' the micelles from each other so they can get closer together, even though their outer charges would normally repel each other. Adding too much salt (and in turn, more ions) causes the micelles to swell so intensely that they begin to completely lose their spherical shape and then bend, distort and burst. When this happens, the solution becomes thinner as surfactant molecules in these burst structures can move around each other more easily than when they were in enlarged spherical micelles.

DIFFERENTIATION IDEAS

EASIER

Students can make up and test one sample. Use a simpler explanation that the salt dissolves into ions that help the micelles get closer together in the water.

Use only samples A, C, E, G and I.

MORE CHALLENGING

Students can make and test multiple samples, making and averaging several readings for time (viscosity). Note that students can only progress from a sample with lower salt solution to one with higher salt solution (eg. D then F) and must only add the additional solution required to the whole quantity of surfactant – see instructions on the student sheet.

Consider the role of the ions from salt in more detail, thinking about the polarity of the outer micelles.

You may want to add that when salt is added, the Na+ ions also mask the micelles' outer charge, allowing them to get closer together as well as increasing their diameter.

SAMPLE RESULTS (Using a miniature ball bearing with mass 0.07g.)

SAMPLE	A	B	C	D	E	F	G	H	I
SALT SOLUTION (ml)	48	56	64	72	80	88	96	104	112
TIME (s)	2.6	3.2	6.5	9.3	10.6	10.2	7.8	5.5	3.0