Investigating cross-linking – making slime

This experiment is great fun and always popular with students. It can be made as difficult or as straightforward as you wish, depending on the level and ability of the class. For the least able, making the slime and observing the changes in its properties may be enough. For the more able, detailed measurements and observations are possible.

Equipment required

Per student, pair or group:

- PVA solution approx 100 cm^3 per group – see notes below
- Borax solution – 0.8 g borax in 20 cm^3 water will allow students to make about four batches of slime; scale up according to the number of groups (**Minimal hazard**)
- Food colouring or a water soluble dye such as fluorescein (optional) – can be added when mixing the solutions
- Approx 4 x 100 cm^3 beakers
- 1 x 25 cm^3 measuring cylinder
- 1 x 10 cm^3 measuring cylinder
- Stirring rod.

Notes

PVA solution can be made from PVA glue (wood glue or white paper glue). The composition of the glue may vary depending on its source so check that the mixture works and adjust the glue/water mix accordingly. Two parts glue to one part water generally works well.

Alternatively, it is possible to buy solid PVA. To make the PVA solution using this starting material, add about 4 g PVA to 100 cm^3 water at 90 °C. Stir with a magnetic stirrer until the PVA dissolves. Cool and add enough water to make the volume up to 100 cm_3 (to replace any water lost by evaporation).

SEP (Science Enhancement Programme) slime kits, which include PVA, borax and dye, are available through Middlesex University Teaching Resources. See **http://www.mutr.co.uk** (accessed November 2005) for more information.

Health and safety

- Wear eye protection and/or clothing protection if desired.
- Read our standard health and safety guidance at https://rsc.li/3QKisMu
- Borax and PVA both represent a minimal hazard.
- As borax is a weak alkali, it can cause skin irritation in those with eczema, sensitive skin or cuts. Disposable gloves should be made available for these students. Most others will enjoy handling the slime as it is very tactile.
- Borax is toxic if large quantities are ingested so students should wash their hands at the end of this activity and certainly before any food or drink is consumed.

The best slime

Typically the 'best' slime can be made by using a 5:1 PVA to borax mixing ratio, but this can vary, especially if diluted wood or paper glue is used.

Possible alternative investigations

Students could investigate:

- The amount of stretch achieved in a given time or the time taken to stretch a given amount of slime (both can be converted to a stretch rate of mm s-1)
- Slime with the greatest bounce
- Slime that can stretch the most without breaking.

Instead of plotting viscosity against the amount of borax used, students could investigate one of the following factors:

- Temperature – the slime can be left in a water bath until it has reached the desired temperature.
- pH – the pH of the slime mixture affects the degree of cross-linking and can be varied by adding borax/borate buffers.

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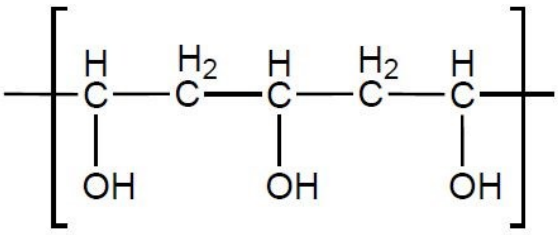
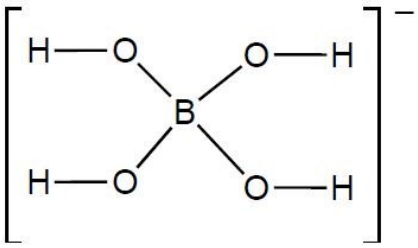
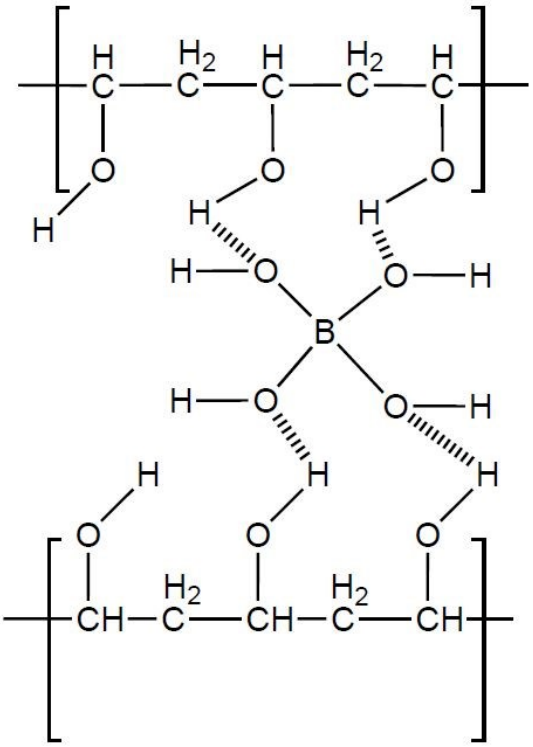
PVA glue contains the polymer polyvinyl alcohol (also called polyethenol) and has the structure:



Borax forms the borate ion when in solution. This ion has the structure:



The borate ion can make weak bonds with the OH groups in the polymer chains so it can link the chains together as shown below. This is called cross-linking.



This cross-linking changes the properties of the polymer from a viscous liquid to a far more viscous slime. The slime contains as much as 96% water trapped between the molecules.

Investigation

Find out how the viscosity of the slime changes as the amount of borax used changes.

What you need

- PVA solution
- Borax solution (Minimal hazard)
- 4 x 100 cm^3 beakers
- 1 x 25 cm^3 measuring cylinder
- 1 x 10 cm^3 measuring cylinder
- Stirring rod.

Health and safety

Wear eye protection and/or clothing protection if desired.
Read our standard health and safety guidance at https://rsc.li/3QKisMu
The chemicals used in this practical are of minimal hazard, although borax is a weak alkali and is a poison if you eat a large amount of it. Wash your hands at the end of the experiment and certainly before you eat or drink anything.
If you have eczema, sensitive skin or cuts on your hands, wear disposable gloves.

Basic slime mix

Put 20 cm^3 PVA solution in a beaker. Add between 1 and 10 cm^3 borax solution (make sure you know how much you have added). Stir vigorously for several minutes to ensure the PVA and borax are thoroughly mixed. Leave the mixture for a few minutes for all the cross-links to form and then remove it from the beaker and roll it into a ball.

Testing for viscosity

There are several ways you could do this – a couple of suggestions are given here, but there are many other ways too.

- Put the slime in a small beaker and leave it to settle. Place a coin on the surface and time how long it takes to sink.
- Draw a circle on a piece of paper about the size of a small beaker. Draw another circle outside the first one, about 1 cm away. Put an overhead projector slide on top or put the paper into a plastic wallet. Roll your slime into a ball and put it in the middle of the circles. Start timing when the slime reaches the first circle and stop when it reaches the second.

Recording your results

Record your results in a table. Plot a graph of the property you measured against the volume of borax used.

Explaining your results

- Describe what your results show. Are you surprised? If so, why?
- Try to explain your results in terms of cross-linking.