76 PVA polymer slime

A solution of **polyvinyl alcohol (PVA)** can be made into a **slime** by adding **borax** solution, which creates crosslinks between **polymer** chains. In this activity, some interesting properties of the slime are investigated. Students are guaranteed to enjoy the activities involved.

This experiment is easy to set up – providing the chemicals are available, and should take no more than about 30 mins. It can be done by students in groups of two or three.

Apparatus and chemicals

Eye protection

Each working group requires:

Beaker (100 cm^3)
Measuring cylinder (50 cm^3)
Disposable plastic cup
Metal spatula
Petri dish (or watch glass)
Water-based felt-tipped pen
Spirit-based felt-tipped pen
Disposable plastic gloves

Polyvinyl alcohol, (-[$CH_2CH(OH)]_n$-), 4% (or 8%) aqueous solution, 40 cm^3 (see note 1)
Borax, hydrated sodium tetraborate ($Na_2B_4O_7.10H_2O$), 4% (or 8%) aqueous solution, (**Low hazard**), 10 cm^3 (see note 1)
Food colour or fluorescein (**Low hazard**) (optional)
Hydrochloric acid, about 0.5 mol dm^{-3}, (**Low hazard** at this concentration), 20 cm^3 (optional) (see note 2)
Sodium hydroxide, about 0.5 mol dm^{-3} (**Corrosive**), 20 cm^3 (optional) (see note 2)

Technical notes

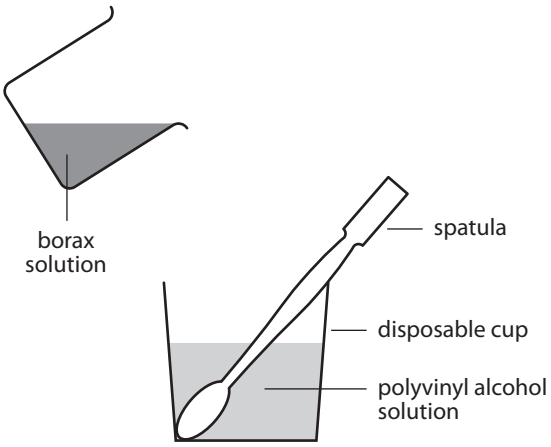
Borax, hydrated sodium tetraborate ($Na_2B_4O_7.10H_2O$) (**Low hazard**) Refer to CLEAPSS® Hazcard 14
Fluorescein (**Low hazard**) Refer CLEAPSS® Hazcard 32 and Recipe card 35
Hydrochloric acid (**Low hazard** at concentration used) Refer to CLEAPSS® Hazcard 47A and Recipe card 31
Sodium hydroxide (**Corrosive**) Refer to CLEAPSS® Hazcard 91 and Recipe card 65
Slime. Refer to CLEAPSS® Recipe card 59

1 Polyvinyl alcohol (PVA) can be high MW (about 120 000) or low MW (about 15 000). If high MW PVA is used, prepare a 4% solution by placing 960 cm^3 of water into a tall 1 dm^3 beaker. Measure out 40 g of high MW PVA and add this slowly to the beaker of water, with stirring. If low MW PVA is used, prepare an 8% solution by placing 920 cm^3 of water into a tall 1 dm^3 beaker. Measure out 80 g of low MW PVA and add this slowly to the beaker of water, with stirring.

   In each case, heat the mixture gently, stirring occasionally, until the solution clears. Avoid boiling the solution. After cooling, this solution can be poured into suitable smaller containers, which can then be sealed and stored indefinitely.

   If a 4% aqueous solution of PVA is used a 4% aqueous solution of borax will be required. If an 8% aqueous solution of PVA is used an 8% aqueous solution of borax will be required.

2 The hydrochloric acid and aqueous sodium hydroxide are best supplied in small glass bottles fitted with teat pipettes.



Procedure

HEALTH & SAFETY: Wear eye protection, and protective gloves if handling the slime.

a Place 40 cm^3 of the polyvinyl alcohol solution in the plastic cup.

b If supplied, add one drop of food colour or fluorescein dye to the solution. Stir well.

c Measure out 10 cm^3 of borax solution into the beaker and add this to the polyvinyl alcohol solution, stirring vigorously until gelling is complete. This gel is sometimes known as a 'slime'.

d Wearing disposable gloves, remove the slime from the cup and knead it thoroughly to mix the contents completely. Roll the slime around in your hand, gently squeezing the material to remove air bubbles at the same time. Alternatively, place the slime in a plastic bag and mix and squeeze the mixture from outside the bag.

Tests

e Test the properties of your slime in the following ways.

1 Pull the slime apart slowly. What happens?
2 Pull the slime apart sharply and quickly. What happens?
3 Roll the slime into a ball and drop it on to the bench. What happens?
4 Place a small bit of slime on the bench and hit it hard with your hand. What happens?
5 Write your name on a piece of paper with a water-based felt-tipped pen. Place the slime on top, press firmly, and then lift up the slime. What has happened to the writing and to the slime? Try the same again, this time using a spirit-based pen. Does this show the same effect?

Tests 6–8 below are optional.

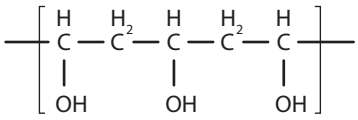
6 Place a very small piece of slime in a Petri dish. Add the dilute hydrochloric acid dropwise, stirring well after each drop. When you notice a change record the number of drops added and your observations.
7 Now add dilute sodium hydroxide solution to the same sample used above in 6, stirring after each drop. When you notice a change record the number of drops added and your observations.
8 Can tests 6 and 7 be repeated time and time again to give the same results?

Teaching notes

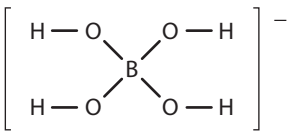
Tell students to keep the slime away from clothes as it can produce permanent stains. The slime can be stored in an air-tight container, such as a plastic bag with a twist-tie. It is advisable to dip the slime in some water before storing, to keep it from drying out. Slime gets dirty from handling and may become mouldy after several days. When this happens you should throw it away. Do not put it down the sink because it clogs the drain.

Slime-type materials are available under a variety of different brand names, and can be found in many toy stores. Slime is sometimes described as a reversible cross-linking gel. The cross-linking between the polymer chains of polyvinyl alcohol occurs by adding borax, $Na_2B_4O_7.10H_2O$ (sodium tetraborate).

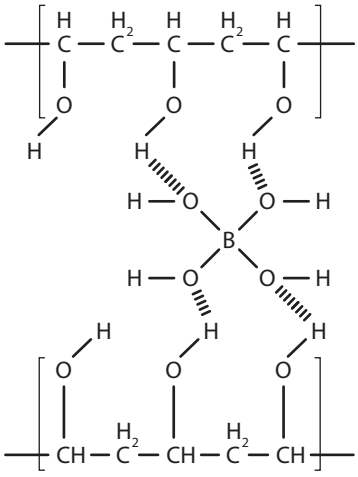
PVA glue contains the polymer polyvinyl alcohol (also called polyethenol) and has the structure:



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.



Slime is a non-Newtonian fluid that is dilatant – ie under stress, the material dilates or expands. Other well known stress-thickening materials are quicksand, wet sand on the beach, some printer's inks, starch solutions and 'Silly Putty'. Dilatant materials tend to have some unusual properties.

- Under low stress, such as slowly pulling on the material, it will flow and stretch. If careful, you can form a thin film.
- Pull sharply (high stress) and the material breaks.
- Pour the material from its container then tip the container upwards slightly, the gel self siphons.
- Put a small amount of the material on a table top and hit it with your hand, there is no splashing or splattering.
- Throw a small piece onto a hard surface; it will bounce slightly.

Adding acid to the slime breaks the crosslinking producing a liquid with lower viscosity. Adding alkali reverses the process and the slime should be regenerated.

Various types of slime have been manufactured. In this investigation you use the polymer polyvinyl alcohol, which is reasonably cheap and is readily available from suppliers because it is widely used as a thickener, stabiliser and binder in cosmetics, paper cloth, films, cements and mortars. In ethanol solution polyvinyl alcohol solution dries to leave a thin plastic film that is useful in packaging materials, especially as it is biodegradable.

Reference

This experiment has been reproduced from Practical Chemistry:
http://www.practicalchemistry.org/experiments/intermediate/polymers/pva-polymer-slime,153,EX.html

Useful resource

This website has a short video of preparing slime.
http://matse1.mse.uiuc.edu/polymers/e.html

This website gives a background on slime
www.madehow.com/Volume-6/Slime.html

This website contains more links
www.msm.cam.ac.uk/SeeK/slime.htm

(Websites accessed December 2009)