OBJECTIVES
1. Investigate cross-linking properties of polymers
2. Measure viscosity of a substance
3. Examine the relationship between cross-linking, viscosity and the onset of gelation in a polymer

BACKGROUND INFORMATION
PART 1
Poly (vinyl alcohol) chains dissolved in water may be held together by temporary covalent bonding using borate. When sufficient borate is used the mixture will undergo gelation and form slime. Since the borate serves to cross-link the PVA, the degree of cross-linking can be varied by changing the borate concentration.

PART 2
The falling ball viscometer is an old method for determining viscosities of Newtonian fluids. Though slime is a non-Newtonian fluid capable of exhibiting large normal forces, it is easy for students to appreciate that the more viscous is the mixture, the longer it takes a metal ball to fall a specified distance through it.

PART 3
One way of changing the concentration of borate available to hold the PVA chains together is to “disable” the borate by protonation with a strong acid. The titration of slime with sulphuric acid allows students to examine the relationship between cross-linking, viscosity and the onset of gelation.

PART 4
Since the “killing” of the slime is reversible, the addition of NaOH a little beyond the endpoint of the indicator allows reconstitution of the slime. This process of “killing” and reforming the slime can be repeated, but the quality of the gel changes and these gels tend to form two-phase mixtures with an opaque gel.

WHAT YOU NEED
- 300mL 7% PVA solution
- 15mL Concentrated sulphuric acid 1M
- 15mL Sodium hydroxide 1M
- 5mL Acid-base indicator (eg. Methyl orange)
- Food colouring
- Water
- 4x 250mL beakers
- 4x 100mL measuring cylinders
- Stop watch
- 4x stainless steel balls diameter ~1.59cm
- Glass stirring rod

Teachers notes:
- To make 100mL 7% solution of PVA add 7g of powdered or crystalline PVA (1 teaspoon=5g) to 100mL of water. Heat on hot plate with magnetic stirring for 2hrs or until solution dissolved.
- You can substitute PVA solution with PVA wood glue from your supermarket or craft shop. If using wood glue you will need to increase your concentration from 60ml to 95ml in each slime mixture.

WHAT TO DO

PART 1: PREPARATION OF GELS

Make sure you use Methyl Orange (acid-base indicator) in Slime 1 as this slime will be used in part 3 for titration of gel

1. Measure PVA, Water and Colouring into each of the 4x 250mL beaker according to proportions listed in the table below and stir.
2. Add Borax into each of the 250mL beakers according to the table and stir. As you stir the slime should start to form.

<table>
<thead>
<tr>
<th>Slime</th>
<th>Colour</th>
<th>PVA (mL)</th>
<th>Water (mL)</th>
<th>Borax solution (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methyl Orange</td>
<td>60</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Blue</td>
<td>60</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td>60</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>60</td>
<td>40</td>
<td>5</td>
</tr>
</tbody>
</table>

PART 2: DETERMINE THE VISCOSITY OF THE SLIME

3. Pour the four gel solutions into separate 100ml measuring cylinders.
4. Have your stopwatch ready.
5. Drop the stainless steel ball into the measuring cylinder and time the amount of time it takes for the ball to sink from the 70ml to 10ml mark
6. Record your findings in the table below.
PART 3: TITRATION OF THE GEL “KILLING SLIME”
7. Use slime 1 as this contains the acid-base indicator.
8. Pour slime from measuring cylinder back into the 250mL beaker.
9. Using a burette add 2.5ml of sulfuric acid at a time.
10. Record your findings in the table below.

OBSERVATIONS

<table>
<thead>
<tr>
<th>MH$_2$SO$_4$</th>
<th>pH</th>
<th>Indicator Colour</th>
<th>Gel Behaviour$^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0mL</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12.5mL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^*$Gel behaviours eg. Thick gel, gel, gel/liquid, liquid/gel, liquid

PART 4: RECONSTITUTION OF THE “SLIME”
11. Using the gel solution from part 3 add 2.5mL of Sodium hydroxide at a time until your slime has reformed to close to its original form.

QUESTIONS
Why would it be important to be able to change the property of a gel?

CURRICULUM
Key concepts:
S2.7, S2.8, S2.11, R5.1, R5.3. R5.4

REFERENCE