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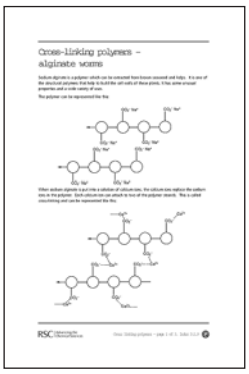
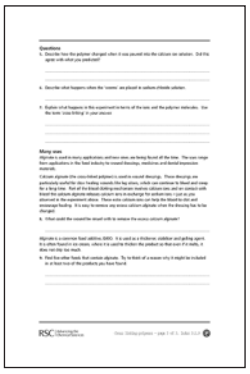
Cross-linking polymers – alginate worms





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This practical provides a fun look at cross-linking and a chance to explore some of the many and varied uses of sodium alginate.

Sodium alginate is a polysaccharide of repeating monosaccharide units, each containing a carboxylate ion:

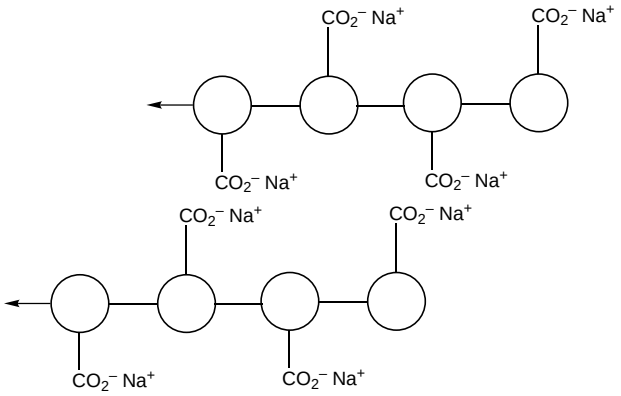

Figure 1 Structure of sodium alginate

The naturally occuring form of this polymer is alginic acid (the protonated form), which can be extracted from brown seaweed and kelp. It usually has a molar mass of around 240 000.

In this experiment, the sodium ions of sodium alginate are replaced with calcium ions. Since each calcium ion can bond to two carboxylate groups, the ions can cross-link the polymer chains, which results in the formation of an insoluble, gel-like substance.

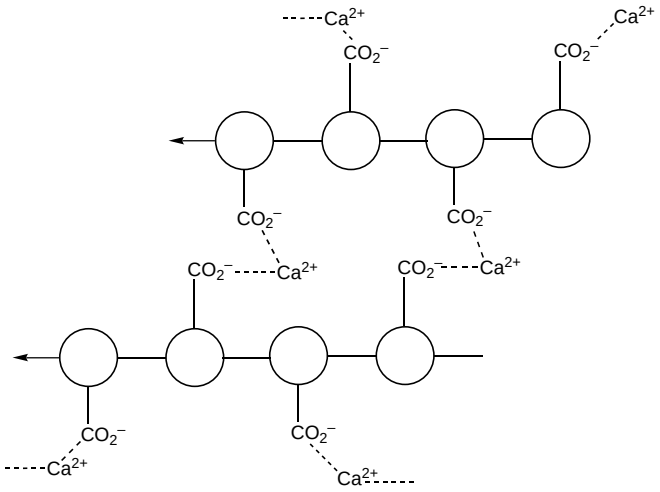

Figure 2 The cross-linked polymer

If the cross-linked alginate is placed in a solution of sodium ions, these replace the calcium ions and the gel-like worms fall apart again.

Equipment required

Per pair or group of students:

- 5 cm^3 sodium alginate suspension – see notes
- Dropping pipette
- 2 x 150 cm^3 beakers
- 100 cm^3 saturated sodium chloride solution – made in distilled water
- 100 cm^3 calcium chloride solution – 1 g calcium chloride per 100 cm^3 distilled water
- Labels for the beakers or pens to label the glass
- Eye protection.

Health and safety

Solid calcium chloride is an irritant. A solution of the suggested concentration is not an irritant.

Wear eye protection.

Notes

To make the alginate suspension, add 2 g sodium alginate to 100 cm^3 distilled water. Do not use tap water, especially in a hard water area. It is best to make the suspension at least a day in advance and allow it to stand overnight so that it becomes homogeneous. For this experiment, the results are clearer if a few drops of food colouring are added. This can either be done when making the suspension or students could do it themselves and perhaps be offered a choice of colours.

Gaviscon® can be used as an alternative to sodium alginate. This will give coloured and opaque worms as a result of the presence of other ingredients in the antacid, which can be quite fun. Any leftover Gaviscon® cannot be used medicinally.

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It is also possible to cross-link alginate with other ions. Both nickel(II) chloride and copper(II) chloride can be used. Nickel gives pale green and copper pale blue worms. These worms do not break down in the presence of sodium chloride and so are not suitable for this experiment but could be used to create a colourful demonstration. If you carry out such a demonstration, be aware that nickel salts are sensitisers. Avoid skin contact and wash your hands after use.

If the 'worms' are not removed from the calcium chloride straight away they can take a long time to break down in the sodium chloride. If left in the calcium chloride, the worms feel very different – they are much harder. The Gaviscon® worms break down faster in the sodium chloride solution than the sodium alginate ones.

It is also possible to try to make worms in sodium chloride solution. The Gaviscon® will form rather pathetic worms which disintegrate in time. The sodium alginate does not form worms at all if squirted straight into sodium chloride.

Disposal

The solutions can be filtered or strained and the worms put in the rubbish bin. The easiest way to do this is with a tea strainer.

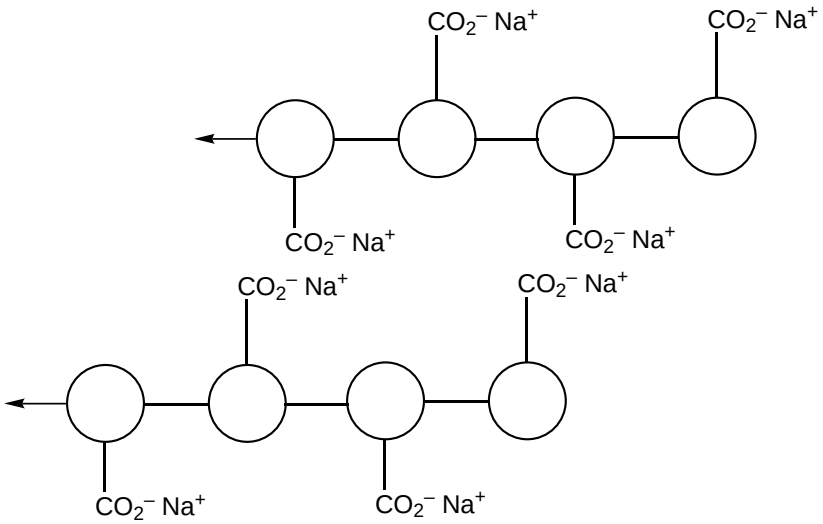
Answers to questions

1. The alginate or Gaviscon® is a viscous liquid.
2. a. Sodium ion: Na^+.
   b. Calcium ion: Ca^{2+}.
3. Calcium has two positive charges and can therefore attract/bond to two of the negatively charged ions on the alginate. Sodium has only one positive charge and can form only one bond with the polymer.
4. Students should be able to predict a thickening of the polymer.
5. The polymer thickens and becomes a solid. It should agree with the prediction.
6. When the worms are placed in sodium chloride solution they become much softer, get fatter and eventually fall apart.
7. The polymer is cross-linked when it is put into the calcium chloride solution. As the polymer chains are linked they are unable to move independently of each other and the material becomes a lot thicker and solidifies. When the worms are put into the sodium chloride solution, the sodium ions displace the calcium ions and the cross-links begin to fall apart. Eventually, when most of the calcium ions have been displaced, the worms turn back into a liquid.
8. Sodium chloride solution could be used to rinse the wound.
9. Foods listed could include: some fruit drinks and snack bars, various sauces, cheese spread and many other processed foods, stuffed olives. Alginate is almost always used as a gelling agent, a thickener or a stabiliser.

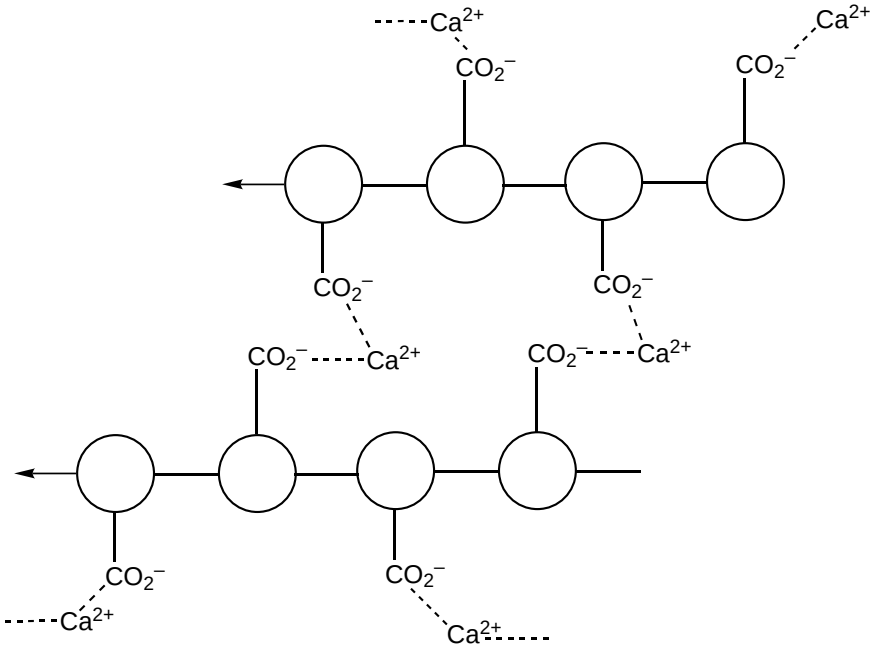
Cross-linking polymers – alginate worms

Sodium alginate is a polymer which can be extracted from brown seaweed and kelps. It is one of the structural polymers that help to build the cell walls of these plants. It has some unusual properties and a wide variety of uses.

The polymer can be represented like this:



When sodium alginate is put into a solution of calcium ions, the calcium ions replace the sodium ions in the polymer. Each calcium ion can attach to two of the polymer strands. This is called cross-linking and can be represented like this:



- Collect approximately 5 cm^3 sodium alginate suspension or Gaviscon® solution.

1. Describe the sodium alginate suspension or Gaviscon®.

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2. What is the formula of
   a. a sodium ion?

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   b. a calcium ion?

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3. Why can the calcium ion attach to two strands of the polymer, but the sodium ion to only one?

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4. Predict how you think the properties of the polymer will change when it is poured into a solution of calcium ions.

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Equipment required

- Approx 5 cm^3 sodium alginate suspension or Gaviscon®
- Dropping pipette
- 2 x 150 cm^3 beakers
- Approx 100 cm^3 sodium chloride solution
- Approx 100 cm^3 calcium chloride solution
- Labels for the beakers
- Eye protection.

Health and safety

Wear eye protection.

What to do

- Put the calcium chloride solution into one of the beakers and the sodium chloride solution into the other. Label the beakers clearly.
- Using the pipette, squirt the sodium alginate or Gaviscon® into the calcium chloride solution. You are aiming to make 'worms,' although you can make beads if you prefer.
- Remove a few of your worms straight away and put them into the beaker of sodium chloride solution.
- Swirl both beakers gently and observe what happens to the worms in each one. You can remove and squeeze the worms as well as observing their appearance. You will need to wait a few minutes for all the reactions to be complete.

Questions

5. Describe how the polymer changed when it was poured into the calcium ion solution. Did this agree with what you predicted?

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6. Describe what happens when the 'worms' are placed in sodium chloride solution.

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7. Explain what happens in this experiment in terms of the ions and the polymer molecules. Use the term 'cross-linking' in your answer.

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Many uses

Alginate is used in many applications and new ones are being found all the time. The uses range from applications in the food industry to wound dressings, medicines and dental impression materials.

Calcium alginate (the cross-linked polymer) is used in wound dressings. These dressings are particularly useful for slow healing wounds like leg ulcers, which can continue to bleed and weep for a long time. Part of the blood clotting mechanism involves calcium ions and on contact with blood the calcium alginate releases calcium ions in exchange for sodium ions – just as you observed in the experiment above. These extra calcium ions can help the blood to clot and encourage healing. It is easy to remove any excess calcium alginate when the dressing has to be changed.

8. What could the wound be rinsed with to remove the excess calcium alginate?

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Alginate is a common food additive, E400. It is used as a thickener, stabiliser and gelling agent. It is often found in ice cream, where it is used to thicken the product so that even if it melts, it does not drip too much.

9. Find five other foods that contain alginate. Try to think of a reason why it might be included in at least two of the products you have found.

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