Polymers

Student Notes

Polymers is funded as part of the Reach and Teach educational programme supported by the Wolfson Foundation

THE WOLFSON FOUNDATION

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Activity 1: Developing a glue

Procedure

HEALTH & SAFETY: Wear eye protection

Making the glue

a Measure 100 cm^3 of milk and 20 cm^3 of vinegar into a beaker. Place the beaker on a tripod and gauze and heat over the Bunsen burner. Stir constantly until small lumps start to form. Stop heating, but keep stirring until no more lumps form.

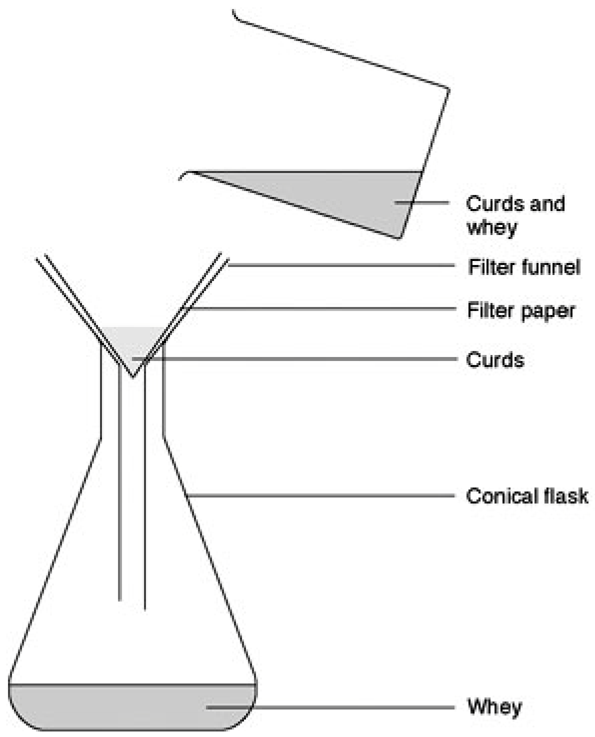
b Let the lumps settle, then decant the liquid from the top. Filter the rest of the mixture and keep the solid part (which is called the curds.) Wash the beaker.

c Gently squeeze off any excess liquid from the curds and then put them into the beaker. Add 15 cm^3 of water and stir until the mixture is smooth.

d Add about half a spatula of the base and check that the mixture is neutral using indicator paper. If it isn't, add more base until it is. This is the glue.

e Use the glue to stick together two lolly sticks. Only have 2 cm of the sticks overlapping and stuck together. Label the lolly sticks with the milk and base used.

f Make other glues by using different bases and milks and use them to stick together more lolly sticks.



Testing the glue

a Arrange two tables or chairs about 10 cm apart. Lay your glued lolly sticks so that they form a bridge between the two.

b Hang a weights hook onto the lower of the two lolly sticks as close to the glued join as you can. Add weights about 10 N at a time and record the force required to break the glue.

Student questions

Here are some questions to answer.
1 What do you think is the purpose of the vinegar in this experiment?

2 Why is sodium hydrogen carbonate added?

3 What is the gas given off when the sodium hydrogen carbonate is being added?

4 Use a search engine to find information about casein, which is present in milk. What type of substance is casein?

Activity 2: Latex

Making rubber from latex. To make a rubber ball, place $10cm^3$ of latex solution in a small beaker. Add about 5 cm^3 of vinegar and stir (citric acid solution works just as well). This causes cross-links to form and a rubber ball forms quickly. Wearing vinyl protective gloves and eye protection, pick out the rubber ball, place it in a bowl of water and squeeze well to remove excess latex. Dry the ball with a cotton cloth. The ball can be tested for its elastic properties in a bounce height experiment.

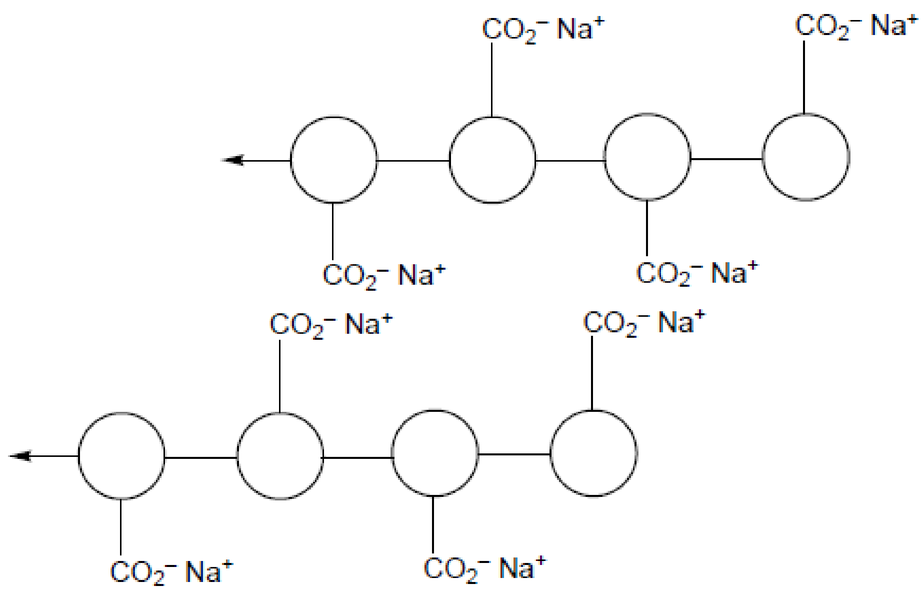
Try making foam rubber by adding one spatula of sodium hydrogen carbonate before you add the vinegar. Bubbles of carbon dioxide permeate the rubber as it forms. Compare this to normal rubber in a bounce test.

To make an elastic band, place a pencil or test tube end in the latex solution so that the end is well covered and then dip the end in a beaker of vinegar, followed by a beaker of water. The rubber can be rolled off the end as a ring. It has been suggested that you can test the strength of the rubber band in a simple stretch test.

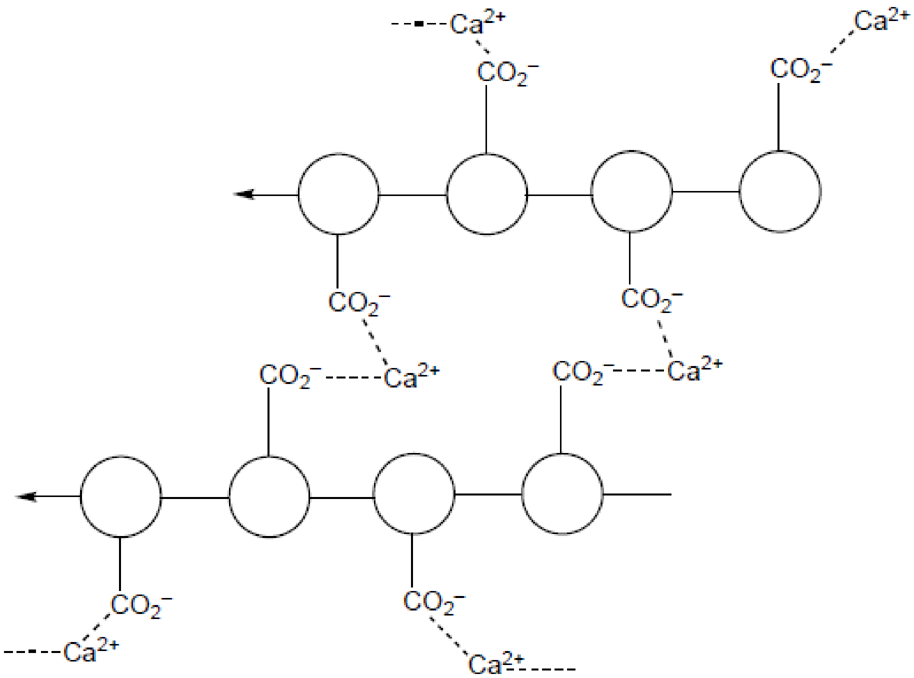
Activity 3: Cross-linking polymers – alginate worms

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 (**low hazard**) See CLEAPSS Hazcard 95C or Gaviscon® (**low hazard**)
- Dropping pipette
- 2 x 150 cm^3 beakers
- Approx 100 cm^3 saturated sodium chloride solution (**low hazard**) See CLEAPSS Hazcard 47B
- Approx 100 cm^3 1% w/v calcium chloride solution (**low hazard**) See CLEAPSS Hazcard 19A
- 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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Activity 4: Making polylactic acid

Polylactic is another very versatile polymer that students will meet in their everyday life. It is even used as a packaging material as well as being a food additive!

Lactic acid can be made from glucose or other sugars by bacteria or it can be obtained directly from milk. It is added to food and drink products, but it can also be used as the starting point for making a plastic called polylactic acid. Polylactic acid can also be made from petrochemicals (chemicals from oil).

Polylactic acid is used for making items as diverse as packaging materials and surgical thread.

In this activity you will make some polylactic acid and discover why it has an ever-increasing number of uses.

Making the plastic

This activity allows you to join about 10–30 lactic acid molecules together to begin to make a polymer. In industry several hundred molecules are joined together and so the properties of the polymer product are different from those of the polymer you will make.

You will need

- Test-tube
- Test-tube holders
- Bunsen burner and heat proof mat
- Anti-bumping granules
- Lactic acid (**Irritant**) See CLEAPSS Hazcard 38C
- Hydrochloric acid 2 mol dm^{-3} (**Irritant**) See CLEAPSS Hazcard 47A
- Petri dish or white tile
- Eye protection.

Health and safety

Wear eye protection.

The boiling point of lactic acid is 122 °C. It will get very hot during the experiment. Be careful not to get it on your skin. If you do, put your skin under the cold tap immediately and then tell your teacher.

What to do

- Fill a test-tube 1/5 full with lactic acid.
- Add 5 drops of hydrochloric acid and two anti-bumping granules.

- Put the test-tube holders around the top of the test-tube and begin to heat the tube. Be careful not to point the open end of the test-tube at anyone in the room – try to point it towards a wall.
- Keep the mixture gently boiling and stir or gently shake the tube occasionally to mix the contents.
- After about 10 or 15 minutes the mixture will begin to go a yellowish colour. Leave it for another minute or two and then quickly pour the contents of the tube out onto either a petri dish or a white tile.
- Leave the mixture to cool.

Questions

1. If you have successfully polymerised the lactic acid, what will have happened to the size of the molecules?

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2. Look at the lactic acid you started with and your product. Describe the differences in properties between them (be careful – your product will be very sticky).

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3. Try to explain the change in properties in terms of the size of the molecules in the materials.

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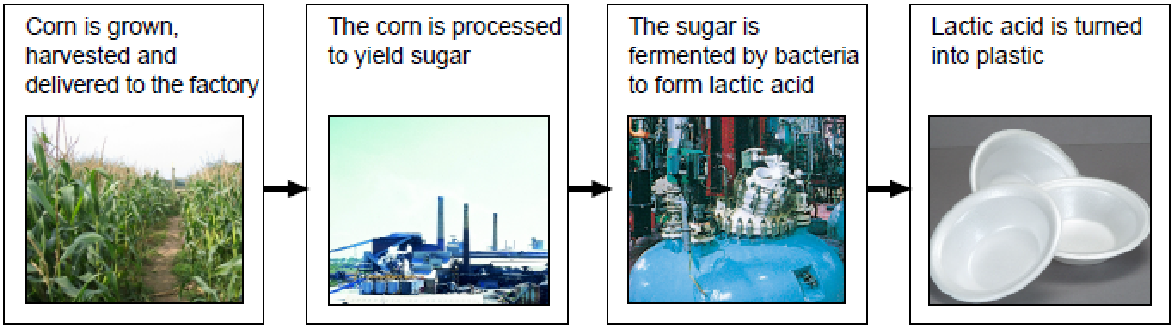
Using polylactic acid

Polylactic acid is commercially manufactured in the USA and in Japan. It can be made into consumer items as diverse as disposable plates and cups, packaging and clothing. The lactic acid used to make it is derived from corn. The process used to make it involves both biotechnology and chemistry.



1. What are most plastics are made from? (What is the raw material?)

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2. What is the raw material for making polylactic acid?

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When the plastic polyethene is made, energy is used to make the ethene and to turn the ethane into polyethene. As ethene is a gas, it is usually piped from place to place. When polylactic acid is made, the corn has to be transported from the field to the factory and the distances involved can be vast. The PLA (polylactic acid) plant in Nebraska is in the middle of a huge corn field to minimise transportation costs.

3. Look at the stages of the process for making polylactic acid shown above. Which of the stages uses energy? Where is this energy likely to come from?

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To make a kilogram of polyethene, 81 MJ worth of fossil fuels is required. This includes 29 MJ worth of raw materials and 52 MJ of fuels that are burnt to release the energy needed for the manufacturing process. To make a kilogram of polylactic acid, 56 MJ of fossil fuels is required.
All of this is burnt to release energy. When fossil fuels are burnt, carbon dioxide is released into the environment. When a fossil fuel is turned into plastic, the carbon dioxide is not released but is locked in the plastic and only released into the environment if that plastic is burnt or decomposes.

4. When polylactic acid and polyethene are made, which results in the most carbon dioxide being released to the environment?

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5. Why is this less of a problem than it might seem at first? (Hint: think about what the polylactic acid is made from).

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6. Polylactic acid is about five times as expensive as polyethene. Why do you think this is?

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The chemical industry is trying to make itself 'greener.' There are three main ways it is likely to do this:

- Use less oil
- Develop cleaner chemical processes
- Avoid damaging ecosystems.

It is also important to reduce any risk to employees working in the chemical industry and to the users of its products.

7. Which of the two products (polyethene and polylactic acid) uses less oil?

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Although the oil saving is not much at the moment, it is hoped that in time the process for making polylactic acid will become more efficient and use less oil. This could be achieved by burning leftover parts of the corn to produce energy or by scientists spending a lot of time doing research to find a better way to make the product. Improvements have already been made that have significantly reduced the cost of polylactic acid.

However, businesses have to make money and there is no advantage for a manufacturer who develops an environmentally friendly product that is very expensive to produce. A manufacturer could spend a lot of money on research and not manage to find a way of using less energy. Consumers are not normally willing to pay more for an item just because it is 'environmentally friendly.'

8. Do you think the government should do something to help companies who make 'greener' packaging? Packaging that is not degradable could be taxed, for example, or the government could pay for some of the research needed. Remember – this means that you will end up paying for it eventually! Things wrapped in plastic may become more expensive or taxes may go up, which could lead to your parents having less money to spend on you. Explain your answer.

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One of the main benefits of polylactic acid is that it is biodegradable. Polyethene is too, but it will probably take hundreds of years to biodegrade. Polylactic acid can be put into a compost heap and will degrade within a few months.

9. Where does most rubbish in Britain end up? What happens to it there?

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10. Which products would it be best to make out of polylactic acid. How would you market those products?

Continuing the theme of familiar addition polymers, the following activity investigates the use of starch from potatoes as a source material. As with polylactic acid the polymer formed is very versatile and has many uses.

Activity 5: Making a plastic from potato starch – extracting starch

In this activity you are going to extract starch from potatoes. This starch can be used to make a plastic.

A similar process is used in industry to extract starch, which is then used in a number of products, including food and packaging.

You will need:

- Approx 100 g clean (not muddy) potatoes
- Grater
- Tea strainer
- Distilled water
- Pestle and mortar
- 100 cm3 measuring cylinder.

What to do

- Grate about 100 g potato. The potato does not need to be peeled, but it should be clean.
- Put the potato into the mortar and add about 100 cm_3 distilled water. Grind the potato carefully.
- Pour the liquid off through the tea strainer into the beaker, leaving the potato behind in the mortar. Add 100 cm^3 water, grind and strain twice more.
- Leave the mixture to settle in the beaker for 5 minutes.
- Decant the water from the beaker, leaving behind the white starch which should have settled in the bottom. Add about 100 g distilled water to the starch and stir gently. Leave to settle again and then decant the water, leaving the starch behind. You can now use the starch to make a plastic film.

Making a plastic from potato starch – making the plastic

In this activity you will make a plastic film from potato starch and test its properties.

Potato starch is a polymer made of long chains of glucose units joined together. It actually contains two polymers:

- Amylose, which is a straight chain of glucose units
- Amylopectin, which is a branched polymer, also made of glucose units.

The amylopectin prevents the starch from becoming plastic-like. You will use hydrochloric acid to break down the amylopectin and change the stucture and properties of the polymer.

You will make two different batches of the potato plastic. In one you will add some propan-1,2,3-triol (also known as glycerol), which will act as a plasticiser. In the other batch, you will leave the propan-1,2,3-triol out.

Making the potato plastic

You will need:

- Eye protection
- 250 cm^3 beaker
- Large watch glass
- Bunsen burner and heat proof mat
- Tripod and gauze
- Stirring rod
- Potato starch
- Propan-1, 2, 3-triol (**Low Hazard**) See CLEAPSS Hazcard 37
- Hydrochloric acid 0.1 mol/dm3 (**Low hazard**) See CLEAPSS Hazcard 47A
- Sodium hydroxide 0.1 mol/dm3 (**Irritant**) See CLEAPSS Hazcard 091
- Food colouring
- Petri dish or white tile
- Universal Indicator paper
- Eye protection
- Access to a balance
- 25 cm^3 measuring cylinder
- 10 cm^3 measuring cylinder.

Health and safety

Wear eye protection.

What to do

- Put 25 cm^3 water into the beaker and add 2.5 g potato starch, 3 cm^3 hydrochloric acid and 2 cm3 propan-1,2,3-triol.
- Put the watch glass on the beaker and heat the mixture using the Bunsen burner. Bring it carefully to the boil and then boil it gently for 15 minutes. Make sure it does not boil dry – if it looks like it might, then stop heating.
- Dip the glass rod into the mixture and dot it onto the indicator paper to measure the pH. Add enough sodium hydroxide solution to neutralise the mixture, testing after each addition with indicator paper. You will probably need to add about the same amount of sodium hydroxide as you did acid at the beginning (3 cm^3).
- If you wish you can add a drop of food colouring and mix thoroughly. Be careful not to spill the food colouring – it stains.
- Pour the mixture onto a labelled petri dish or white tile and push it around with the glass rod so that you have an even covering.
- Label your mixture and leave it to dry out. This will take about 1 day on a radiator or sunny windowsill or two days at room temperature.

Repeat the steps described above, but leave out the propan-1,2,3-triol. Make sure you label your mixtures so that you know which one contains propan-1,2,3-triol and which does not.

Making a plastic from potato starch – examining your plastic

Look carefully at your two petri dishes containing potato plastic.

1. Describe carefully the properties of each of the substances you have made.

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2. What difference has adding the propan-1,2,3-triol made?

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The propan-1, 2, 3-triol is acting as a plasticiser. Plasticisers are used in commercial products to change the properties of the polymer, just as you have used the propan-1,2,3-triol to change the properties of the potato plastic. The propan-1,2,3-triol gets in between the polymer chains and prevents them from lining up in rows to form a crystalline structure. When the polymer becomes crystalline, it also becomes brittle and inflexible. You can think of the plasticiser as a small molecule that gets between the polymer chains and helps them to slide easily over each other so that the polymer behaves like a plastic.

3. Draw a diagram of the polymer chains with and without the propan-1,2,3-triol and use it to help you explain why the potato plastic has very different properties when propan-1,2,3-triol is present. Label which one is which.

Use a simple line like this to represent a polymer chain:

and like this to represent propan-1,2,3-triol.

Using plastics from potato starch

1. Do you think the plastic you made from potato starch will be biodegradable? Explain your answer.

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2. How could you test your plastic to find out?

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Extracting starch from potatoes takes a lot of energy. You had to grate the potatoes, grind them and rinse them several times. Similar processes are used in industry to extract starch, although sweetcorn (maize) is used more often than potatoes. The leftover bits are often used in animal feed so that none of the material is wasted.

3. In industry, where would the energy needed to extract the starch come from?

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4. What are most plastics made from? (What is the raw material used to make them?)

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Plastics made from plants or other living things are known as bioplastics. 'Bioplastic' does not mean the same thing as 'biodegradable plastic'. Some biodegradable plastics are made from oil and some bioplastics are not biodegradable.

5. Explain the meaning of the terms bioplastic and biodegradable.

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6. Write a list of the advantages of making plastics for which the raw material comes from plants.

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7. What are the disadvantages? (Hint: think about growing the plants.)

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Your starch plastic will dissolve in water if you leave it overnight.

8. What effect will this solubility have on the number of things that this plastic can be used for? Write down three things for which it could not be used and some things for which it could.

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To try to make starch more useful, researchers have tried blending it with other plastics like polythene. They hoped that this would make the overall product more biodegradable than polythene on its own. Unfortunately, this was not the case. The plastic tended to fall to bits but the pieces were less biodegradable than ordinary starch.

More recently, a scientist called Catia Bastioli from Italy has taken starch treated in the same way that you have treated it (with acid and propan-1,2,3-triol) and mixed it with the polymer PVA (used in white glue). The polymer that results is biodegradable but also water soluble. This means that its use is limited to things like packing dry goods, or replacing polystyrene foam, which is not biodegradable and is made from oil.

The method used to turn the starch into small pieces of foam packaging material is similar to the technique used to make foods such as Rice Krispies and Coco Pops.

Name of product	Price in £ per kg
Starch/PVA blend	3.40–4.40
polythene	0.50–0.60
polystyrene	0.60

9. The letter below was sent to a magazine. The editor does not know much about science and so has asked you to write a reply to be published in the next edition. Make sure that your reply:

- Uses accurate scientific information
- Is clear and concise
- Answers the question.

You may find the following website helpful when researching your answer. If you use information from a website, do not forget to think about whose website it is and if it is likely to be biased. If so, what effect this bias might have on the information on the site.

http://www.greenlightproducts.co.uk

Dear Editor

I try to be as environmentally-friendly as I can and I like to encourage others to do the same. I found out recently that it is possible to make plastics out of starch from plants, but most plastics are still made out of oil. I am horrified and wondered if you know why this is?

Yours sincerely

Anne Other

Activity 6: Experiments with a smart material – hydrogels

A smart material is one that changes shape in response to changes in its environment. Hydrogels are smart materials and their properties are exploited in a number of products that are currently available on the market. Chemists are working to develop other applications for this unusual type of material.

You are going to investigate three readily available products that contain a hydrogel: disposable nappies, plant water storage crystals ('water crystals') and hair gel. Record detailed observations as you carry out each experiment.

Plant water storage crystals – part 1

You will need

- 1 teaspoon of water crystals
- Large beaker (at least 1 dm^3) or plastic tub
- 500 cm^3 concentrated tea.

What to do

- Estimate the volume of your water crystals.
- Put about 500 cm^3 of the tea into the beaker or tub. Add 1 tsp of water crystals, stir gently and leave for at least half an hour (or overnight).

Plant water storage crystals – part 2

You will need

- Your water crystal and tea mixture from part 1
- Sieve (or a large funnel lined with a paper towel or large piece of filter paper)
- 2 x 250 cm^3 beakers
- Salt solution
- Distilled water
- Dessert spoon
- Piece of white paper
- 2 x stirring rods
- Tea strainer (if you have not got a sieve)
- 2 petri dishes.

What to do

- Sieve your water crystal mixture. It is best to do this over a large tub rather than over the sink in case you drop the sieve. Carefully wash the gel crystals once or twice in water to remove any excess tea. Estimate the new volume of your crystals.
- Place the two 250 cm^3 beakers on a piece of white paper.

- Put two dessert spoons of your gel crystals into each beaker, estimate their volume and then add about 200 cm^3 salt solution to one beaker and about 200 cm3 distilled water to the other. Label the beakers. Keep the remaining gel crystals.
- Stir the mixtures gently – use a separate stirring rod for each one so that the solutions are not ontaminated. Leave for 10–15 minutes, stirring occasionally.
- Place the two petri dishes on the white paper. Pour a little of your solutions into the petri dishes. Use a tea strainer to prevent any crystals getting into the petri dishes.
- Note the colour of each liquid.
- Sieve each of the remaining mixtures separately, discarding the excess liquid and returning the crystals to the beakers. Estimate the new volume of crystals in each beaker.

Hair gel

You will need

- Hair gel
- Salt
- Petri dish
- Teaspoon or spatula.

What to do

- Put a large teaspoonful of hair gel onto the petri dish lid.
- Gently sprinkle salt from a spatula over the hair gel.

Disposable nappy

You will need

- A disposable nappy
- Scissors
- A large ice cream tub or similar container
- Distilled water
- Salt
- Dessert spoon or similar measure
- A stirring rod or spoon
- A large beaker (at least 600 cm^3)
- Eye protection
- Gloves if you have sensitive skin.

What to do

- Cut the middle section out of the nappy. You want the thicker piece which is designed to absorb urine. Discard the other piece.

- Make sure your ice cream container is completely dry – wipe it with a paper towel if necessary. If there is any moisture in the tub the experiment will not work properly.
- Wear eye protection for the next step. Put the centre piece of the nappy into the ice cream container and gently take it apart. You should start to see small white grains coming away from the nappy and this is what you are trying to collect. Keep gently pulling the nappy apart until you have collected as many of the grains as you can. Do not do this roughly or you will lose your product and put a lot of dust and fluff into the air. Avoid breathing in any dust you do create.
- Remove and dispose of all the fluff and other parts of the nappy, keeping the white grains in the bottom of the tub. The grains are heavier than the other materials and fall to the bottom of the heap, which makes it easier to separate them out.
- Estimate the volume of the grains.
- Pour the grains into the large beaker and add about 100 cm^3 distilled water (you can just use the markings on the beaker to measure the volume). Stir the mixture and keep adding distilled water until no more can be absorbed. Stir between each addition of water. Estimate the final volume of the hydrogel.
- Add a dessert spoonful of salt and stir.

Summary

Write a summary of what happened in each of your experiments.

What have you learnt about hydrogels?

Can you explain any of their unusual properties?

Hydrogels

Technician notes

Each experiment will require:

Part 1

Tea

1 teaspoon of water crystals (phostrogen Swellgel)

1 dm3 beaker

500 cm3 strong tea (1 bag)

Part 2

Tea

Plastic sieve

2 x 250 cm^3 beakers

200 cm^3 sat NaCl soln

Distilled water

Plastic spoon
2 x petri dishes

Hair gel
1 teaspoon of cheapest hair gel
Salt
Petri dish
Teaspoon

Disposable Nappies
Ultra-absorbant nappy
Scissors
Ice cream tub (or similar)
Distilled water
Salt
Dessert spoon
Large beaker (at least 600 cm3)
Disp gloves

Hydrogel & sugar
Plant storage crystals as before
Sugar
Distilled water
2 x 250 cm^3 beakers
Sieve

Hydrogels and how they work

1. How much did the volume of the hydrogel in your experiments increase when it was put into water?

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2. What happened to the volume of the hydrogel when salt was added?

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3. Why is the hydrogel a 'smart material'?

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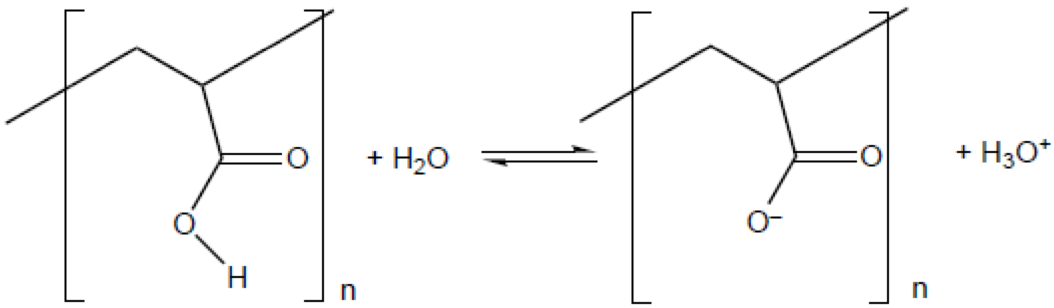
Understanding the structure and bonding of hydrogels helps to explain their properties. This in turn helps chemists to develop new hydrogels and find further uses for them.

Hydrogel structure

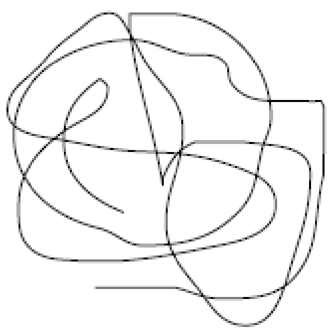
The hydrogel you have used is a polymer of a type of substance called a carboxylic acid. The acid groups stick off the main chain of the polymer, as shown in the diagram below.

When the hydrogel is put into water these acid groups react, the hydrogen atom comes off and the polymer chain is left with several negative charges along its length.

(Note: H_3O^+ is another way of writing H^+ in solution and shows that an acid is present.)



A polymer chain in solution tends to coil up so it looks like this:



However, the hydrogel polymer chain now has several negative charges along its length.

4. What will the negative charges do to each other?

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5. What effect will this have on the polymer chain?

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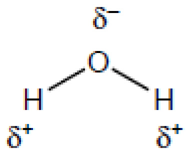
This diagram shows a water molecule.



6. What will happen to the water molecules when they get near the polymer?

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Both of these effects mean that the molecules of the polymer get larger as they get wet. This makes the solution more viscous because the polymer resists the flow of the solvent molecules around it.

Quite why the polymer absorbs so much water is still not fully understood.

Drug delivery and smart materials

Research is currently being undertaken to find out whether it is possible to use hydrogels and similar materials as a drug delivery system – a way to get drugs and medicines to where they are required in the body.

1. What methods are currently used to get drugs and medicines into the body?

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2. If a pill is swallowed, where does it go in the body?

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These methods can cause a number of problems. While all drugs are rigorously tested to make sure they are safe for the vast majority of people, many drugs cause bad reactions in a few people. The negative effects range from an upset stomach to serious allergic reactions. Chemists are now trying to develop a delivery system that will target a drug at the particular site where it is required. For example, if you have a bad cut on your leg and take antibiotic pills, the drug travels all round your body and not just to your cut leg. This increases the risk that the drug will cause problems. If the drug is only released at the cut then the likelihood of an adverse reaction is reduced. When the drugs are extremely strong, such as those used in chemotherapy to treat cancer, the possible side effects are wide ranging and include hair loss, severe stomach upset and lethargy. Targeting the drugs so that only the cancer cells are affected is a major goal in current research. Since drugs can be toxic to the body, the aim is to place them in a non-toxic carrier so they can pass through the body without causing any damage. The carrier needs to be smart so that it will release the drug at the required site and nowhere else. Chemists are investigating a wide range of potential carriers, including hydrogels.

The experiment you did with tea and hydrogel is a model of this type of drug delivery system. The drug is first loaded onto the carrier and then it is released at the right location.

3. In this model, which is the drug and which is the carrier?

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4. What happens to the hydrogel when it is soaked in tea solution? Give as much detail as you can.

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5. What happens to the tea in the hydrated crystals when they are soaked in salt solution? What happens to it if the crystals are soaked in distilled water? Explain your observations in as much detail as you can.

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In this model, the presence of the salt changes the behaviour of the 'carrier,' causing it to release the 'drug.' As more is understood about exactly how drugs work, research is focusing on how to deliver them in a way that ensures they make their active ingredients available at the time and place required by the body.

One type of substance being studied for use in carriers is microgels. These are similar to hydrogels but the particles are far smaller, often only up to 100 nm in diameter. This is an example of nanotechnology.

6. If the particles are very small, what effect will this have on the overall surface area of the carrier and on the rate at which the drug is released when the conditions are right?

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Hydrogels and microgels can also change shape and release a drug in response to a change in pH or temperature. Conditions such as temperature, saltiness or ionic concentration and pH can all be different in an infected or diseased area of the body than under normal conditions. If chemists can understand both how the disease operates in the body and how the microgels and hydrogels behave in different conditions it should be possible for them to target drugs accurately at the sites where they are required.

The previous activities have focussed upon addition polymers and their properties. Activity 7 demonstrates the manufacture of a condensation polymer, in this case nylon. The experiment clearly illustrates the idea of two different monomers bonding alternatively and eliminating a small molecule, a condensation product. It is important to remind students that although it is called a condensation product, it is not necessarily a water molecule, it can be hydrogen chloride as in this example.

Activity 7: Making nylon – the 'nylon rope trick'

Topic

Polymerisation.

Description

A solution of decanedioyl dichloride in cyclohexane is floated on an aqueous solution of 1,6-diaminohexane. Nylon forms at the interface and can be pulled out as fast as it is produced forming a long thread – the 'nylon rope'.

Apparatus

- Eye protection
- Disposable gloves
- One 25 cm^3 beaker.
- A pair of tweezers.
- Retort stand with boss and clamp.

Chemicals

The quantities given are for one demonstration.

- 2.2 g of **1,6-diaminohexane** (hexamethylene diamine, hexane-1,6-diamine, H2N(CH2)6NH2). (**liquid – corrosive; solution** (at concentration below) – **low hazard**) See CLEAPSS Hazcard 3B
- 1.5 g of **decanedioyl dichloride** (sebacoyl chloride, ClOC(CH2)8COCl). (**corrosive**) See CLEAPSS Hazcard 41
- 50 cm^3 of **cyclohexane**. (**highly flammable, harmful**) See CLEAPSS Hazcard 45B
- 50 cm^3 of deionised water.

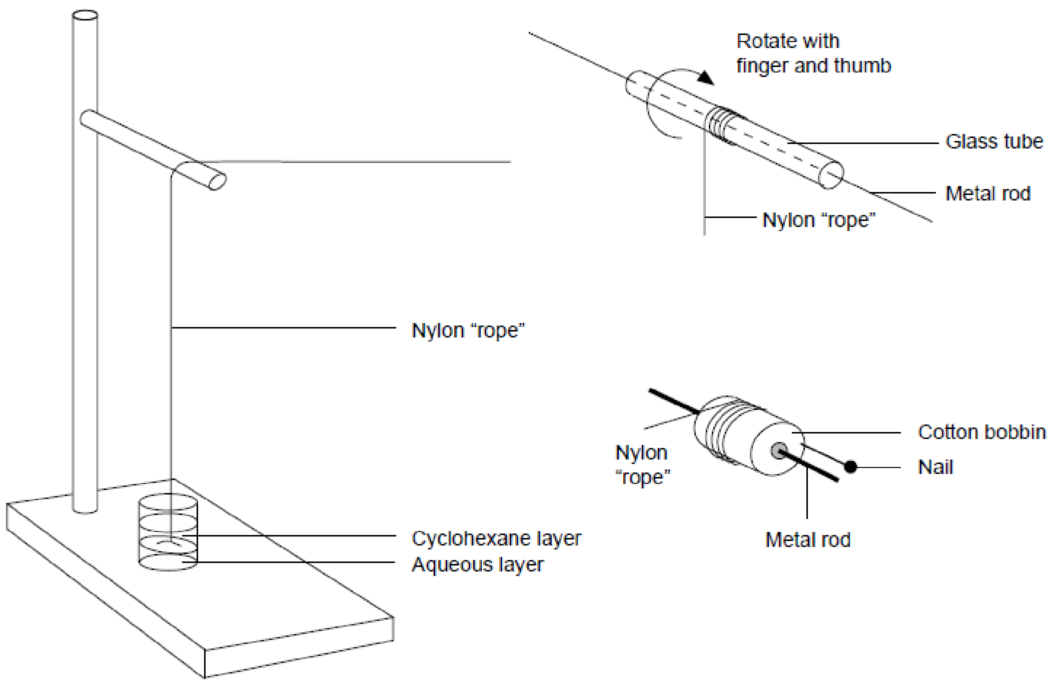
Safety

- Wear eye protection.
- Wear disposable gloves.

Method

Pour 5 cm^3 of the aqueous diamine solution into a 25 cm^3 beaker. Carefully pour 5 cm^3 of the cyclohexane solution of the acid chloride on top of the first solution so that mixing is minimised. Do this by pouring the second solution down the wall of the beaker or pour it down a glass rod. The cyclohexane will float on top of the water without mixing. Place the beaker below a stand and clamp as shown (see figure).

A greyish film of nylon will form at the interface. Pick up a little of this with a pair of tweezers and lift it slowly and gently from the beaker. It should draw up behind it a thread of nylon. Pull this over the rod of the clamp so that this acts as a pulley. Continue pulling the nylon thread at a rate of about half a metre per second. It should be possible to pull out several metres. Take care, the thread will be coated with unreacted monomer and may in fact be a narrow, hollow tube filled with monomer solution. Wearing disposable gloves is a wise precaution.



The nylon rope trick

Theory

The reaction is a condensation polymerisation

$nH_2N(CH_2)_6 NH_2 + nClOC(CH_2)_8COCl \rightarrow H_2N[(CH_2)_6NHCO(CH_2)_8]_nCOCl + nHCl$

The nylon formed is nylon 6 –10 so called because of the lengths of the carbon chains of the monomers. Nylon 6 –6 can be made using hexanedioyl dichloride (adipoyl chloride).

The diamine is present in excess to react with the hydrogen chloride that is eliminated. An alternative procedure is to use the stoichiometric quantity of diamine dissolved in excess sodium hydroxide solution.

Glossary

Below are some of the terms used within this document:

Term	Definition
Addition	The reaction between monomers of the same type containing a double bond. Only one product is formed.
Condensation	The reaction between two different monomers that results in a chain of alternating monomers. Each reaction results in a secondary product consisting of a small molecule.
Monomer	A small reactive molecule.
Plasticiser	A chemical substance that alters the properties of a polymer.
Polymerisation	The joining together of many monomers.

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