Te Kete Aronui
Aspire Inquire Inspire

The MacDiarmid Institute
for Advanced Materials and Nanotechnology

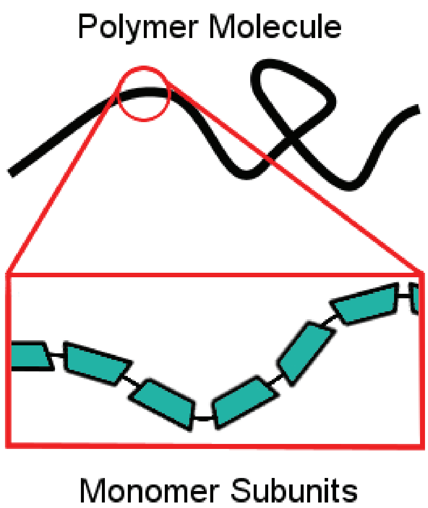
Kōrero with Scientists

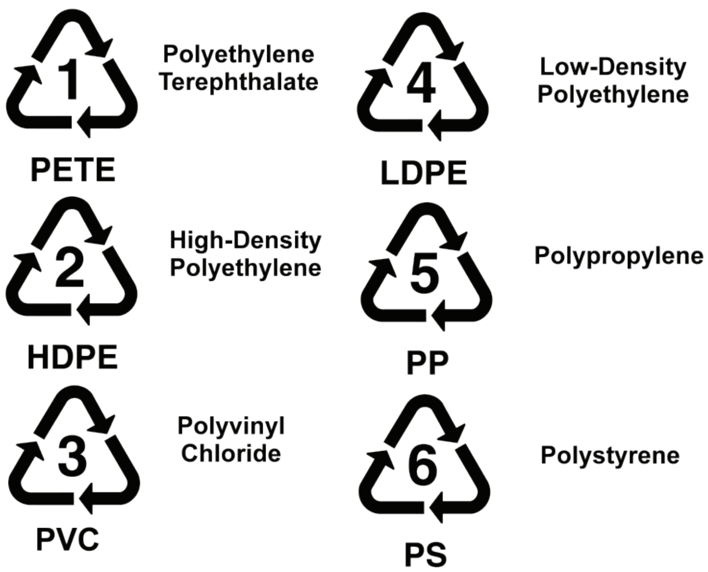
Polymer Chemistry.

Teachers' Guide.

Introduction :

Polymers are long molecules made up of many repeated subunits joined end-to-end. Their name comes from Greek: poly (many) and mer (parts). Polymers are found throughout nature: examples include proteins and DNA. The starch found in vegetables and the cellulose found in trees (and paper) are polymers made from many sugar molecules joined end-to-end; you may have heard the called poly saccharides which means 'many sugars'.





Man-made polymers are usually known as plastics. Examples include nylon, polyvinyl chloride (known as PVC, or vinyl), Bakelite, polystyrene, polyethylene and polypropylene. Plastics have a huge variety of uses but are most commonly found in clothing and packaging – you can identify the type of plastic used in most bottles and containers by checking its recycling code.

The properties that a polymer has depends on a number of factors such as the length of the polymer chain, the type of subunits used, and whether there are any links between separate polymer chains. Chemists can fine tune these factors to design polymers suitable for different tasks. In this guide we will explore several polymers and examine their properties.

Ideas for investigations:

1. Prepare slime and investigate its properties

PVA (polyvinyl alcohol) is a water-soluble polymer often used as a glue in paper-craft and wood working. PVA glue is a thick liquid – in this experiment we will use borax to create a slime sample, demonstrating how chemists' can make a polymer more solid-like by adding 'cross-links'.

Equipment and consumables

- PVA glue – available from stationery shops and hardware stores.
- Water.
- Plastic cups.
- Plastic spoons/popsicle sticks for stirring.
- Paper towels, rubbish bags for clean-up.
- Borax (sodium borate) – available from Mitre 10 Mega ($14 for 1 kg), Bunnings Warehouse ($10 for 1 kg) and most pharmacists (often behind the counter, approximately $15 for 50 g).
- Food colouring

Making the slime

1. In a plastic cup, dissolve 1 tsp. of borax powder in approximately 1/5 of a cup of warm water. Food colouring can be added to the colour the slime.
2. In another plastic cup, add 3 tbsp. of PVA glue to 3 tbsp. of water. Mix well using a plastic spoon or popsicle stick until the mixture has an even consistency.
3. While stirring well, slowly add about 2 tsp. of the borax solution to the PVA mixture. You should see the mixture begin to clump.
4. Continue stirring until you have an even consistency. The mixture will begin to gather into a single mass which may cling to and hang from the spoon (or popsicle stick) – at this point it is safe to handle.

If your mixture remains sticky or fails to clump together into a single mass, slowly add more of the borax solution, 1 tsp. at a time, while stirring.

Once finished with your slime, dispose of it in a rubbish bin and make sure to wash your hands afterwards.

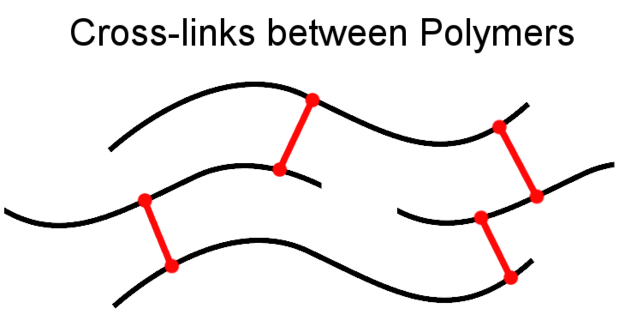
Investigating the properties of slime

The slime is a *gel*, that is to say, it has some properties in common with both liquids and solids. Students can do some experiments to identify liquid and solid- like behaviour, for example:

- Leave slime sitting: the slime will slowly flow to cover the base of its container, like a liquid.
- Roll the slime into a ball and drop it on a hard surface: it will bounce like a solid;
- Slowly pull the slime into a thread – now try the same action, but much faster. In general, the slime will behave like a liquid under slow movement, but will act as a solid under fast and sudden movements.
- Students can try making a number of different slime mixtures using increasing amounts of borax; compare their behaviours. The larger the amount of borax added the more solid the slime will become.

How it works:

PVA glue consists of many long, thin polymer molecules mixed with water. In this mixture, the PVA molecules are generally free to move around and slide past each other (imagine a boiling pot of spaghetti or a tank of eels). The borax produces cross-links in the polymer, connecting one point of a PVA molecule to another point on a separate molecule (imagine a fishing net – each knot between two strings represents a cross-link). This reduces the ability of the polymer molecules to slide past each other, making them behave less like a liquid. By adding more borax more cross-links are created, making the slime more like a solid. Once there are enough cross-links the PVA molecules are held tightly in place.



2. Water-absorbing polymers

There are a number of water-absorbing polymers; polyacrylamide and sodium polyacrylate are the most common examples. These polymers are capable of absorbing more than two hundred times their own weight in water – because of this they are used as the active ingredient in disposable nappies, are often used in pot plants to increase the amount of water that can be retained in soil, and even find use as artificial snow (appearing white and fluffy after having absorbed water).

Equipment and consumables

- Plastic cups
- Water
- Paper towels
- Eye droppers (available from most pharmacists, also found online at: www.thescienceshop.co.nz/shop/Science+Equipment+%26+Glassware/Eye+Dropper+glass.html $1.80 each. www.purenature.co.nz/shop/Cosmetic+Ingredients/Equipment/Disposable+Plastic+Pipette+-+100+pack.html $12 for 100 disposable droppers)
- Bucket for clean-up
- Ice-cream container
- Polyacrylamide – typically known as 'Water crystals', (or similar) in gardening centres. ($5 at Palmers Garden Centre, $9 at Oderings)
- Sodium Polyacrylate – a good source are absorbent travel urinal products e.g. 'Travel John', available in some pharmacies and online stores for $10 – 15 (www.equipoutdoors.co.nz, www.pharmacy-nz.com, www.healthexpress.co.nz). A small amount of sodium polyacrylate can also be extracted from disposable nappies – cut open the nappy, tear the cotton pad into small pieces, place in an ice cream container and shake for several minutes; approximately one tablespoon of white sodium polyacrylate crystals should collect in the bottom of the container.
- Polyacrylamide toy figures that expand when wet - can be found in Paper Plus stores, approximately $5 each and are re-usable

Using sodium polyacrylate and polyacrylamide

When dry, sodium polyacrylate is a white, fluffy powder; polyacrylamide may appear as white crystals. To use simply add water to the dry polymer – it only takes a few seconds for the water to be absorbed. Try to find out how much water the polymer can hold, and note how the appearance changes as more water is added. These polymers are safe to handle. When finished, dispose of all waste in a rubbish bin – do not tip into a drain.

Investigate properties of sodium polyacrylate and polyacrylamide

- Secretly add a small amount of the polymer to a non-transparent cup. In front of the class, add water, wait for several seconds for the water to be absorbed (say a few magic words), and then invert the cup – no water will come out, to the amazement of the students!
- In the case of sodium polyacrylate, adding table salt (sodium chloride) will cause the gel to revert back to a liquid form! Add approximately as much salt as you had polymer (eg: 1 tsp of salt for 1 tsp of sodium polyacrylate powder). Stir the mixture well. It may take several minutes for the gel to dissolve. Note – even though the gel has returned to a liquid state, do not dispose of it down a drain.
- Demonstrate how nappies work: draw two identical circles on a paper towel and place a small amount of water-absorbing polymer in the centre of one circle. Using an eye dropper, slowly add drops of water to the centre of each circle, making sure to count each drop that is added. Keep adding drops until the water reaches the edge - compare the amount of water required to reach the edge of each circle.
- Figurines made from polyacrylamide can be found in Paper Plus stores throughout New Zealand. When placed in water, these toys expand to five or six times their original size over the course of approximately two days. Have the students predict the eventual size of the figure, and then periodically measure its length and weight. These figures can be reused by removing them from the water and slowly allowing them to dry. Does the toy return to its original size and weight? The range of figures varies between stores and includes items such fish, dinosaurs, zombies, and penguins. Prices are typically around $5.

How it works:

In general, substances dissolve in water if they have a positive or negative charge. For example, table salt (sodium chloride) dissolves because it is made of positive sodium ions and negative chloride ions. Sodium polyacrylate and polyacrylamide both have charged areas in their molecules – this means that they can attract water in the same way as table salt, but because the charged areas are on long polymer molecules, they cannot dissolve completely (as though they are tied together with string) causing them to form a gel.

In the case of sodium polyacrylate, adding table salt causes the gel to liquefy because, when compared to the water molecules, the sodium ions in the salt have a much stronger attraction to the polymer. This means that the sodium ions can push the water molecules from the polymer – removing the water from the polymer and, in effect, reversing the process that occurred when the polymer was dissolved in water. The salt does not have the same effect on polyacrylamide because, in this case, sodium ions are not so strongly attracted and are unable to push water off the polymer.

Useful Websites:

http://simple.wikipedia.org/wiki/Polymer (A description of polymers using simple English with links to further information).

www.pslc.ws/macrog/kidsmac/site_map.htm (A website aimed at children describing the properties and uses of polymers).

www.discovery.com/tv-shows/curiosity/topics/polymer-based-products-you-use-every-day.htm (A description of common uses of polymers and the ways in which their properties lend them to certain applications).

www.materialseducation.org/educators/mated-modules/docs/Slime.pdf (A lesson plan from the American curriculum).

www.acs.org/content/acs/en/education/resources/k-8/science-activities/characteristicsofmaterials/polymers.html

www.acs.org/content/acs/en/education/outreach/kidschemistry/activities.html
See 'Jiggle Gels'. This website gives presenter and teachers guides and student's lab guide