Pasta Polymers

YEARS 8/9 – working in groups of 4

What is green chemistry?

Green chemistry aims at changing the mindset and practices associated with everyday chemistry, to be safe, sustainable, environmentally friendly, renewable and non-toxic.

Plastics are all around us. Conventional plastics are made from non-biodegradable materials that take centuries to break down in landfill and sometimes end up polluting our environment.

The main composition of most plastics is polymers. You will remember from the biodegradable water bottle experiment that polymers are large molecules made up from lots of smaller ones (monomers) in a long chain.

Polymers are formed by a process called polymerisation, which reacts the smaller monomers to form a long polymer chain. Some polymers have longer, free flowing chains that make the plastic more **flexible**, while other polymers are more tightly packed, making the material more **rigid**.

Understanding what polymers are is important in the development of greener replacements for traditional plastics. The four different kind of chain polymers we will be focussing on are:

1. Homopolymer – a polymer consisting of only one kind of monomer.
2. Alternating copolymer – a polymer consisting of repeating units of monomers.
3. Block copolymer – a polymer consisting of two (or more) repeating units of monomers.
4. Random polymer – a polymer consisting of two or more monomers arranged randomly.

Cross-linkers are also present in many natural and synthetic polymers. A cross-linker binds chains of polymers together. You have already explored what happens when you add a cross-linker (calcium) to alginate when you made biodegradable water bottles. Below is a picture to help you refresh your memory.

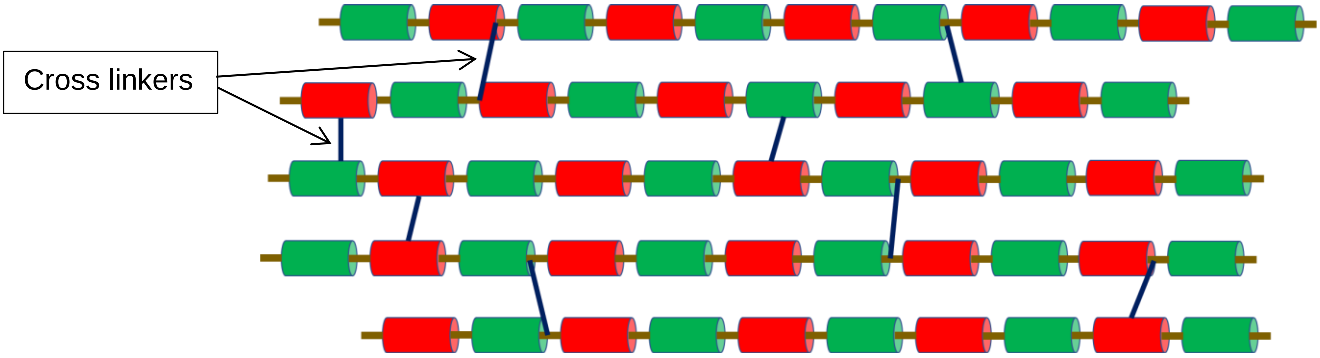

Figure 1: Structure of a copolymer following the addition of a cross-linker.

Get thinking!

What are some objects that help to visualise polymers?

Use this prompt to get the students thinking about what the structure of a polymer looks like. Getting them to try and visualise what a polymer (cross-linked or not) looks like may help them understand how the chemistry works. Some examples are:

- Beaded bracelet: each bead is a monomer and the full beaded bracelet itself is the polymer
- Fish net: if the fishnet wasn't cross linked, it would not be able to catch fish.

In this exercise, you will make the four different kinds of polymers (a homopolymer, alternating copolymer, block copolymer and random polymer). Following this, you will explore the properties of the polymer upon cross-linking and discuss what applications the different outcomes may have.

***Materials:* Assuming groups of four - each student will make 4 different polymer chains (16 polymer chains per group)**

Part 1: Red and green pasta (2 different monomer units) - 1 bag of monomers.

- **Each group requires one bag of pasta:** containing the correct green and red pieces of pasta to create 4 of each of the polymer types.

Part 1: Brown or white twine.

- Each kit has 160 m of twine included. Each group will require 16 pieces of twine cut to ~75 cm

Part 2: Paper clips (cross-linker 1).

- Each group will require 12 paperclips.

Part 2: Black twine (cross-linker 2).

- Each group requires 8 pieces of black twine cut to 30 cm.

Method - Part 1: Creating polymer chains from pasta (groups of 4)

1. Collect all materials.
2. Each person in the group should make one each of the following polymers using 10 - 15 pastas (monomers) per polymer chain. Tie a large knot in the brown/white twine provided and thread monomers onto the twine to create your polymer.

    - Homopolymer (using green pasta)
    - Alternating copolymer (using red and green pasta)
    - Block copolymer (using red and green pasta)
    - Random polymer (using red and green pasta)

Method - Part 2: Cross-linking your polymers (groups of 4)

1. From part 1, each person in the group should have 4 polymer chains, one of each type of polymer. If you don't, go back to part 1 and make the four polymer chains.
2. As a group, cross-link your **homopolymer** chains using ~8 paperclips. Pay attention to how much movement your polymer complex has.
3. As a group, cross-link your copolymer chains using ~8 pieces of black twine.
4. As a group, using up to 10 crosslinkers of any kind, create a polymer that is **flexible** from your block copolymer
5. As a group, using up to 10 crosslinkers of any kind, create a polymer that is **rigid** from your block copolymer

Questions

1. What do the individual red and blue pastas represent?

They represent different kinds of monomers, when joined together, they form a polymer.

2. What is the reason(s) for using different types of monomers to make polymers?

Different monomers have varying chemical and physical properties. When more than one type of monomer constitutes a polymer, the properties of the polymer are the combinatorial properties of all its individual monomers, thus enabling the possibility of 'tailor-made' polymers for different applications by varying the types of monomers.

3. What is the effect of adding the cross-linker?

Cross-linkers join the linear chains of polymers together and transform the individual chains from a 2D structure to a 3D network, forming a polymer structure of larger molecular size, and thus molecular weight.

4. Define rigid and flexible. How does the type and number of cross-linkers used correlate with the definitions?

Flexible - when the movement between individual polymer chains in the direction perpendicular to the cross-linkers happens easily upon the application of force.

Rigid - when the movement between individual polymer chains in the direction perpendicular to the cross-linkers is more difficult upon the application of force.

The polymer-network formed is more rigid when the number of cross-linkers used increases. Cross-linkers restrict the movement of the individual chains in the perpendicular direction.

5. Which cross-linker (paperclip or black twine) formed a more rigid polymer?

The paper clips should form a more rigid polymer.

6. Which cross-linker would you use to hold a marble in your polymer structure? What is the reason for your selection?

Paper clips as they make a more rigid polymer structure, with less space in between the individual polymer chains.

7. Think about how you, as a Scientist, could design plastics to be biodegradable and 'green'?

In considering this question we want to engage the students in thinking about green alternatives. Ask the students to think about what part of the polymer could be changed to make it more green. As an example, substituting a non-biodegradable monomer with a greener alternative may result in a more environmentally friendly plastic.

If students want more information, the following describes green and biodegradable polymers, how they differ from each other and how they are defined.

Biodegradable polymers

- If polymers can be broken down into individual monomer units and then further break down into natural elements in a short span of time, they are referred to as biodegradable.
- Biodegradable polymers can be synthetic, natural or a combination of both.
- Examples of natural biodegradable polymers are silk, keratin, cellulose and even our DNA!
- Examples of synthetic biodegradable polymers are some types of polyester and poly(lactic acid).

Green polymers

- Green polymers are polymers made using sustainable methods.
- Green chemistry focusses on replacing a synthetic polymer with a natural counterpart or if that's not possible, reducing the impact on the environment during synthesis e.g. minimising energy inputs and waste products.
- The green nature of polymers can be improved by using biodegradable cross-linkers that join the polymer strands.
- While all biodegradable polymers can be considered green polymers (if they are made in a sustainable way), not all green polymers may be biodegradable.