# Flexibility in the Bathroom – Polymer additives

Plastic is amazing stuff. It's a polymer, which means each molecule is made up of lots of smaller individual molecules allowing it to be varied almost infinitely to achieve a range of materials with astonishing diversity.

You use plastics in your life every single day without even thinking about it. They are in things like light switches, shoes, carpets, bottles, electronics, clothes, cars, traffic signals, makeup, food packaging… the list is endless because the properties of polymers are adaptable to different applications.

Plastics can't be amazing on their own though; there are some properties that need to be added to them to allow them to do their job effectively. One example is colour – most polymers aren't the bright colours you see in shampoo bottles, pigments are added to achieve this effect. Other additives are used to help with the manufacturing processes – getting a bottle out of a mould for example.

## Flexibility in the Bathroom

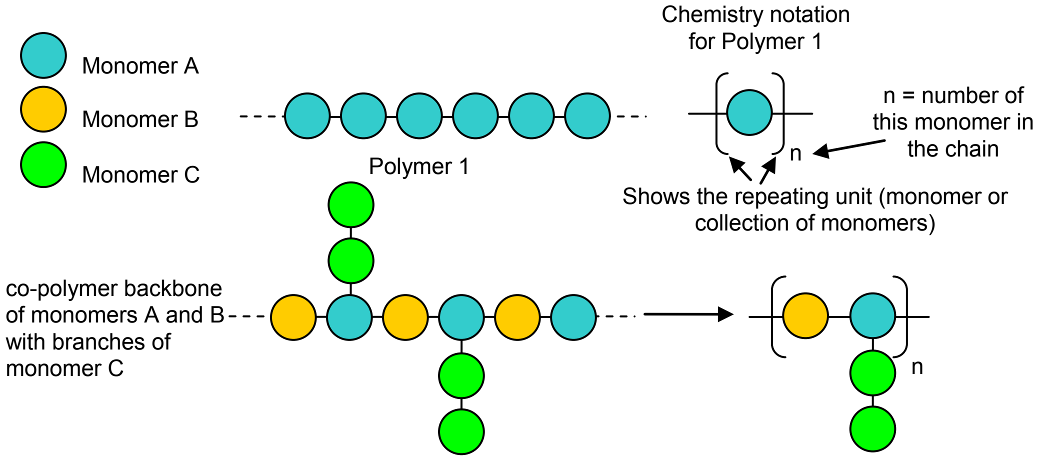
Health and beauty products are one area where people tend to stick to what they know. If you like one shampoo for example, why would you change brand? As well as the name, the shape and colours of the packaging are just as important in branding. If someone were to break into your bathroom and take all the labels off your bottles, you would still know what each one contained because of the style of the packaging.

Polymer additives added to the plastics that make your packaging can make it more distinctive so that brands are easier to recognise. They can also make it more attractive and easier to use – slip additives are added to help the removal of lids, anti-static additives stop bottles attracting dust and anti UV absorbents stop your shampoo being damaged by the sun. Polymers on their own are great but with additives as well, they are invaluable.

## Polymers

Polymers are large molecules which are made up of lots of smaller molecules. The smaller building blocks are called monomers. Monomers can have a range of structures and polymers can be made of one, two or many different monomers which can be joined together in any order. This makes polymer chemistry extremely flexible and polymers can be made to have a wide range of useful properties. Polymers in nature include such substances as wood, DNA, proteins, wool and silk.

Polymers have a general structure which consists of a backbone made of a string of monomers from which branches can grow. Carbon based polymers are the most common but some polymers can be made out of other elements, such as silicon.



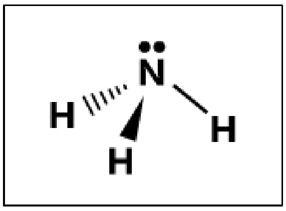

Polymers are manufactured in large quantities and additives are added to the mix during the manufacturing process. Additives are often added at one stage and then activated later so that the correct effect is achieved.

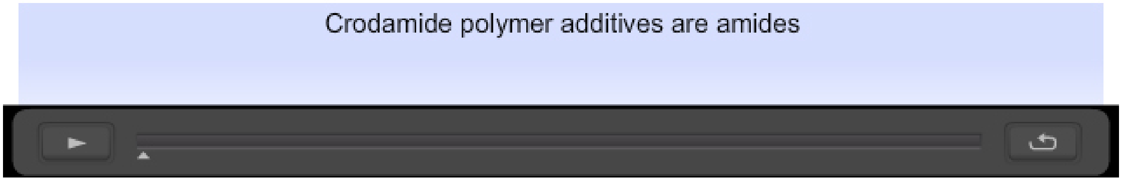
## Slip Additives

Have you ever done a lid up really tightly and then discovered you can't undo it again? This is a surprisingly big problem for manufacturers – how are consumers going to enjoy their products if they can't get at them? This could be solved by making sure people don't do caps up too tightly but then there is a risk of the product leaking. So instead of leaving it to chance, manufacturers add compounds to their plastic lids to make them leak proof and easy to unscrew. These are called "slip additives".

Croda's slip additives are made from amides which are molecules containing nitrogen that can be classified as primary or secondary depending on what is attached to the N atom.

**Animation: Amides**

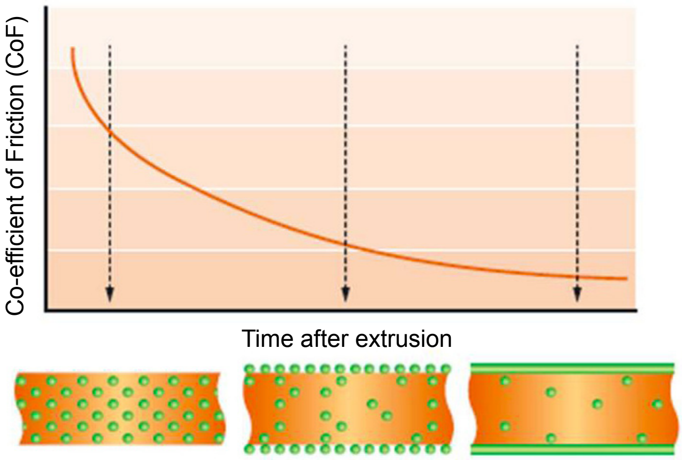



Amides can reduce friction between two polymer surfaces, making lids easier to undo. They can also prevent surfaces adhering (sticking) to each other, an effect known as anti-blocking. The structure of the amide chosen depends on what it needs to do.

Amides are added during the plastic manufacturing process. They start off evenly distributed through the plastic and move around inside the plastic as it cools down, a process called migration. The amide ends up on the surfaces of the plastic forming a layer in contact with anything the plastic touches. This layer reduces friction (measured as the coefficient of friction) and stops the two plastics from sticking to each other.

**Slip development in polymers**




Amide uniformly distributed in the polymer immediately after extrusion (plastic moulding process)

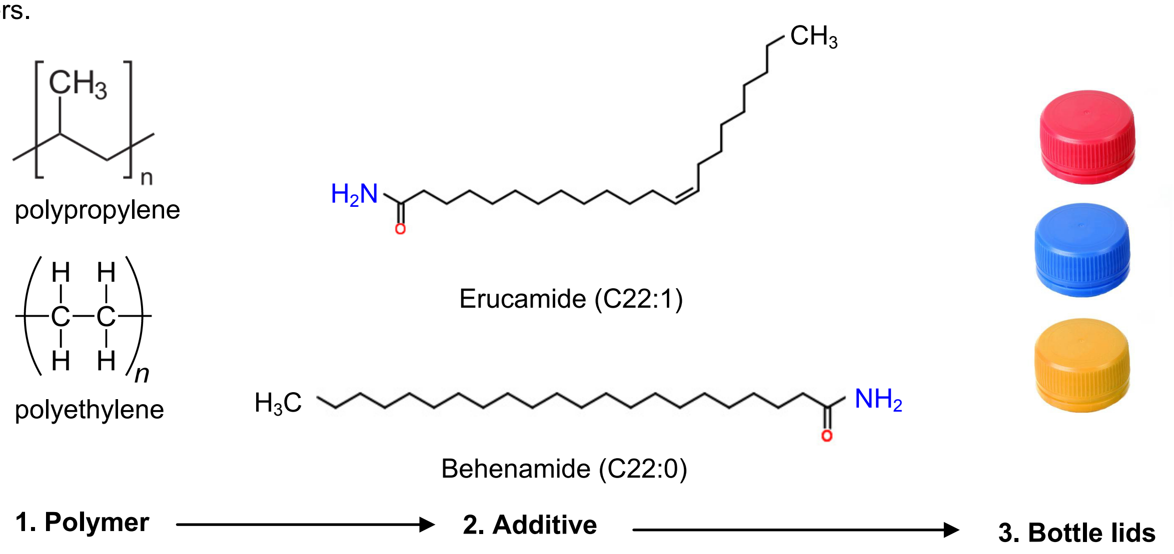
As the polymer cools, amide migrates to the outer surface and forms a partial layer. Friction drops rapidly

Complete layers of amide on the surface, migration reaches equilibrium. Friction reaches a minimum

Carbon chains can be described using special chemical shorthand – C22:1 means a hydrocarbon chain of 22 carbons with 1 double bond, C18:0 means a chain of 18 carbons with no double bonds. The molecular structure of the amide dictates which types of polymers it can be used with.

| Structural features | Advantages |
|---|---|
| Double bond in carbon chain (unsaturated) | Very good as a slip agent with some anti-blocking |
| No double bond in carbon chain (saturated) | Good as an anti-blocking agent but not as a slip agent |
| Longer carbon chain (20-22 carbons) | Migrates slowly but doesn't evaporate (low volatility) and is more stable |
| Shorter carbon chain (~18 carbons) | Migrates quickly but has high volatility and is less stable |

For high temperature polymer manufacturing for example, two primary amines, erucamide and behenamide are ideal due to their long chains. They are used with polypropylene and linear-low density polyethylene polymers.




Croda's amide additives have trade names: Erucamide is Crodamide E and behenamide is Crodamide BR.

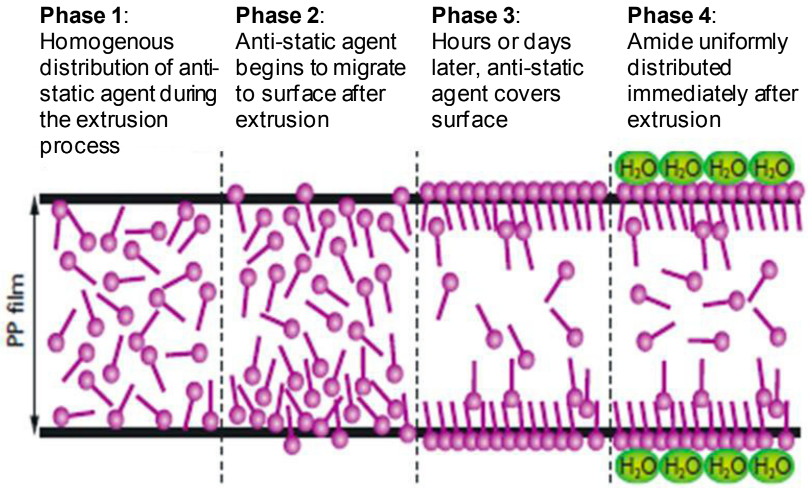
## Plastic Spotting

Different types of plastics have to have a mark on them to show what they are so that they can be recycled correctly. Each type of plastic is numbered and given an acronym.

1. PET / PETE is Polyethylene Terephthalate – water bottles
2. HDPE is High Density Polyethylene – shampoo bottles
3. PVC is polyvinyl chloride - window frames
4. LDPE is Low Density Polyethylene – carrier bags
5. PP is Polypropylene – margarine tubs
6. PS is Polystyrene –cups, yoghurt pots, hamburger boxes.


Everything else is shown as numbers in the centre of the triangle

A lot of plastic bottles commonly used in the home are made from polypropylene (PP) or high density polyethylene (HDPE). These are both excellent electrical insulators. This means that static charge can build up on the bottles which attract dust and other bits of household fluff. The customer won't want to buy shampoo covered in dust, so anti-static additives are added to the polymers to prevent the build-up of charge.




Like slip additives, anti-static additives are also added to the polymer during production. When the polymer is first extruded, the additive is distributed throughout the plastic but over time it migrates to the surface of the plastic through four distinct phases.

Once at the surface, the additive makes the surface more hydrophilic (water loving) which attracts water molecules from the air to stick to the bottle. The water reduces the resistance of the surface of the bottle and allows it to discharge the static before the bottle is covered in dust.

Click this **Do Something** button to try out some polymer chemistry for yourself

## UV protection

Croda have patented a UV protection range called Solasorb which is based on very fine powders of metal oxides. When added to polymers in small quantities, these particles can absorb UV radiation and stop it from getting into the bottle but they don't change how the bottle looks, so you can still see through the plastic. Solasorb protects the contents of bottles from degradation from the UV radiation and increases shelf life of the products.

All three bottles were filled with the same blue solution.

- The left hand bottle was kept in the dark as a control
- The middle bottle was exposed to UV radiation and does not contain Solasorb
- The bottle on the right contains Solasorb and was also exposed to UV radiation – it is clear that Solasorb protects the contents from colour fade

Metal oxides can absorb UV radiation because of the way the electrons in the metal are arranged. Metals such as titanium, used in Solasorb, are in the "transition metal" part of the periodic table. These elements have space in their outermost electron shell that is not filled by electrons. By absorbing UV radiation, electrons can move around in the outermost shell and use up the energy. If an element cannot use the energy up in this way it won't absorb it, which is why metals outside the transition metal series would not have the same effect.

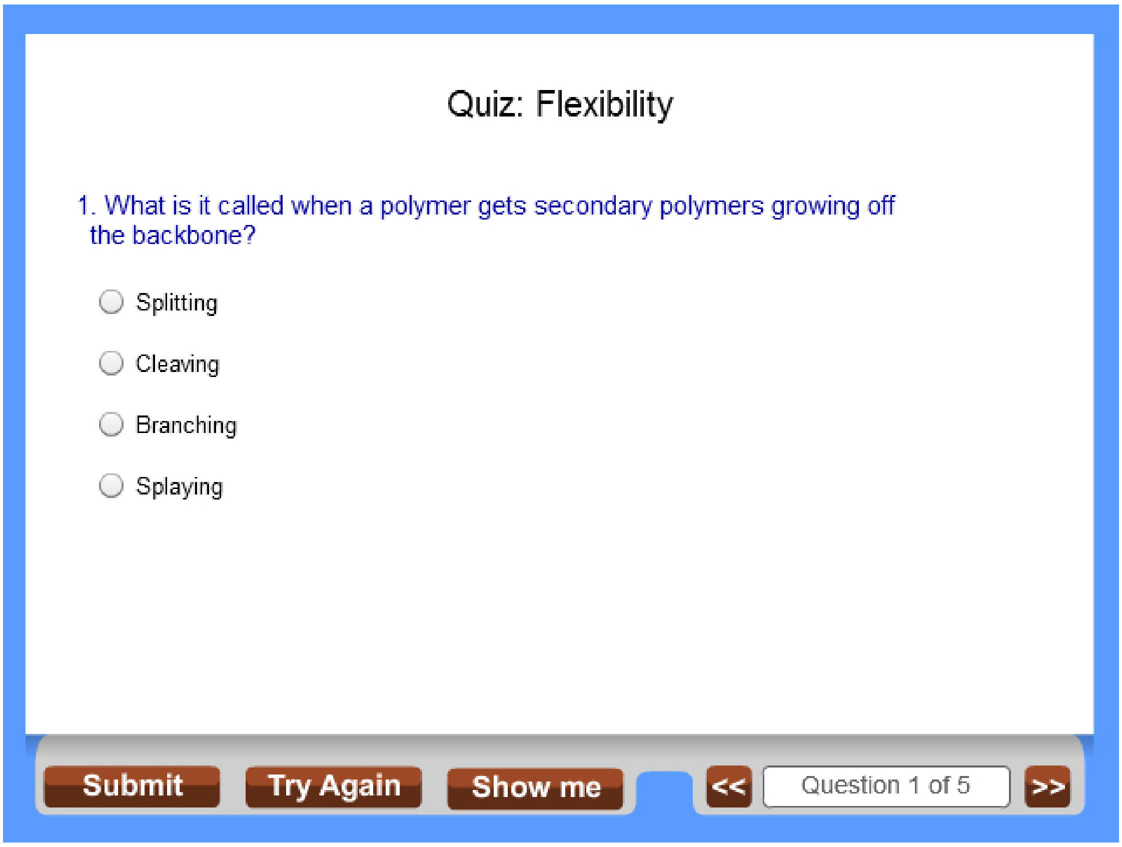
## Conclusion

Polymer materials are everywhere in modern life and in order for them to do their jobs properly, they need some help. There are an almost infinite number of different polymers available which means a large number of additives are required. The additives discussed here make the polymer easier to use by stopping lids from sticking to the bottle, they also stop the container from building up static electricity (which attracts), dust and protect the contents from damaging UV radiation.

The types of additives range from organic amide materials to inorganic solid metal oxides and each is developed for use with a particular type of polymer. As better polymers are developed, new additives will be needed, which makes this an ever expanding area of research.

## Test your knowledge

Take the short quiz below to test your understanding of polymer additives.



# Practical Polymer Experiments

## Disclaimer:

Before carrying out any experiment or demonstration (or preparation work for these), teachers and technicians are responsible for complying with any of their employer's risk assessment requirements making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.

## Polymer Putty – Ages 14-16

This experiment is a take on the classic borax putty experiment. Students make the putty using borax and polyvinyl acetate (PVA) and can create a bouncing polymer ball or polymer slime. Made this way, students can feel for themselves polymer chains forming during the reaction.

### Health and safety note:

Make sure the students wear appropriate eye protection. Borax solution is toxic.

### Apparatus:

- Saturated solution of sodium borate (borax solution) - toxic
- PVA glue
- Water
- Dropping pipette
- Small zip lock plastic bag
- Food colouring if required
- Measuring cylinder

### Method:

1) Place a 50p sized blob of PVA glue into the plastic bag.
2) Add 0.5 $cm^3$ water to the glue and several drops of food colouring if required.
3) Close bag securely and mix together with fingers until evenly combined. Note how the glue feels.
4) Add around 2 $cm^3$ borax solution (toxic).
5) Close bag and mix again. Note how mixture starts to feel different as polymerisation reaction occurs.
6) Once polymerised, the putty can be removed from the bag, it will be sticky to the touch to begin with but if worked (preferably while wearing gloves) it will dry out and form a ball.

### Modifications to this experiment for different abilities:

- Use 8% PVA solution (made from PVA powder) and 10% or saturated borax solution (toxic) to produce a clear and looser slime which is more like slime than putty.
- Ask more advanced students to make their own solutions up before they make the slime.
- Ask students to work out the best concentration to use to produce a particular type of product. For example, what is the optimum concentration of borax required to produce a bouncy ball? Students can use ready-made solutions or produce their own solutions as required.

# Making Nylon Threads[1] – Ages 14-16 demonstration, possible for ages 16-18 as an experiment

Nylon is the name given to any synthetic polyamide. Acyl chloride from any dicarboxylic acid reacts via a substitution reaction with any amine to form a nylon polymer and HCl.

This experiment produces a long string of nylon from the interface between the two starting solutions. Depending on availability of materials and class ability, it works well as either a demonstration or an experiment for students to do. A competition can be run to see who can get the longest string, although this can get messy.

## Health and safety note:

Make sure the students wear appropriate eye protection.

The reactants are irritating to the skin, so wear gloves throughout the procedure. Heptane is flammable. Remaining liquid should be mixed to form nylon. The nylon should be washed prior to disposal. Any unreacted liquid should be neutralised prior to washing it down the drain. If the solution is basic, add sodium bisulfate. If the solution is acidic, add sodium carbonate.

## Apparatus:

- Solution of 6 g sebacoyl chloride in 70 $cm^3$ heptane (flammable)
- Solution of 3 g 1,6-diaminohexane in 70 $cm^3$ water
- Metal tweezers or forceps
- Small beaker
- Measuring cylinder

## Method:

1) Use equal volumes of the two solutions. Place 1,6-diaminohexane into the bottom of the small beaker.
2) Tilt the beaker and slowly pour the same volume of sebacoyl chloride solution down the side of the beaker so that it forms a layer on the top.
3) Dip tweezers into the interface of the liquids and pull them up to form a strand of nylon. Continue to pull the tweezers away from the beaker to lengthen the strand. You may wish to wrap the nylon rope around a glass rod or lay it out along a stretch of bench for measuring.
4) Rinse the nylon with water, ethanol or methanol to remove the acid from the nylon. Be sure to rinse the nylon before handling it or storing it.

[1] Chemical Magic, 2nd Ed., Leonard A. Ford (1993) Dover Publications, Inc.