Changing the properties of polymers and plastics

The properties of polymers and plastics can be changed in a number of ways. One way is of course to produce a different polymer or plastic with a different chemical structure, but there are also other possibilities. This series of activities allows students to explore some of them:

- The use of plasticisers – see **Making a plastic from potato starch** or the activity in this section on plasticised and unplasticised PVC (polyvinyl chloride)
- Cross-linking polymer chains – see **Making slime** or the activity on rubber
- The effect of changing the length of the polymer chains
- The effect of the presence of branched chains

Four of the activities (PVC, rubber, chain length and branched chains) could be set up as a circus and carried out by the whole class in turn. Alternatively, groups of students could each do one of the four experiments and then report back to the class. **Making a plastic from potato starch** and **Making slime** are likely to be very popular activities and are probably best done as class experiments. Details of these activities are given separately.

Equipment required

Set 1: Plasticised and unplasticised PVC

- Plasticised PVC – squeezy toy and/or PVC cling film
- Unplasticised PVC – piece of uPVC pipe or guttering.

Set 2: Cross-linking (or vulcanising) rubber

- Rubber – microscope slide with a thick coating of Copydex glue (set up at least the night before)
- Vulcanised rubber – thick rubber band.

The glue can be peeled off the microscope slide by students when they are ready to use it. One sample will not last long enough for all groups to use it so have several in reserve.

Set 3: Changing the length of polymer chains

- Candle wax or candle
- Polyethene (*eg* carrier bag)
- Sample of medium chain length hydrocarbon (*eg* kerosene) in a sealed tube.

Set 4: Branching chains in polyethene

- High density polyethene – a ‘rustly’ supermarket carrier bag
- Low density polyethene – a ‘quiet’ department store carrier bag.

All the above items should be labelled.

Additional items:

- Assorted worksheets and helpsheets as chosen by the teacher for each group
- Some groups may need glue and scissors.

Differentiating the activity

Students should describe the properties of the samples in each set and try to explain the difference they observe. The activity can be left very open-ended and students given no help, or the support documents listed below can be used:

- List of possible properties for students to choose from (**List of properties**)
- Table to complete (**Table**)

- Explanations for use in completing the table (**Explanations**)
- Cut and stick diagrams (**Diagrams**)
- Information sheet (**Information sheet**).

Each item in the list is provided as a separate document so teachers can choose how much help to give to each class or group of students.
The most able students could be given the samples and perhaps the diagrams. They can discuss in groups why there are differences between the polymers in each group of substances. If they get stuck or wish to check their answers when they have thought of an explanation they could be given the information sheet.
The least able students could be given the properties list and the table to begin with, then the diagrams and explanations when they have decided on the properties. Giving them only one step at a time will help to prevent them from becoming overwhelmed.

Possible answers to questions

The depth at which these questions can be answered could vary widely depending on the abilities of the students concerned.

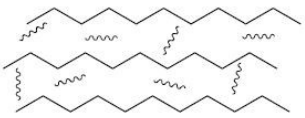
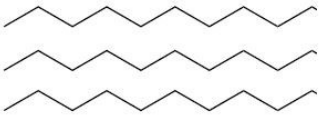
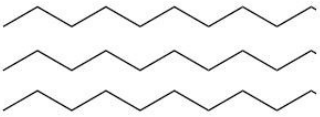
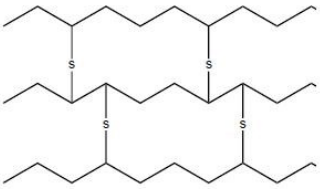
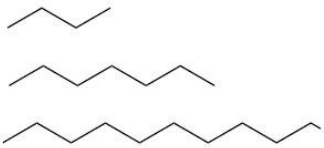
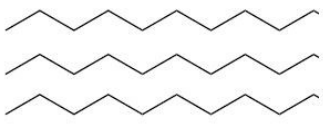
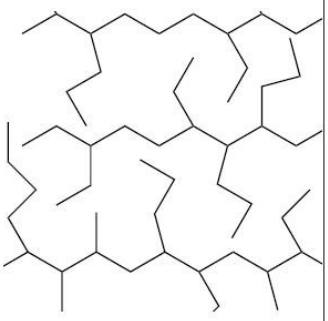
Changes to polymer	Properties and differences in properties	Diagram of the molecules	Why the plastics have different properties
Plasticisers Plasticised PVC	Very flexible; soft.		The chains with small plasticiser molecules between them slip and slide over each other more easily. This makes the plastic more flexible. Without plasticiser molecules the plastic is tougher and more rigid because the chains line up in rows and hold on to each other more tightly.
Unplasticised PVC	Rigid; hard.		
Cross-linking Rubber (Copydex)	Very elastic and stretchy; does not always go back to original shape; soft.		The substance made of molecules that are cross-linked is harder and less flexible than the one without cross-links. The links stop the molecules moving over each other so the structure is more rigid.
Cross-linked rubber (elastic band)	Elastic – but not as elastic as the Copydex; harder than the Copydex.		
Length of chains Kerosene	Viscous liquid		Longer molecules can get tangled up in each other. They also stick together better. This means that substances made of longer molecules are harder and have higher melting points.
Candle wax	Soft solid		
Polyethene	Stretchy/elastic solid		
Branching chains High density polyethene	Rustles when moved; stretchy/elastic		The plastic which has no side chains on its molecules has a higher density because more molecules can pack into the same amount of space. The molecules can slide over each other more easily if there is nothing in the way to stop them. When there are side chains or branches in the way, the polymer chains cannot slide over each other so easily because there are more interactions between the chains.
Low density polyethene	Not as stretchy as the high density polyethene		

Table of example answers

Changing the properties of polymers and plastics

You are going to investigate how the properties of polymers and plastics can be changed. You will be given four sets of polymers. Look at one set at a time. Describe the properties of each material in the set, paying particular attention to how the polymers are different from each other.

Ignore the colour of your samples.

Draw a diagram of the molecules of each substance using the diagram sheet to help you. Some diagrams will need to be used more than once.

Explain why the polymers have different properties by describing their molecules and how they are different from each other.

Think carefully about how you present your results.

Changing the properties of polymers and plastics – list of properties

The plastics and polymers you have been given may have some or all of the properties listed below. You can use each property in the list as many times as you need to or not at all.

Ignore the colour of the plastics.

- Stretchy or elastic
- Rustly or noisy when moved
- Strong
- Weak
- Flexible
- Brittle
- Soft
- Hard.

You can also use any other properties you can think of to describe the plastics.

Changing the properties of polymers and plastics – table

Changes to polymer	Properties and differences in properties	Diagram of the molecules	Why the plastics have different properties
Plasticisers Plasticised PVC Unplasticised PVC			
Cross-linking Rubber (Copydex) Cross-linked rubber (elastic band)			
Length of chains Kerosene Candle wax Polyethene			
Branching chains High density Polyethene Low density polyethene			

Changing the properties of polymers and plastics – explanations

Below are some explanations that might help you complete your table about the properties of plastics.

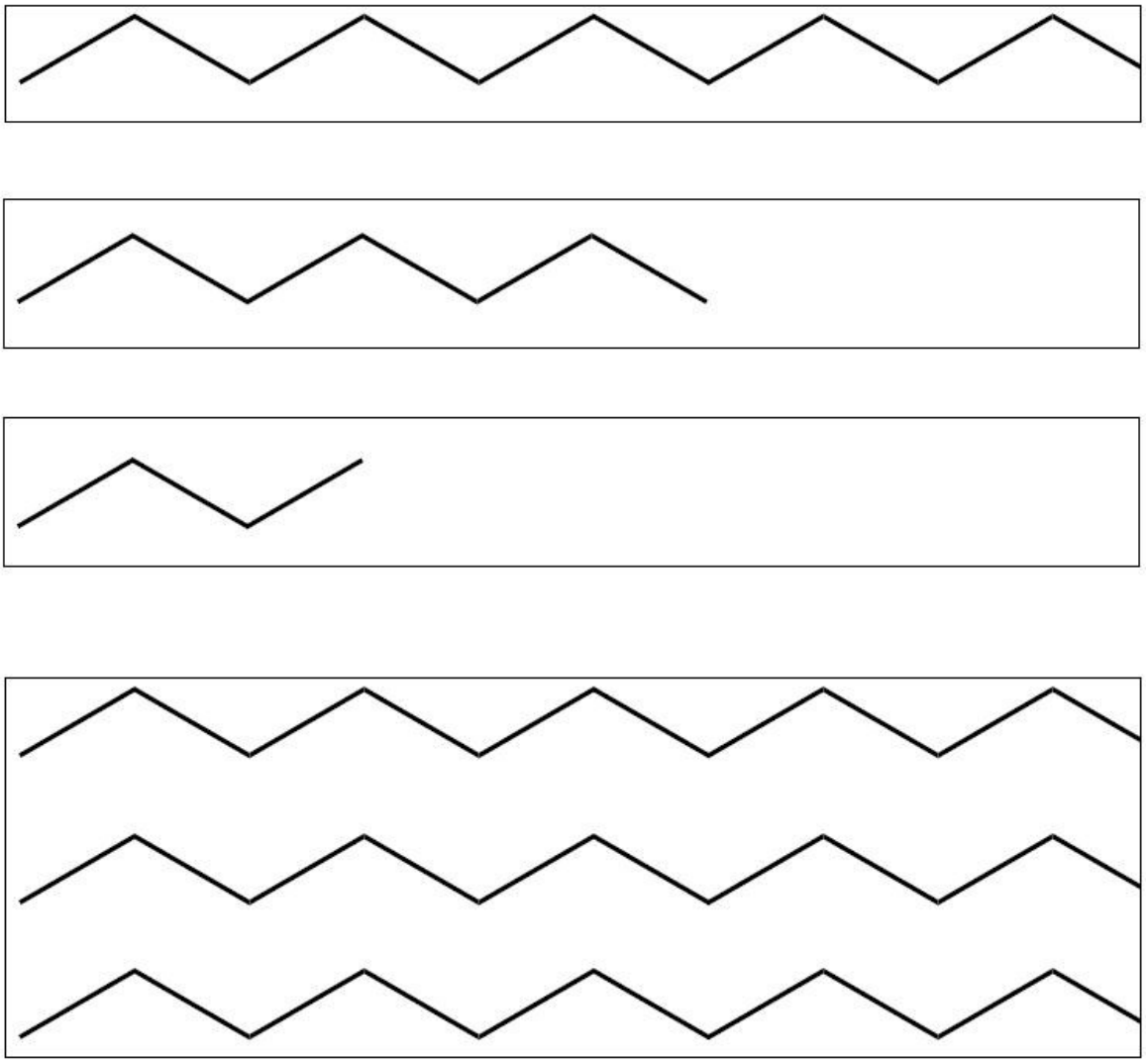
Longer molecules can get tangled up in each other. They also stick together better. This means that substances made of longer molecules are harder and have higher melting points.

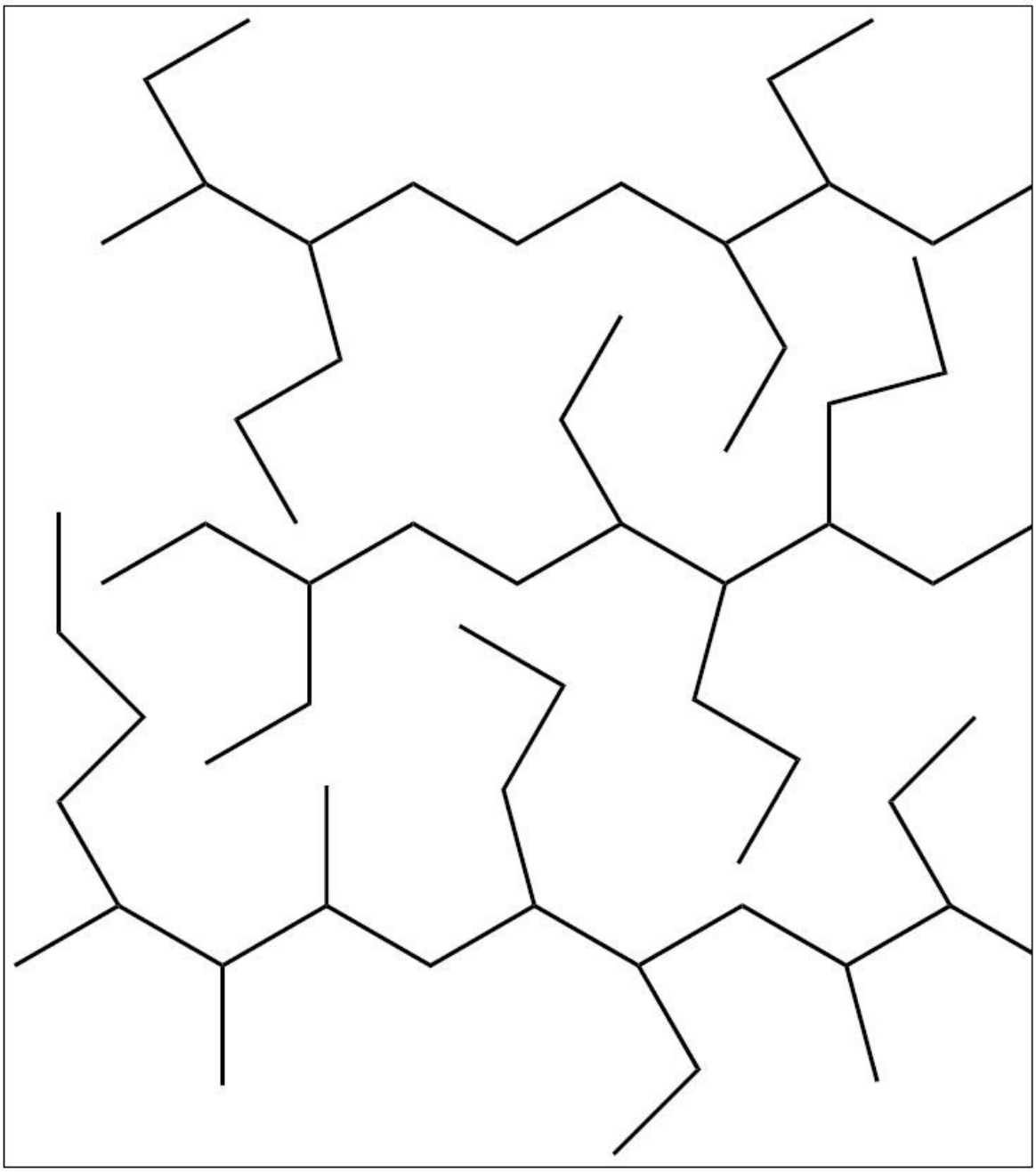
The plastic which has no side chains on its molecules has a higher density because more molecules can pack into the same amount of space. The molecules can slide over each other more easily if there is nothing in the way to stop them. When there are side chains or branches in the way, the polymer chains cannot slide over each other so easily because there are more interactions between the chains.

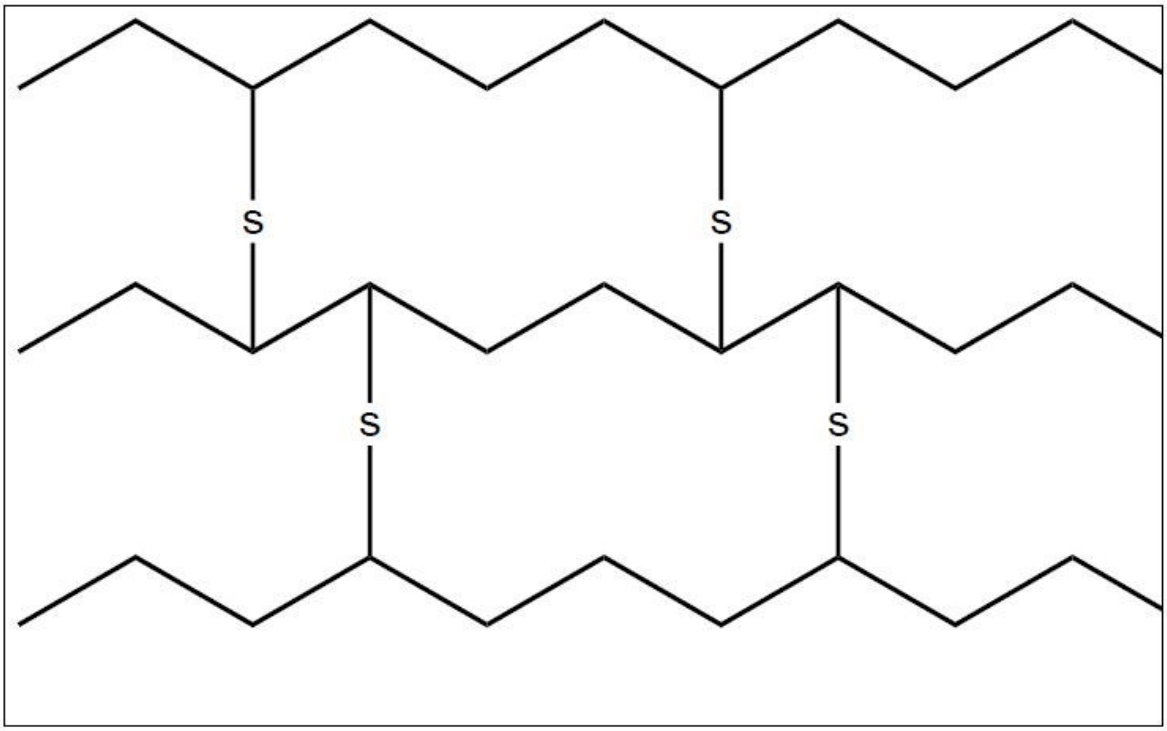
The substance made of molecules that are cross-linked is harder and less flexible than the one without crosslinks. The links stop the molecules moving over each other so the structure is more rigid.

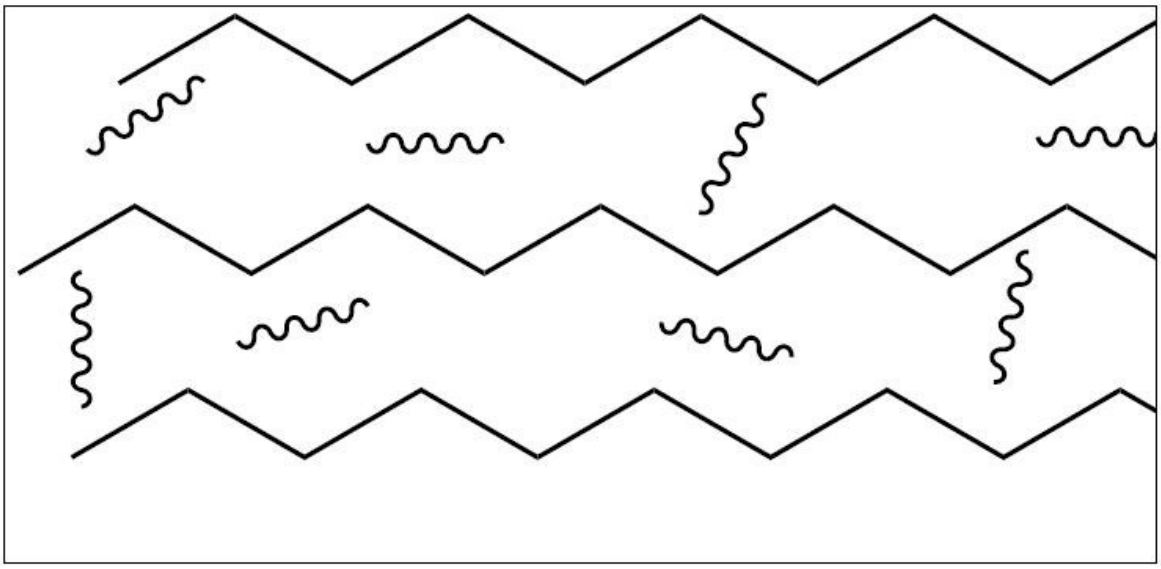
The chains with small plasticiser molecules between them slip and slide over each other more easily. This makes the plastic more flexible. Without plasticiser molecules the plastic is tougher and more rigid because the chains line up in rows and hold on to each other more tightly.

Changing the properties of polymers and plastics – diagrams









Changing the properties of polymers and plastics – information sheet

The properties of polymers and plastics can be altered in a number of ways. This information sheet describes four of them.

Plasticisers

A plasticiser is a small molecule that can be put in between the large molecules of a polymer. The plasticiser acts a little bit like oil in a car engine – it helps the polymer molecules slide over each other easily. Without the plasticiser the molecules attract each other and tend to stick together.

This gives the substance a rigid structure which might make it useful in construction. The plasticiser changes the properties of the substance and allows it to be used for a wider range of things.

Branching chains

Polymers are usually made by heating the monomer and passing it over a catalyst. The sort of catalyst used can affect how much the polymer chain branches. Polymer branches are like the branches of a tree – they are made of the same stuff as the main chain but go off in a different direction.

If the polymer chains have no branches, they pack in close to each other and the material has a high density. The chains can pass over each other easily so the material is very stretchy. If the polymer chains have a lot of branches then the chains cannot pack together as closely and the material has a lower density. The branches catch on each other, preventing the chains from sliding easily past one another. This makes the plastic less stretchy.

Cross-linking

Rubber and some other polymers can be cross-linked. A chemical reaction takes place that connects the chains to each other permanently. This makes the whole structure more rigid and less elastic. It also makes the material a lot stronger and harder. Vulcanised rubber is cross-linked using sulfur. Some of the structures inside your body are held together in the same way because proteins can be cross-linked with sulfur too.

The length of the polymer chains

Long chains get tangled up in each other and stick together far more than short chains. This means that polymers made of long chain molecules have higher melting points than those made of short chains. Shorter molecules can pass over each other more easily so materials made of these molecules are softer and more ‘squishy’.