9 Everyday substances

Planning page

Getting started

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- Animation: Polymerisation

Main ideas
- Chapter 9 crossword

Review
- Chapter 9 test

Essential Learnings for Chapter 9

Essential Learnings	References		
	Student book (page number)	***Workbook (page number)***	***Teacher Edition CD (Assessment task)***
Knowledge and understanding ***Natural and processed materials*** Matter can be classified according to its structure	pp. 196–214	pp. 71–72	Assessment task 9 Plastics
Science as a human endeavour Responsible, ethical and informed decisions about social priorities often require the application of scientific understanding	p. 201 pp. 206, 208		Assessment task 9 Plastics
People from different cultures contribute to and shape the development of science	p. 212		
Ways of working Plan investigations guided by scientific concepts and design and carry out fair tests	Experiment p. 195		
Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	Experiment p. 195 Try this p. 211	pp. 68–73	
Research and analyse data, information and evidence			

QSA Science Essential Learnings by the end of Year 9

Vocabulary

biodegradable
caustic
corrosion
detergent
ethanol
fibres
fractional distillation
galvanised
hydrocarbon
methane
molecular
monomer
polymer
polymerisation
polystyrene
polythene
properties
synthetic
thermoplastic
thermoset
viscosity
viscous
vulcanisation

Focus for learning

Relate the uses of everyday materials to their properties (page 191).

Equipment and chemicals (per group)

Experiment page 195* 4 test tubes and stoppers, 4 clean nails, oil, boiled water, salty water, silica gel, samples of aluminium, copper and iron (Try this)

Activity page 197 molecular models kit

Investigate 20 page 199 hotplate (or burner, tripod and gauze), 2 beakers (approx 400 mL), 2 test tubes with stoppers, large evaporating basin, stirring rod, wash bottle, spatula, 90% ethanol (or methylated spirits), kerosene, olive oil or castor oil, sodium hydroxide solution (6M), sodium chloride solution (saturated), piece of filter paper, measuring cylinder (10 mL)

Activity page 205 milk, vinegar, 2 beakers, coarse cloth, rubber band

Experiment page 207* small samples of various plastics

Resistance to chemicals: beakers, dilute hydrochloric acid, dilute sodium hydroxide, turpentine, ethanol

Resistance to heat: Bunsen burner, heatproof mat, screwdriver

Insulating properties: 1.5 V battery and holder (or power pack), piece of metal, torch bulb and holder, ammeter or multimeter, 4 connecting wires

Density: displacement can, measuring cylinder

Flexibility and stress: overhead projector, 2 pieces of polaroid

Investigate 21 page 211 permanent crease solution (3% sodium hydrogen sulfite or sodium metabisulfite solution containing a little detergent), 2 pieces of woollen fabric, sponge, evaporating basin (or similar container), container for washing wool samples, detergent, steam iron

* Students to list equipment they will need, which may be different from what is listed here.

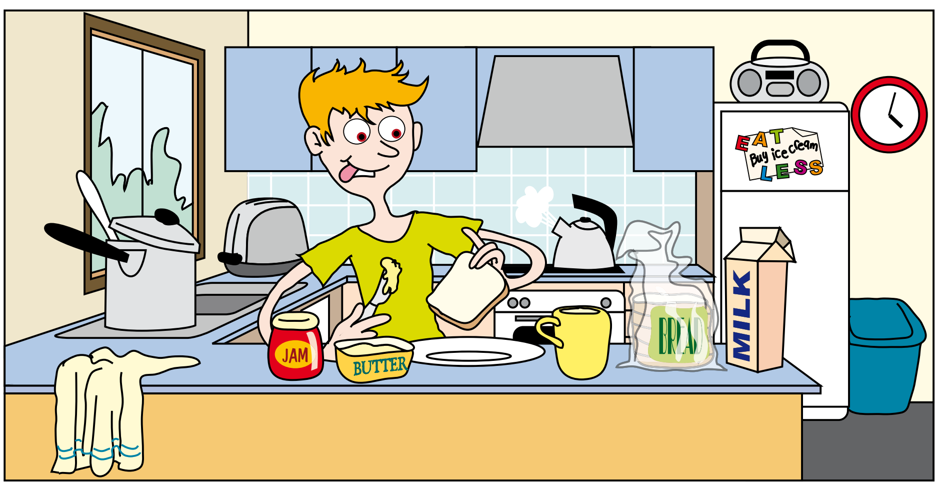
9 Everyday substances

Getting Started

Look carefully at the cartoon below. You will see many different objects made of many different substances.

- Draw up a table like the one on the right and list as many different objects as you can and the substances you think they are made of. One example has been done for you. You may not be able to complete the right-hand column yet, but you should be able to by the time you have finished this chapter.

Object	Substance it is made of	Useful properties of this substance	How the substance is made
kitchen sink	stainless steel	strong, does not rust	from iron obtained from iron ore



Starting point

1 For this chapter, the students could develop a 'graffiti wall' around the theme of everyday substances.

- Graffiti walls are a way of promoting linguistics. They are spaces used for brainstorming or communicating words, concepts or ideas about a topic. A portable board is ideal to use as the 'wall'. It can be brought into each lesson so the students can add to or adapt it without interference from other classes. If you have an interactive whiteboard, make sure you save the document appropriately so it can be easily retrieved.
- The tool is especially useful when introducing new vocabulary, and can act as a science dictionary/ thesaurus. Encourage your students to search for new and interesting words or concepts. Develop the idea further and have a second 'question wall' for questions and answers. Arrange this 'wall' in two columns—one for the questions and the other for the answers. The wall can be added to progressively throughout the chapter.

2 Ask the students to skim through this chapter and jot down about 10 questions about everyday substances they would like to know the answers to. Allow them to use the section headings as pointers to help generate their questions. At the completion of this chapter, get the students to take out their set of questions and see how many they can answer. They will probably be delighted to discover they know most of the answers (if not all).

3 In today's society we need to be able to cope with rapid change, make choices between numerous alternative courses of action, and make many group and individual decisions. As teachers, we need to develop our students' skills so they are equipped to be able to think through processes objectively and make wise decisions. In your daily teaching, make sure you create tasks which develop these skills. (Essential Learning: Responsible, ethical and informed decisions about social priorities often require the application of scientific understanding.)

Hints and tips

- Metals are usually found as ores (compounds). Metals which are found in their elemental state are referred to as native or noble metals (gold, silver, platinum). A metal's properties determine how it can be used. The main properties which make metals similar are their:
  - conductivity (heat and electricity)
  - lustre (shininess)
  - malleability.
- Noble metals are found in their elemental state because they are unreactive. This means they do not corrode easily and are therefore often used for jewellery or for objects placed in areas where corrosion is a problem. Transition metals are the metals we are familiar with and know as everyday substances. These metals are used for many industrial purposes and in numerous items around the home. Alkali and alkaline metals are usually found only in compounds because of their high reactivity with non-metals.
- If you mix different metals together, you can change the overall properties of the combined metal, resulting in a substance called an alloy. Many of our most useful building materials and metallic items around the home are alloys. Discuss how the properties of the alloy are different from those of the metals it is made from. How is the alloy more useful than the metals it is made from?
- You may find it useful to introduce the periodic table here and briefly explain its structure.

9.1 Metals

In certain places in the Earth's crust we find metal compounds called ores which can be mined and the metals extracted. The ways these metals are used depend on their properties, as shown in the photos on this page.

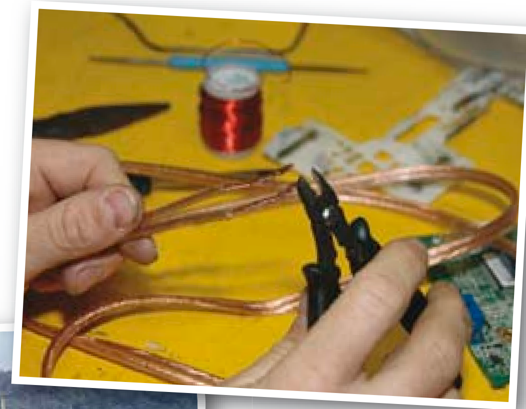


Fig 2 Pure copper is easily drawn into wires, and is an excellent conductor of electricity. So it is used for electrical wiring.

Fig 3 Because aluminium is strong and light and resists corrosion, it is used in boat building.

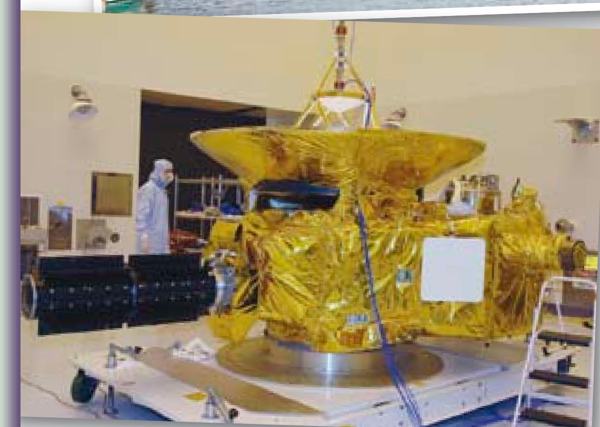


Fig 4 The shininess of gold makes it an excellent reflector of light and other radiation. This is why gold shielding is used to protect satellites and other spacecraft from solar radiation.

Alloys

Pure iron is of little use for making things because it is too soft and stretches easily. It also rusts very easily. When a little carbon (about 0.5%) is mixed with it, it becomes much harder and stronger. It is then called *steel*, and is used in buildings, bridges, ships and car bodies. When nickel and chromium are mixed with iron, it becomes even harder and no longer rusts. This substance is called *stainless steel*, and is used for kitchen sinks, tableware and surgical instruments.

These metal mixtures are called **alloys**. They have properties different from those of the metals they are made from. These properties depend on the proportions of each metal used. There are thousands of different alloys, and some of these are listed in the table on the next page.

Learning experience

Take a selection of metals and alloys into class for the students to observe by seeing and feeling. They can construct their own table similar to the table on page 193, but get them to divide theirs into 'Metals' and 'Alloys', then add a column for 'Physical appearance'. Other alloys could include bronze, nichrome, white gold and steel.

Learning experience

Can you change the properties of a metal? As an extension activity you may wish to investigate this with the class by performing the following practical investigation into how annealing, quenching and tempering affect the properties of a metal.

You will need four pieces of steel wire (hairpins are ideal), steel wool, Bunsen burner and heatproof mat, 250 mL beaker filled with water, tongs and safety glasses.

Construct the following table and fill it in as each step is completed.

	Number of bends to break steel	Effect on the properties
1 None		
2 Annealing		
3 Quenching		
4 Tempering		

continued

Activity

Alloy	Made from . . .	Special properties	Uses
stainless steel	70% iron 20% chromium 10% nickel	does not stain, corrode or rust	kitchen sinks, tableware, surgical instruments, artificial limbs
duralium	96% aluminium 4% copper	light and strong	aircraft parts
brass	70% copper 30% zinc	shiny, hard and does not corrode	musical instruments, car radiators, ornaments
aluminium bronze	92% copper 6% aluminium 2% nickel	harder than brass, does not corrode	'gold' coins
cupro-nickel	75% copper 25% nickel	light, hard and does not corrode	'silver' coins
solder	60% tin 40% lead	soft, low melting point	joining wires and pipes
Nitinol	55% nickel 45% titanium	if bent it slowly returns to its original straight shape, does not corrode	dental braces

Use the table to answer these questions.

1 Which metals are used to make duralium?
2 Name a lead alloy.
3 Which of the alloys in the table contain copper?
4 What differences are there between the alloys used to make 'gold' and 'silver' coins?
5 Suggest why stainless steel is more expensive than ordinary steel.
6 Suggest how the Nitinol wire used in dental braces straightens teeth.

Fig 5 Nitinol dental wire is used to straighten teeth.

Research

The alloy bronze is thought to have been discovered by the Sumerians around 3500 BC, in an area now in Iraq. Ask the class to investigate when other alloys were discovered, who used them and for what uses.

Homework

Investigate the alloy nichrome and find out why it is often used in electrical devices. What links can you make between this alloy and electricity (Chapter 8)?

1 Bend the wire repeatedly until it breaks. Count how many bends it took.
2 *Annealing*: With a second piece of wire, heat the middle in a blue flame until it glows red. Allow it to cool before bending it until it breaks.
3 *Quenching*: Heat a third piece of wire the same way but this time drop it into the beaker of water to cool before bending and breaking it.
4 *Tempering*: Heat and quench the fourth piece of wire. Polish it with the steel wool then reheat the shiny part of the metal until it turns blue. After it has cooled, again bend the wire until it breaks.

What conclusions can be drawn from this investigation? Find out where these three processes are used in industry.

Learning experience

The students could write a page that could be included in a history book about the process of extracting iron from iron ore. The process is very involved and this is probably why iron was not used until around 1500 BC. The students may like to write an informative piece outlining the history of the Iron Age. More creative writers may choose to be in character and write about 'My personal experiences during the Iron Age'.

Research

Students could research how some tarnished metals are cleaned. What chemistry is involved in the tarnishing and the cleaning process? What safety precautions are necessary? Is there only one way to clean the metal? If not, what are some other methods? Which is the safest procedure? Which is the most environmentally friendly? The responses to each question should be accurately detailed. The students could present their information as an instruction booklet that could be given to households, or they could choose to design a web page for the school intranet.

Homework

For each of the protective measures to prevent rusting listed on this page, ask students to find out how and why each one stops or slows corrosion. For example, painting steel or iron keeps oxygen from reacting with the metal underneath the paint. Why are paints containing zinc used?

Learning experience

Many church spires in Europe are made from copper, which once shone brightly and reflected the sun's rays. Unless they have been recently restored, these spires are now coated in a greenish compound. Lübeck in Germany, for example, is often known as 'The City of the Seven Spires'. If you view the skyline you can see all seven of the copper church spires which nowadays are green. Imagine what they would have looked like just after their completion. Can you or your students think of any building in the local area or elsewhere that has a copper roof? Share experiences.

Fig 7 Painting the Sydney Harbour Bridge is a never-ending job.

Corrosion

When a metal reacts with air, water or other substances in its surroundings, new substances are formed. This process is called **corrosion**. Iron and steel corrode in damp air to form rust (brown iron oxide), which has properties very different from the metals.

When left exposed to the weather for many years copper becomes coated with a greenish compound. Aluminium becomes coated with aluminium oxide, but this thin coating protects the metal from further corrosion. Gold (impure), silver and brass slowly become tarnished (discoloured), especially in cities where there are acidic gases in the air. This is why metal objects need to be cleaned regularly.

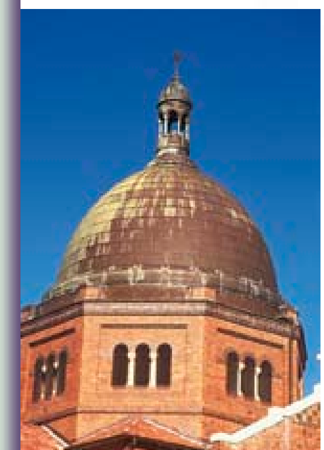


Fig 6 Notice how the copper on the domed roof has corroded.

How to stop rust

When iron is made into stainless steel it does not rust. But stainless steel is expensive to use in large quantities, so other methods of protection are used. These usually involve coating the metal with some unreactive substance to keep out air and water.

1 Painting

Steel exposed to the weather has to be painted regularly. Paints that contain zinc are often used.

2 Coating with oil, grease or tar

Objects such as bike chains and the inside of car engines, which cannot be painted, are protected this way.

3 Coating with plastic

Garden chairs, dish racks, tennis court fences and the inside of steel cans are protected in this way.

4 Coating with metal

Cans used to store food are made from steel coated on both sides with a layer of tin. Tin is used because it is fairly unreactive, and non-toxic. If the tin coating becomes damaged, the exposed iron will corrode rapidly, spoiling the contents of the can. This is why it is unwise to use scratched or dented cans.

Bumper bars on older cars are plated with chromium, and cutlery is sometimes coated with nickel.

5 Sacrificial protection

Iron for garden sheds, roofs, guttering and light poles is coated with zinc or a zinc–aluminium alloy. This process is called *galvanising*. The zinc slows down corrosion because it is more reactive than iron. This means it corrodes first and is sacrificed to protect the iron. After many years the iron becomes exposed and starts to rust.

When a bar of zinc is attached to the side of a steel ship, it corrodes instead of the steel. When it is nearly eaten away it is replaced by a fresh bar.

Learning experience

Conduct a class discussion about corrosion. Have students ever seen rusty iron, or a piece of silver that has dulled and lost its shine? What is the cause of this? Why do some metals seem to be more affected by corrosion than others? (Metals such as magnesium, aluminium, zinc, iron and tin are more reactive.) Ask the students to look around the school, their house, garden and garage for examples of corrosion, as well as protective measures that have been used. Construct a class chart which contains information about each metal. Each student should enter at least one example they have found. Include information about each metal's signs of corrosion (if any), and the measures (if any) that have been used to stop it.

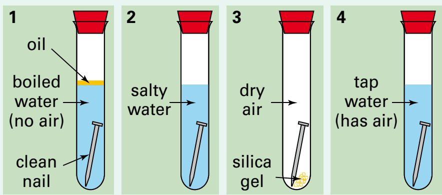
Experiment
WHY DO THINGS RUST?

Research question

What effect do air, water and salt have on the rusting of iron?

Planning

1 You need to vary the amounts of air, water and salt, but control all other variables. One way to do this is to use four test tubes as shown.



What is the purpose of the oil in test tube 1?

Why use the silica gel in test tube 3?

2 Before you start, predict what will happen.

3 Don't forget to prepare a data table to record your observations over a week or so.

4 You could vary the concentration of the salty water.

5 You could try coating a nail with grease.

6 You could weigh the nails before and after to make your experiment more quantitative.

7 Your teacher could show you how to do the experiment by covering the nails with agar in petri dishes.

Discussion

1 Try to explain your results. Were your predictions correct?

2 Suggest ways of improving your experiment.

Write your conclusion

try this

Design a controlled experiment to compare the rates of corrosion of aluminium, copper and iron indoors and outdoors. If possible, carry out your experiment and write a report.

Check!

1 Kris thought their car was rusting faster because they lived near the sea. Do your results in the experiment support this idea?

2 What is an alloy? Why are alloys used instead of pure metals?

3 Suggest why aluminium rather than steel is used to make aircraft bodies.

4 Name three household objects made from stainless steel. Suggest why they are made from this alloy.

5 a What is corrosion? Give some examples.
b Which two substances cause corrosion?

6 Why don't aluminium window frames need to be painted?

challenge

1 Iron that is tin-plated rusts very slowly. Why?

2 What is the process of galvanising? How does this prevent iron from rusting?

3 Why is it unwise to buy dented cans of food?

4 A sculptor makes two identical statues of bronze. One is placed in Brisbane and the other in Alice Springs. After 10 years the Brisbane statue is badly corroded, but the other is in good condition. Explain why.

5 Oil rigs often have big lumps of magnesium attached to their legs under water. Suggest a reason for this.

6 An advertisement for garages says *Keep your car inside one of these garages and your car won't rust.* Do you think this is correct? Explain.

7 Why do car exhausts rust so rapidly? What are the advantges and disadvantages of stainless steel exhausts?

Lab notes

- This experiment requires a reasonable amount of planning and preparation, regular checks for a week or two during the experiment and careful recording of observations.
- It is a good idea to pool class data if different variables are tested by different groups.
- The rust stains are best removed from the test tubes by using concentrated (4M) HCl for a few minutes and then washing in water.

Check! solutions

1 If you did the Experiment on this page you may have observed that the nail in the salty water rusted more quickly. If so, Kris's idea about the rust in his car would be supported.

2 An alloy is a mixture composed wholly or mainly of two or more metals. Alloys are sometimes used instead of metals because they have different properties and are sometimes more useful than pure metals.

3 The metal aluminium is used instead of steel to make aircraft bodies because it has better properties. It is less dense and resists corrosion.

4 Kitchen sinks, cutlery and cooking pots and pans (and many other objects) are often made of stainless steel. This is because stainless steel is strong, does not corrode and is easy to keep clean.

5 a Corrosion is the process in which metals react with substances in their surroundings to form new substances. Examples include the rusting of iron, and copper turning a greenish colour.
b The two substances that cause most corrosion are oxygen in the air and water.

6 Aluminium window frames do not need to be painted because the metal quickly reacts with oxygen in the air to form a thin coating of aluminium oxide. This prevents further corrosion.

Challenge solutions

1 A coating of tin protects iron because tin does not corrode readily.

2 The process of galvanising involves putting a layer of zinc over the iron or steel, providing a barrier that protects it from rusting. Zinc is also more reactive and will therefore corrode before the iron.

3 If the can is dented the layer of tin may be broken and corrosion can begin. This may produce chemicals which can contaminate or spoil the food.

4 Corrosion is caused by chemicals in the environment. In Brisbane the climate is wetter and there are many more cars and factories producing chemicals which get into the air and cause corrosion of metals. In Alice Springs the conditions are dry and there are less pollution-causing chemicals in the air.

5 Magnesium is a very reactive metal and will corrode before the metals which are used in the legs of the oil rig. This is an example of sacrificial protection.

6 This statement is not altogether correct. Keeping a car in a shed will mean that it not exposed to rain and is protected from other chemicals (eg salt) in the air. This will mean that the rate of corrosion is reduced but it will not be stopped altogether.

7 Car exhausts rust rapidly because the gases from the motor contain water and other gases which cause corrosion. Exhausts also operate at a very high temperature which speeds up the process. This can be prevented by using stainless steel exhausts which do not corrode, although they are more expensive.

Hints and tips

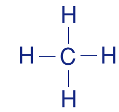
- Revise the fundamentals of atoms, molecules, compounds and so on. Ask questions in the form of a quiz, but don't spend unnecessary time reviewing material.
- It may be important to explain chemical bonding in greater depth, introducing the idea of valency. This way, students are likely to better grasp why carbon forms four bonds. Set a separate task for any gifted or talented students to explain the groups of the periodic table and their relationship with valencies and chemical bonding.
- This chapter has the potential to disengage less able students, so make sure you identify these students and monitor their progress. It may be helpful to set them small challenges along the way. One useful task is to get them to write a dot-point summary of 5–7 points (with diagrams) of some specified pages in this chapter. Although all students can benefit from doing this, some students, such as those who experience learning difficulties or are ESL students, may need more reinforcement of concepts than others.

9.2 Carbon compounds

You walk into a shop selling freshly ground coffee. The aroma of coffee is due to hundreds of different chemical compounds all containing the element carbon. In fact, over 90% of all the compounds on Earth contain carbon. Carbon compounds are made up of carbon and a few other elements—mainly hydrogen, oxygen and nitrogen. All living things are made of carbon compounds; your food is made of them and your clothes are made from them.

The reason there are so many different carbon compounds is that carbon atoms can form four **chemical bonds**, due to the attractive forces between atoms. Carbon can bond (link) to other atoms such as hydrogen and oxygen. For example, methane is the main ingredient in natural gas, and is found in swamps when plant material decays. A methane molecule consists of a carbon atom bonded to four hydrogen atoms. Its *molecular formula* is CH_4, meaning there are four hydrogen atoms (H) for each carbon atom (C).

If you want to show how the atoms are bonded to each other you can use a **structural formula**. For example, the structural formula for methane is:



This is an easy way to draw a three-dimensional molecule in two dimensions. Each line represents a chemical bond.

The second reason there are so many carbon compounds is that carbon can bond to itself. For example, Fig 10 shows a molecule of ethanol (a type of alcohol), the most important ingredient in beer, wine and spirits. Notice that each carbon atom is bonded to four other atoms. Each hydrogen is bonded to only one atom, and oxygen is bonded to two atoms.

In the activity on the next page you can make models of carbon compounds for yourself.

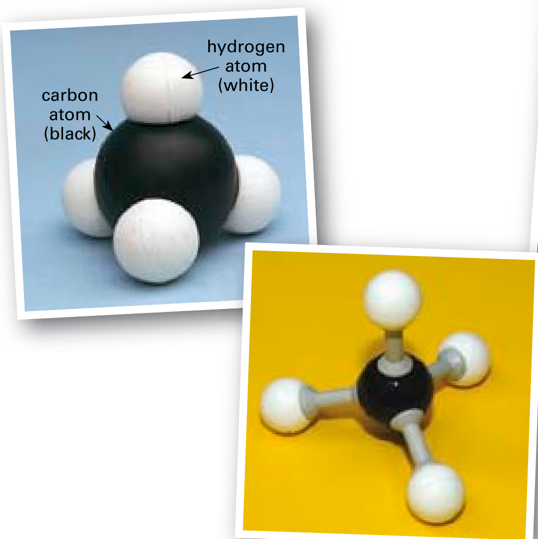


Fig 9 Two different molecular models for methane CH_4

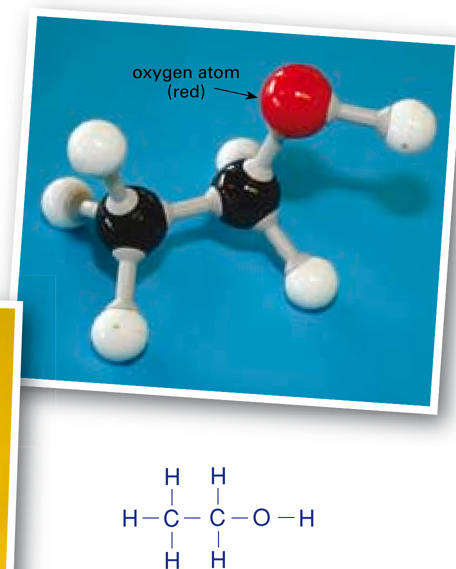


Fig 10 A molecular model of ethanol (C_2H_5OH), with its structural formula

Learning experience

Ask the students to make links between carbon compounds and oil (pages 147–148). They could investigate and report on some different naturally occurring carbon compounds and how they are used in everyday life. Turn this into a Round Table activity, where a group of students are given a set time to brainstorm together before reporting their conclusions to the whole class. It could also be a Think/Pair/Share activity. Both activities encourage co-operative learning, creativity and deeper thinking.

Learning experience

Students can practise drawing some structural formulas for different carbon compounds. Write out the chemical formula on the board and get the students to attempt to draw it first before you show them. Consider the alkanes such as methane, ethane, butane and propane (gases). Alkenes (ethene, propene, butene, etc) may be a little difficult at this stage. Consider showing what glucose $C_6H_{12}O_6$ and its isomers (fructose and galactose) look like.

Activity

You will need a molecular models kit.

1 Your teacher will show you how to use the kits, or you can read the instructions.
 Which colour balls represent carbon atoms? Hydrogen atoms? Oxygen atoms?
 How are the bonds between atoms represented?
 How many bonds can carbon form?
 How do you know?
 How many bonds can hydrogen and oxygen form?
2 Make a model of a methane molecule CH_4 and sketch it with the different atoms labelled.
3 Join two carbon atoms with one bond then add as many hydrogen atoms as possible. This represents ethane—a gas similar to methane.
 Write down the formula for ethane, and draw its structural formula.
4 Make models to represent propane C_3H_8 and butane C_4H_{10}. Compare your models with those made by other students.
 Did you find that there are two different ways of making C_4H_{10}? Draw the two structural formulas.
5 You can use the models kit to have competitions. For example, how many different carbon compounds can you make using 4 carbon atoms, 2 oxygen atoms and 10 hydrogen atoms? You can use all of these atoms or only some of them—but you must obey the bonding rules by filling all the holes in each of the atoms. As you make each compound write down its structural formula.

Fig 11 Students building models using a ball-and-stick molecular models kit

Carbon compounds from oil

Crude oil is a liquid containing a mixture of hundreds of different carbon compounds. Most of these are **hydrocarbons**—compounds of carbon and hydrogen only. These different compounds can be separated by the process of **fractional distillation.**

At an oil refinery the crude oil is heated in a furnace and passed into a large tower called a fractionating column, which is hot at the bottom and cooler at the top (See Fig 12 on the next page.) At the bottom almost all the hydrocarbons boil. Their vapours rise in the column, cooling all the way. When they have cooled down enough they condense back to liquids. Hydrocarbons with high boiling points condense in the lower, hotter part of the column. Hydrocarbons with lower boiling points condense further up, in the cooler part of the column. In this way the crude oil is separated into *fractions* with different boiling points.

Some of the fractions are gases, most are liquids, and some are solids. To explain these differences you need to consider the size of the molecules in the fractions. There are attractive forces between molecules, and the more atoms

Hints and tips

Carbon exists in every living thing and anything that was once living on Earth. Pure carbon exists in three different forms (allotropes): graphite, diamond and amorphous carbon (charcoal, coal).

Activity notes

- Check that the model kits are designed for organic chemistry.
- Check that each kit is complete before issuing it to the students and on return. For this activity, students work best in pairs or groups of three.
- If using kits with springs, explain that if the springs get stuck students should twist them rather than pull them out, otherwise the springs will be permanently stretched.
- Wooden balls/beads in various sizes are usually available where craft supplies are sold, eg stores like Spotlight and The Warehouse. Drill some more holes if needed, dye them with food colouring and use ‘pipe cleaners’ to join them. Alternatively, polystyrene balls and skewers work just as well. They can be painted with acrylic paints—the school art department may be able to help out.

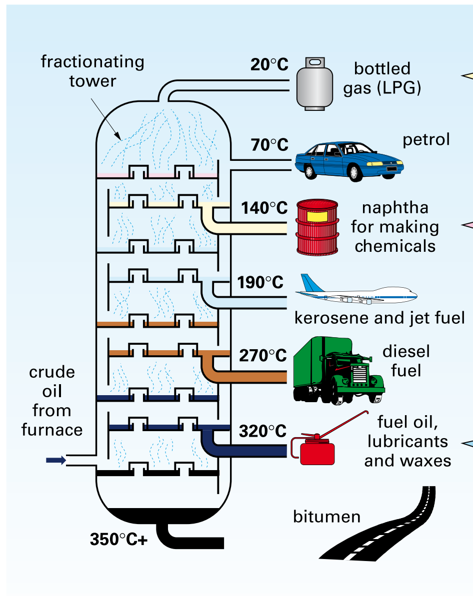
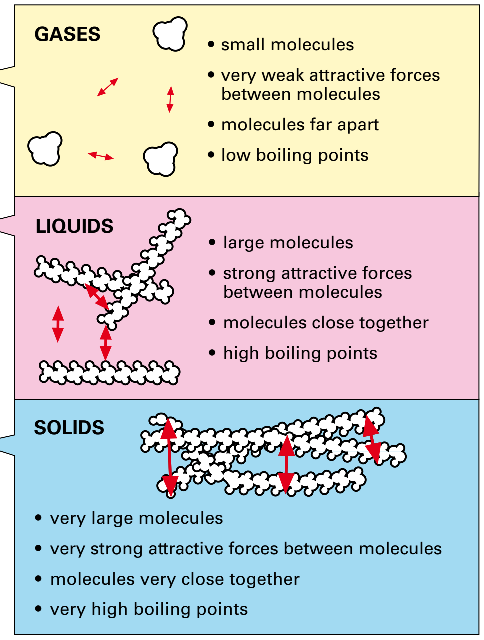


Fig 12 Fractional distillation of crude oil



there are in a molecule the stronger these attractive forces are. Therefore large molecules have very strong attractive forces between them, and are generally very close together.

The fractions from the top of the column consist of small molecules containing only a few carbon atoms. This is why these fractions are gases, eg methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}), with low boiling points.

Most of the fractions from crude oil are liquids. For example, octane in petrol is C_8H_{18}. Their molecules are larger, with stronger forces between them, and closer together than the molecules in the gaseous fractions. As you go down the column, the molecules in the liquid fractions become larger, the molecular forces are stronger and hence the boiling points increase. The **viscosity** also increases. For example, petrol is quite runny (like water), but lubricating oil is thick (viscous). This is because of the stronger attractive forces between the molecules. The larger molecules also tend to get tangled up and cannot move about as easily as the smaller ones.

The solid fractions from the bottom of the column contain very large molecules, with very strong attractive forces, packed close together. For example, the paraffin wax used to make candles contains molecules with 20–27 carbon atoms.

Soaps

Water has always been used to clean our bodies and clothing. However, water cannot remove oil and grease because these substances do not dissolve in water. You need a soap or a detergent to remove them.

It is thought that the first soap was made about 2500 years ago, probably by the Egyptians. Soaps are carbon compounds made by boiling vegetable or animal oils with caustic soda (sodium hydroxide). When salt is added to the mixture, hard lumps of the soap form on the surface. Dyes and perfumes can be added to make the soap look and smell better.

Homework

- Ask students to find out what LPG is the abbreviation for (liquefied petroleum gas), and come up with five uses for the gas. Do they have any at home? If so, where and how is it stored? What safety precautions need to be taken when storing and using it?
- Find out where the major gas fields are in Australia.

Learning experience

Demonstrate viscosity using different liquids. Have about three different grades of oil (petroleum-based) in glass cylinders. (This demonstration can be expensive if the oil is not used for any other purpose, so you may choose to demonstrate with one type of oil and water instead.) Drop a ball bearing into each liquid and time how long it takes for each ball to reach the bottom of the cylinder. The higher the viscosity, the longer the ball will take to reach the bottom. Ask students to suggest in which section in the fractionating tower the oils are likely to be fractioned off.

Learning experience

Have students design a poster to display information about the process of fractional distillation of crude oil. They could use Fig 12 as a guide. Ask them to find out what some of the chemical formulas are for a selection of products listed at each fraction, and add these to their poster. They should also explain the difference between crude oil and refined oil.

Learning experience

Making soap can be dangerous—why? Discover how it was made in medieval times or in another historic period. Explain why, at the completion of the process, it is safe to use on our skin even though it is made with such harmful chemicals. Design a task around these ideas for the students to complete co-operatively in small groups. One type of group task is the Jigsaw model, where each member of the team assumes responsibility for a specific section of the problem. They are responsible not just for finding the information, but for explaining the information to their team members and working to put the ‘jigsaw’ together to complete the problem.

Investigate 20 MAKING SOAP

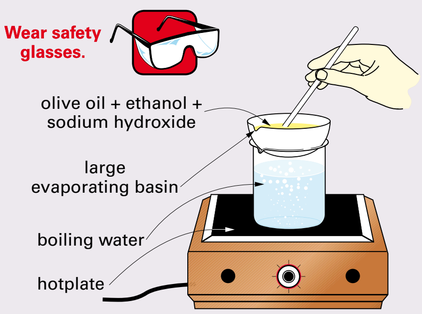
Aim
To make soap and test how well it works.

Materials
- hotplate (or burner, tripod and gauze)
- 2 beakers (approx 400 mL)
- 2 test tubes, with stoppers
- large evaporating basin
- stirring rod
- wash bottle
- spatula
- 90% **ethanol** (or **methylated spirits**)
- kerosene
- olive oil or castor oil
- 6M **sodium hydroxide** solution (**caustic soda**)
- saturated sodium chloride solution
- piece of filter paper
- measuring cylinder (10 mL)


Flammable


Corrosive

Planning and Safety Check
- Sodium hydroxide is very corrosive, especially when it is hot. So you will need to take special care that you do not spill any. What should you do if you do spill it? To protect your hands you could wear plastic gloves.
- Why is it safer to use a hot plate than a Bunsen burner in this investigation?
- You should not test the soap on your skin. Why not?



Method
1 Set up a steam bath as shown below.

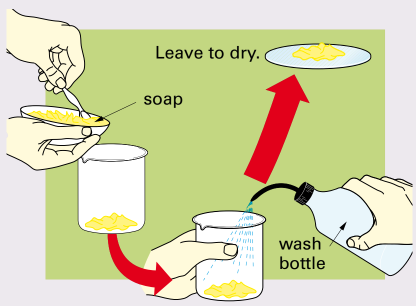
2 Add 5 mL of olive oil and 5 mL of ethanol to the evaporating basin. Then carefully add 5 mL of sodium hydroxide solution, while stirring. (The ethanol speeds up the reaction between the oil and the sodium hydroxide by dissolving the oil.)

3 Continue heating for about 30 min, while stirring. The olive oil should 'disappear' and the mixture become pasty.

4 Turn off the steam bath and add 5 mL of sodium chloride solution, while stirring. Soap is insoluble in this salt solution, and should float to the surface as a white curdy solid.

5 Use a spatula to skim off the soap into a beaker. Rinse it several times with a small amount of water, using a wash bottle.

6 Leave the soap to dry on a piece of filter paper.



7 One-third fill a test tube with water, and add some of your soap. Then put in a stopper and shake. Is a lather (froth) produced?

8 Add 2 or 3 drops of kerosene to water in a test tube, and shake. (Kerosene acts like grease.)

Describe what happens.

9 Now add some of your soap to the kerosene and water and shake it again.

What happens this time? Explain.

Lab notes
- Even if things are well prepared and the class works really well, you will need at least an hour to complete this investigation safely and clean up the equipment.
- It is much safer to use hotplates than it is to use a burner, especially with the ethanol. Special warnings and care are necessary if you use burners.
- Lab coats and safety glasses are absolutely necessary when dealing with caustic soda. Wearing gloves is also a good idea.
- At step 3, students should take it in turns to stir while the others in the group can write up their report or do other class work.

Hints and tips

The discussion of soap can lead into many other associated areas of science, from health (eg diseases and pathogens) to chemistry (eg acids and bases in Chapter 10). Why do we use soap? Why is personal hygiene important? Are there some cultures, people or groups who do not use it? Is that only because it is not available to them, or are there other reasons? Do they use a natural soap substitute?

How soap works

The diagram below shows what a typical soap molecule looks like. The 'tail' of the molecule is a long hydrocarbon chain, and the 'head' is negatively charged. The 'tail' has much the same structure as the compounds in grease and is attracted to and dissolves in the grease. This end is therefore called the grease-loving or water-hating end. The 'head' is attracted to water particles and is called the water-loving end. In the bottom diagram the soap molecule has been simplified to —○.

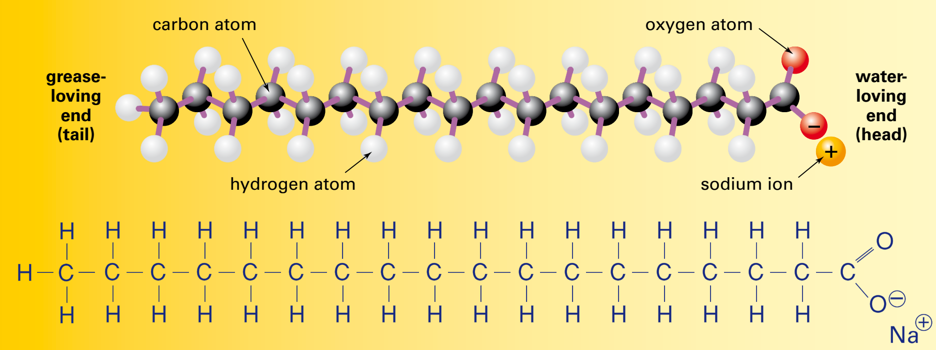
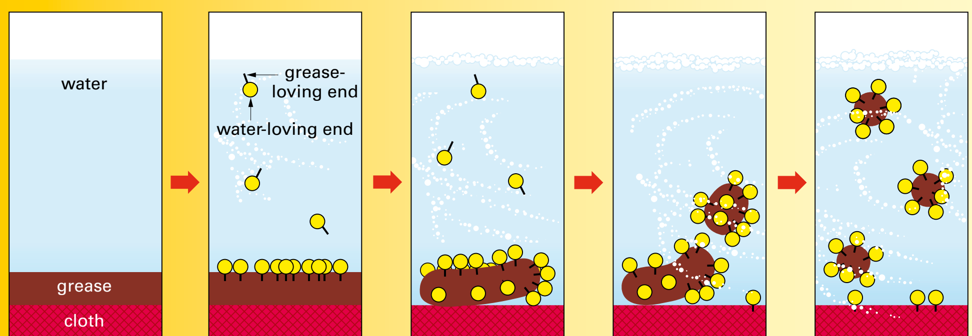


Fig 16 A typical soap molecule. Its chemical name is sodium stearate $C_{17}H_{35}COO^{-}Na^{+}$.



A piece of cloth is covered with grease. Water alone will not remove the grease.

When soap is added, the grease-loving 'tails' stick into the surface of the grease, leaving the charged 'heads' sticking out into the water.

Each droplet of grease becomes surrounded by a layer of soap molecules with their charged heads on the outside.

When the cloth is shaken in a washing machine, the large grease droplets break up into smaller droplets which can be removed from the cloth by further shaking.

The small grease droplets and attached soap molecules repel one another and do not re-attach themselves to the cloth. The excess soap molecules form a protective layer on the cleaned cloth.

Working with technology: To see an animated version of Fig 16, open the **How soap works** animation on the CD.

Research

Ask students to investigate whether there are soaps available that are considered better than others. What is it that makes the soap 'better'? Why is getting the right pH level so important?

Homework

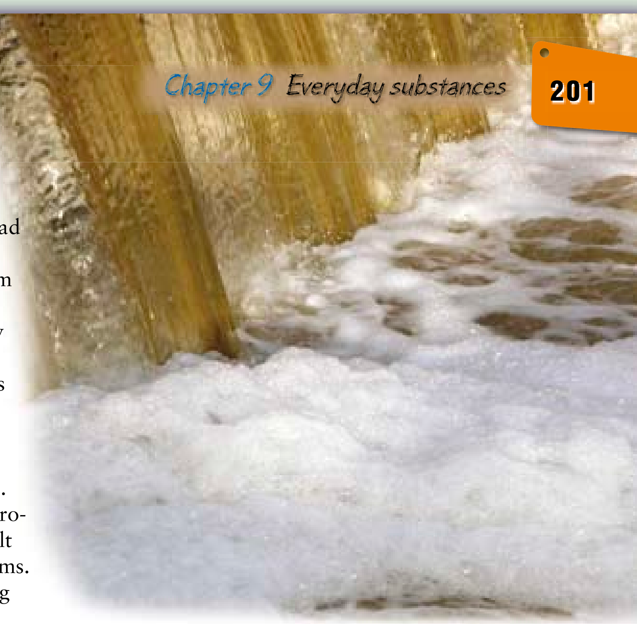
Ask students to have a look at the ingredients listed on a packet of soap. How many are similar to those in the investigation on page 199?

Learning experience

Ask the students to prepare a fact sheet about the chemistry of soap, to be distributed in soap packets or posted on a soap company's website. Make sure the students know who the target audience is, and that they write their sheets using an appropriate language level.

Learning experience

Using the internet or magazines such as *Choice*, ask students to find out which washing powders and detergents are considered the most environmentally friendly and why. The students should present their findings to the class. They could write a concise report to go into the school newsletter to inform parents.



Detergents

Detergents are synthetic compounds with a head and tail structure similar to that of soap. They are usually made from chemicals obtained from crude oil, and they are used as dishwashing liquids, washing powders and shampoos. They work better in hard water than soap does. (Hard water is water containing large amounts of dissolved solids which prevent soap from producing a lather.) This is why detergents are more effective cleaners than soaps.

The first detergents were not **biodegradable**. They were not broken down by microbes (micro-organisms) into simpler compounds. As a result they caused foam to appear in rivers and streams. In some polluted areas, even a glass of drinking water would have a head of foam on it. The problem was solved by changing the ingredients used to make the detergents. The new detergents are biodegradable and in most countries the law requires that all detergents be biodegradable.

A second problem is that many detergents contain chemicals called *phosphates*. These are used to 'soften' the water, allowing the detergents to remove more dirt from clothes. These phosphates are washed into drains and then into rivers and lakes where they are good fertilisers for algae and other water plants, which grow quickly and then die. The decay of these plants uses up the oxygen in the water and as a result fish and other aquatic animals may die. For this reason there are limits on how much phosphate manufacturers can put in detergents.

Check!

1 Explain why carbon forms so many different compounds.

2 Which elements do hydrocarbons contain?

3 How many bonds can each of these atoms form?
- a carbon
- b oxygen
- c hydrogen

4 In what ways are soaps and detergents similar? In what ways are they different?

5 Describe in your own words how dishwashing detergent removes grease from dishes. Use a diagram if you wish.

6 What is the difference between fractional distillation and ordinary distillation?

7 A crude oil sample was separated into four fractions. These were collected in the temperature ranges in the table.

Fraction	Temperature range (°C)
A	5–70
B	70–115
C	115–200
D	200–380

Which fraction would you expect to:
- a be the most like petrol?
- b have molecules with the longest chains?
- c be the most viscous?
- d have the lowest boiling point?

Hints and tips

- Explain the difference between natural and synthetic (something that is synthetic is not obtained directly from natural sources). Discuss how detergents differ from soap.
- Interestingly, soil-wetting agents used in the garden have similar properties to detergents. Washing-up liquid can be used as a cheaper alternative but the environmental impact on the soil needs to be considered if using it as a substitute.

Homework

The use of the word *biodegradable* is becoming more common. Ask students to find out what it means, and what importance it has for our environment. How many chemical products do students have at home that claim they are biodegradable and/or environmentally friendly? What are they, and what are they used for?

Learning experience

Does the local area have soft or hard water? Have students ever travelled overseas and taken their own shampoo with them, only to discover it doesn't lather, or lathers too much? Might recycled water have something to do with the 'hardness' of water? Encourage the students to discuss their personal experiences.

Check! solutions

1 Carbon atoms are able to form four covalent chemical bonds with other carbon atoms or atoms of other elements. This means that a very large number of compounds can be formed.

2 Hydrocarbons, as the name suggests, contain the elements hydrogen and carbon.

3 The number of bonds that can be formed by:
- a carbon is 4.
- b oxygen is 2.
- c hydrogen is 1.

4 Soaps and detergents are similar because they both have a 'head-and-tail' structure and are both effective in removing grease from our bodies and from clothing. They are different because soaps are produced from vegetable and animal oils, whereas detergents are produced from chemicals obtained from crude oil. Detergents work better in hard water than soaps and are usually biodegradable.

5 The detergent molecules have two ends called a head and a tail. One end likes grease molecules and the other end likes water molecules. When detergent is mixed with water and greasy dishes it surrounds the grease molecules, allowing them to be pulled from the surface of the dishes. There is a helpful diagram on page 158 of the textbook.

6 Fractional distillation means that several different products, or fractions, are produced, whereas ordinary distillation usually involves separating a solvent from a solute.

7 Using the information from the table:
- a The fraction most like petrol would be A.
- b Fraction D would have the longest chains.
- c Fraction D would be the most viscous.
- d Fraction A would have the lowest boiling point.

challenge

1 Look at the flow diagram below which shows what happens in a factory making washing powder.

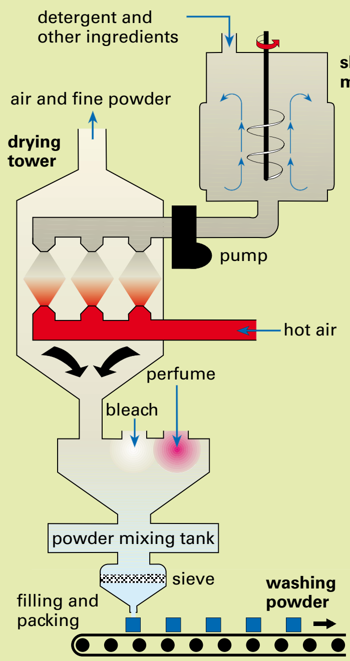
a What raw materials are used by the factory?

b What is the end product?

c Are there any waste materials?

d Why is a sieve used before packing the washing powder?

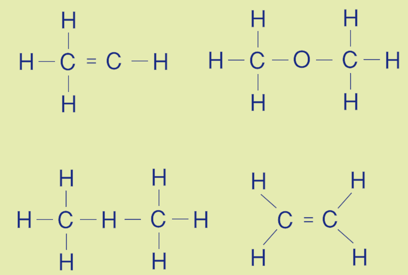
e Suggest why the bleach and perfume are not added with the other ingredients at the start.



2 Methane gas burns in oxygen to produce carbon dioxide and water. Write a word equation for this reaction.

3 Suppose you had to wash in sea water. Which would be best to use—soap or detergent? Why?

4 Examine the following formulas. Which ones are correct according to the bonding rules? For each one that is incorrect, say why. (You could try to construct the molecules using molecular models.)



= represents a double bond

5 CFC-11 (once used in aerosols) has the molecular formula CCl_3F.

a Use the formula to work out what CFC stands for.

b Draw the structural formula for CCl_3F.

6 Butane and isobutane both have the same formula C_4H_{10}. However, isobutane has a lower boiling point and lower density than butane. Use molecular models to explain these differences in properties.

try this

1 Suppose you are asked to test whether liquid detergents wash clothes better than powder detergents. Describe how you would do this, making sure you control variables.

2 Do a supermarket survey of laundry detergents. What does the $\boxed{P}$ symbol mean? What other symbols are used on the packages?

3 Use a molecular models kit to build a soap molecule (Fig 16 on page 200). Use the internet to find out how detergent molecules are different from this.

Challenge solutions

1 a The raw materials are detergents, bleach, perfume and 'other ingredients'.

b The end product is washing powder.

c The main waste material is the fine dust which is expelled with the air from the drying tower.

d A sieve is used to remove any lumps of powder and foreign objects from the powder before it is packed.

e Bleach and perfume are not added at the start because they would be affected by the heat in the drying tower.

2 The word equation is:

methane + oxygen $\longrightarrow$ carbon dioxide + water

Note that the balanced symbol equation is

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

3 It would be better to use a detergent rather than a soap in sea water because detergents work better in water which contains dissolved solutes (eg salt).

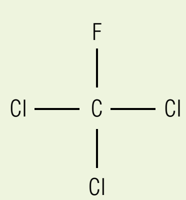
4 The correct formulas are top right and bottom right.

In top left, one of the carbon atoms has five bonds and one has three bonds.

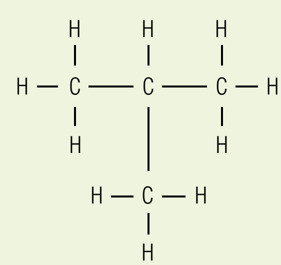
In bottom left, one of the hydrogen atoms has two bonds instead of one.

5 a CFC stands for chloro-fluoro-carbon.

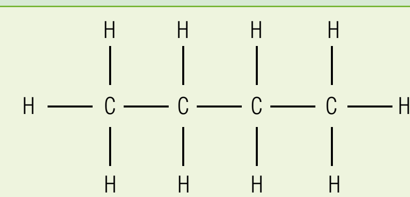
b The structural formula is:



6 Even though these two molecules have the same formula they have different structures as shown below:



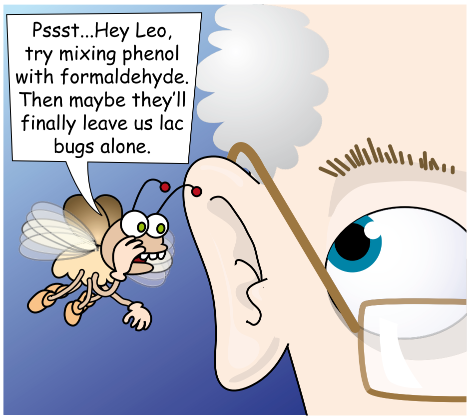
isobutane (branching chain)



n-butane (straight chain)

The n-butane molecules are longer than the isobutane molecules, which means that isobutane has a lower boiling point than n-butane. Also, because of their branching chains, isobutane molecules do not fit together as well as the n-butane molecules, which means that it will have a lower density.

9.3 Plastics and fibres



In 1907 Leo Baekeland, a Belgian working in the United States, was trying to make an artificial substitute for shellac. (Shellac is a material obtained from tiny Indian lac bugs, and was used widely for making varnishes and waxes.) Instead, he made a new substance that kept clogging up his test tubes. Nothing would dissolve this dark brown substance, and on further investigation he found that it could be moulded into shapes. It was a good insulator of heat and electricity.

What Baekeland had done was to mix phenol and formaldehyde, which reacted to form a substance we now call *plastic*. (The word *plastic* means 'easy to mould'.) Baekeland called the new material *Bakelite*, from his own name, and it was soon being used for handles on saucepans and for electrical fittings. It has now been replaced by newer plastics.

Polymers

Suppose you mix two different chemicals, A and B. Each contains small molecules, and they can react together to form a bigger molecule, A–B. However, it is sometimes possible for the molecules to go on linking up to form giant long-chain molecules called **polymers**. (Poly means 'many' and mer means 'units'.)

All polymers contain big molecules that consist of many small molecules (or *monomers*) linked up together. The chemical reaction in which small molecules link up to form polymers is called **polymerisation** (pol-IM-er-eyes-AY-shun). Sometimes the monomers are all the same, and sometimes there are two different monomers.

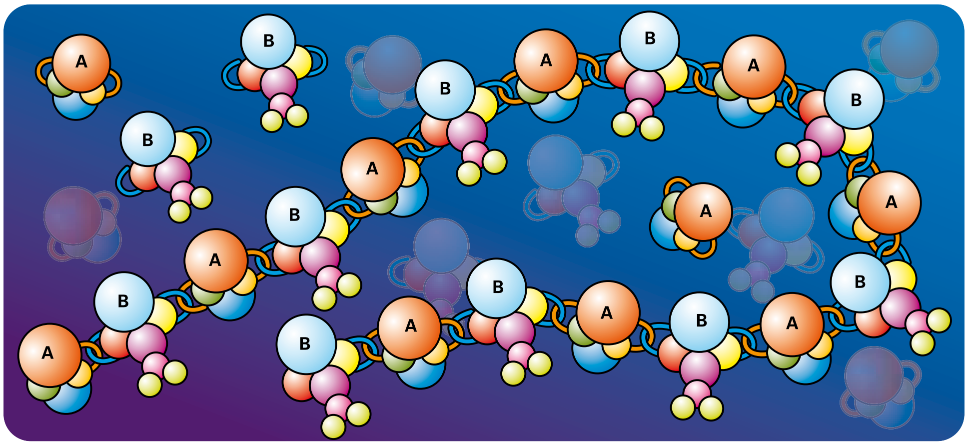


Fig 21 This cartoon shows two different small molecules forming a long-chain molecule. The process is a bit like linking paperclips together.

Hints and tips

- The word *plastic* comes from the Greek word *plastikos*. It means 'easy to mould' or 'able to be moulded'. What we generally regard as everyday plastics should really be called polymers.
- Review the concepts covered so far in this chapter. Ask each student to write down about five questions with answers on a piece of paper for you to collect. Allow only a few minutes to do this. Once you have collected the papers, run a short quiz. You may need to be selective with your questions. Spend no more than about 15 minutes on this activity.

Learning experience

Present a Plastics Timeline to the class or, better still, ask them to help you construct one. Assign pairs of students to investigate either types of plastics or the person(s) involved in notable discoveries. Consider, for example, celluloid (Parkesine), Bakelite, macromolecules and polymers, teflon, nylon, polycarbonate, polythylene, polypropylene, thermoplastics, thermosets, polyesters, polyhydroxybutyrate (PHB).

Learning experience

Get the students to make a table of everyday items that are made of or have some part made from plastic. Have a column in the table labelled 'Suitable alternative'. Next to each plastic item they should write down if there is an alternative material that can be used instead of the plastic. How much do the students personally rely on plastics, and how much does society? Once they have completed the table ask them to make a written response to the following statement:

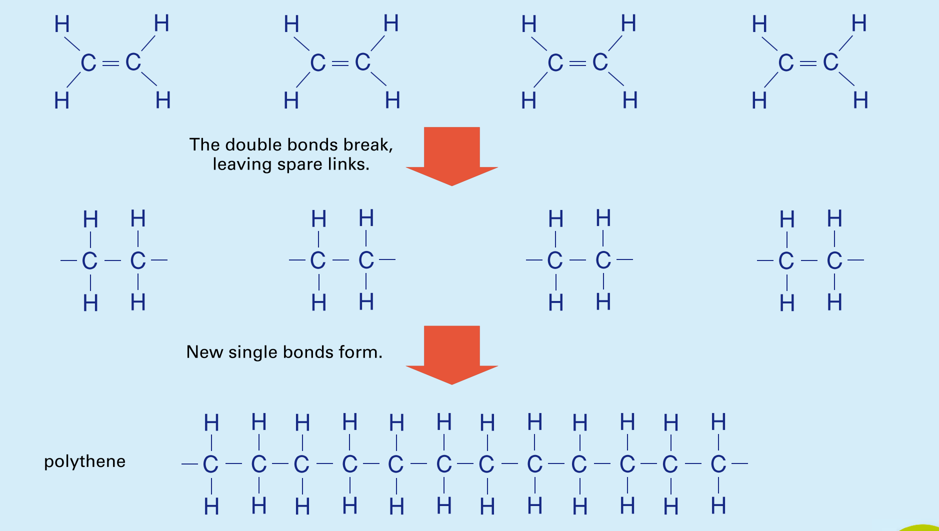
One great thing about plastics is that they are cheap to make from fossil fuels, like crude oil, and they last forever. Unfortunately, these advantages are also their disadvantages, and one day we will run out of fossil fuels.

Get students to draw their responses from the information in their table and in the textbook. Encourage detailed information, critical thinking and their opinions.

Hints and tips

Prepare a PowerPoint presentation on plastics and fibres from the 'Plastics and fibres' section of the textbook, with illustrations to help explain the information. Incorporate the Polymerisation animation from Working with technology into the show. You may also find it useful to incorporate some of the images/ figures from the textbook into the presentation.

Making polythene from ethene



To see how polythene is made from ethene, open the **Polymerisation** animation on the CD. Working with technology

Polythene (or polyethene) is formed by the polymerisation of ethene, one of the many chemicals obtained from crude oil. Ethene molecules contain a double bond (represented by a double line), which makes them very reactive. If the double bonds are broken and then linked to neighbouring molecules, a long chain polymer can form as shown above. These chains can contain up to 50 000 carbon atoms.

Many other monomers besides ethene can be polymerised. For example, vinyl chloride is the same as ethene except that one hydrogen atom in each ethene molecule has been replaced by a chlorine atom. It can be polymerised to form polyvinyl chloride or PVC. Similarly, styrene can be polymerised to form polystyrene.

Natural polymers

Many polymers occur naturally. For example, cellulose and starch in plants are both polymers made from glucose units. If we represent a glucose molecule by the symbol g, then the structure of starch is –gggggggggg–, and the structure of cellulose is –gᵷgᵷgᵷgᵷgᵷ–. In cellulose every second glucose molecule is upside down.

The cells and tissues in your body are made of proteins, which are polymers made from smaller molecules called *amino acids*. These contain carbon, hydrogen, oxygen, nitrogen and sulfur atoms. Fig 23 shows part of a protein molecule made from five different amino acids. Different proteins are made by joining the amino acids in different sequences. With 20 amino acids to choose from, the number of different proteins that can be made is almost unlimited. The protein insulin contains 51 amino acid units, but most proteins contain 500 or more.

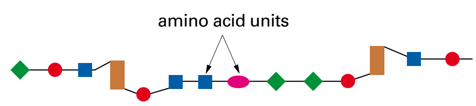


Fig 23 A piece of protein chain formed from five different amino acids

Homework

Ask students to investigate why proteins and amino acids are so important for our body. What purpose do they serve and how do they tie in with the study of polymers in this chapter?

Learning experience

In recent years the media has featured many of the negative aspects of plastics, particularly the environmental impact they are having. Ask the students to explore some of the positive points about plastics and how they have revolutionised our way of life.

Learning experience

To help the students with formulas you could develop a set of cards with different carbon compounds written on them. The front of each card should have the name of a compound and its chemical formula, while the back of the card should have the structural formula. In pairs, get the students to test each other and draw the structural formula for each carbon compound their partner gives them. Develop your list of carbon compounds from the ones listed in this chapter (methane, ethane, butane, propane, glucose, ethene, propene, butene, etc). Some students may find this very challenging so have an alternative activity ready.

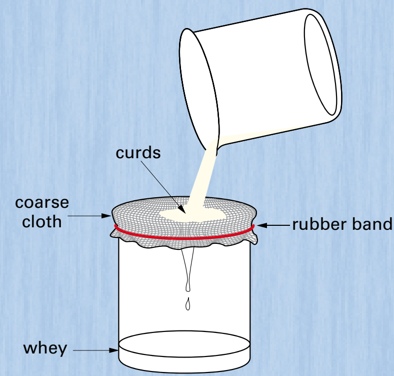
Activity

Milk contains a protein polymer called casein (KAY-seen). It can be extracted by adding vinegar to warm milk, in much the same way that cheese is formed.

Separate the curds (white solid) from the whey (yellowish liquid) by pouring the mixture through some coarse cloth. Squeeze the cloth with your fingers to remove the whey. Knead the casein (curds) in warm water, and shape it into a ball or some other shape.

Leave the plastic to dry for a day or two.

- Describe the properties of your plastic.
- Suggest what you could use casein plastic for.



Properties and uses of plastics

There are two different types of plastics. One type contains long thin molecules which form tangled chains. In these plastics there are strong bonds between the atoms along the chain, but much weaker forces between neighbouring chains. Because of this, the chains can slide over each other easily (Fig 25). Hence these plastics stretch and bend easily and soften on heating. Such plastics are called **thermoplastics**. Examples are polythene, polystyrene, PVC and nylon.

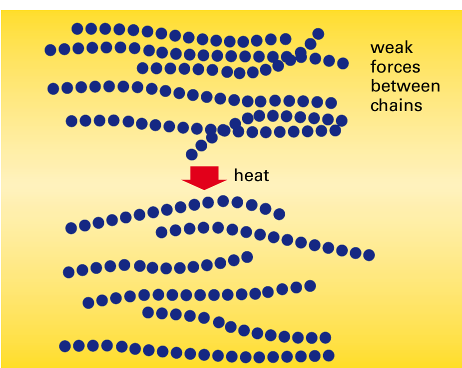


Fig 25 How the chains of a thermoplastic move apart when the plastic is melted

The second type of plastic is made from molecules whose atoms form strong bonds *between* chains as well as along the chains (Fig 26). These plastics are called **thermosets**. They are much harder than thermoplastics, and less flexible. They do not melt when heated. Instead they char (blacken) as the cross-links are broken and the polymer starts to decompose. Examples of thermosets are Bakelite, fibreglass resin, and epoxy glues.

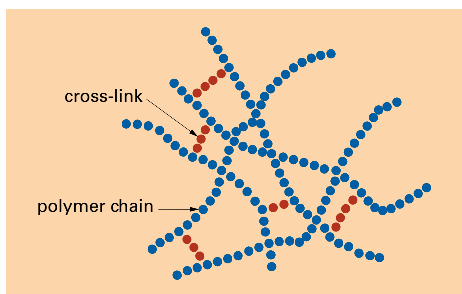


Fig 26 The structure of a thermoset

Thermoplastics can be shaped in a number of different ways. Each method involves heating the plastic so that it becomes soft, shaping it, and then cooling it.

Activity notes

- Make sure the students take care to warm the milk, not boil it. It may be easier to use a microwave if you have access to one.
- Muslin cloth is ideal to use and can be bought at most fabric or craft stores. (This is the type of cloth used in some cheese making.)
- Chocolate moulds can be used to shape the plastic. Once students have pressed the plastic into shape, they should take it out of the mould and leave it to cure.

Hints and tips

Be sure to explain the advantages, disadvantages and differences between thermoplastics and thermosets. Do some additional research and compile a short dot-point summary to give to your class as extra notes.

Learning experience

Plastics have many good properties: they are light, strong, excellent insulators of heat and electricity, generally quite chemically stable, and resistant to corrosion by most acids, bases and solvents. Get the students to find out some properties which are not advantageous (ie they are often degraded by UV light, they are not very stiff, they can distort with time, they can soften at high temperatures, they tend to be brittle at low temperatures, etc). Explain that this is why it is important to choose the appropriate type of plastic for the conditions it will experience.

Hints and tips

- Organise a tour of a local recycling plant. Make sure to check that they offer an education program and there is a person to run the tour. If it is not possible to organise this, you may be able to go on a virtual tour on the internet. (Many local council websites have links to their recycling plants which you may find helpful.)
- Write out an instruction sheet for the students to use with the Webwatch activities so they can navigate successfully around the linked websites.

Homework

Ask students to look at the identification codes in the table, then give them the following questions to answer:

1. Are all these plastics recyclable?
2. How is your household plastic recycled?
3. What items do you put in your recycling bin and how much do you put in there?
4. Do you know what happens to the plastic after it has been collected?
5. Construct a chart detailing the throwaway plastic items your household uses in a week or fortnight, the types of plastic and whether they can be recycled. Come up with at least two ways that your household could reduce the amount of plastic used each week or fortnight.

Name of plastic	Identification code	Common uses
Polyethylene terephthalate	1 PET	soft drink, water and juice bottles
Polythene (high density)	2 HDPE	milk bottles, various household containers, black polypipe
Polyvinyl chloride (PVC or vinyl)	3 V	fruit juice bottles, raincoats, electrical conduits, garden hoses, plumbing pipes
Polythene (low density)	4 LDPE	shopping bags, food wrap film, squeeze bottles
Polypropene (polypropylene)	5 PP	ice-cream containers, take-away containers, chip packets, bumper bars, bank notes
Polystyrene	6 PS	yoghurt containers, refrigerator linings, foam packaging

WEBwatch

Go to www.scienceworld.net.au and follow the links to the websites below.

Macrogalleria
A cyberwonderland where you can explore five levels of information on how plastics and fibres are used and made. Includes many photographs.

American Plastics Council
This site contains a huge amount of information on plastics in our lives and in the environment.

Plastics recycling
Information on the uses of plastics and recycled plastics in Australia.

This Plantic plastic tray is made from corn starch and degrades rapidly in water.

Blocks of crushed plastic ready for recycling

The crushed plastic (left) and the oil obtained from it by the process descibed on page 208

Learning experience

A class exercise from the homework task is to draw a graph of types of plastic and amounts thrown away (treat each item as a discrete unit). Are there any patterns to be seen? Which type of plastic seems to be used the most? Suggest why. Generate a class discussion about the use of plastics in Australia.

Experiment
PROPERTIES OF PLASTICS

Planning guide

1 Use the identification codes in the table on the previous page to collect a range of commonly used plastics.

2 Read through the six properties of plastics on this page, then select the properties you want to test. **Don't burn the plastics, since the fumes released pollute the laboratory and cause breathing difficulties for some students.**

3 You will need to work out for yourselves how to do each test. Write down a plan, which should include:
- how you will do the test, with a diagram if necessary
- what you will measure, and how you will record and display your data
- a list of the equipment you will need
- any safety precautions you will need to take.

Your teacher must approve your plan before you can start.

4 Write a report of your test, noting the properties you think are useful and those that are not so useful for objects made of the plastics you tested.

Resistance to chemicals

Are plastics affected by acids and bases? You could try dilute hydrochloric acid and caustic soda. (Caution: corrosive) Do the plastics dissolve in solvents such as turpentine or alcohol? (Caution: flammable)

Resistance to heat

Put the plastic on a heatproof mat. Heat the end of a screwdriver in a burner, then press it against the plastic. Does the plastic melt?

Insulating properties

Set up a simple electric circuit to test whether the plastics are insulators or conductors. Compare them with metals.

Wear safety glasses.

Degradability

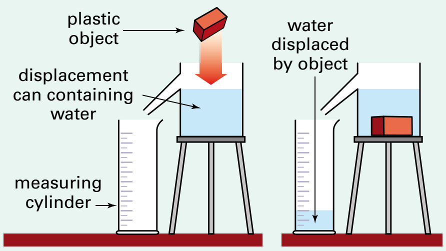
Do the properties of the plastic change when it is exposed to air, sunlight and water or buried for some time? Is this a good thing or a bad thing?

Density

If a plastic floats in water, it is less dense than water—its density is less than 1 g/cm^3. If it sinks, its density is more than 1 g/cm^3. To calculate the density of a plastic sample, you use the formula:

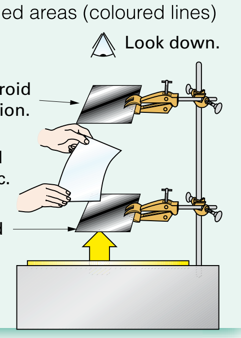
$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

To measure the volume of a plastic object, use a displacement can as shown. If the plastic floats, you will need to hold it under water with a thin piece of wire.



Flexibility and stress

Can the plastic be bent or stretched, and if so does it return to its original shape? To what angle can it be bent before it breaks? Does its flexibility change when the plastic is warmed in hot water? You can check for strained areas (coloured lines) in plastics as shown.



Lab notes

- Students should be told about this experiment well in advance so that they can bring in samples of plastics.
- Be very careful about heating the plastic and getting burns on the skin. If students are burned, use plenty of cold water and consider whether medical treatment is required.
- Degradability will take months rather than weeks and will have to be checked later in the year.
- It is essential students wear safety glasses, particularly if bending and breaking plastics.

Assessment task

This would be a good place to set *Assessment task 9: Plastics*, found on the CD.

Hints and tips

- If you haven't given much time for the students to add to the graffiti wall and question wall (see Starting point, page 191), now would be a good time as there should be many new words and ideas to add.
- Revise the chapter so far by giving students the crossword puzzle on the CD to complete, or challenge them to make their own crossword.

Activity note

Find out how the local council sorts their recycled material. You may like to ask a student or group of students to do some phoning around to find out.

Recycling and reusing plastics

There are two problems with our increasing use of plastics (more than one million tonnes per year in Australia). Firstly, most plastics are made from oil, a non-renewable resource which will become scarce in the future. Secondly, what do we do with plastic objects when we are finished with them? There are many different ways of reusing them. For example, you can use old ice-cream containers to store things in. However, most councils now collect plastic items from homes for recycling.

There are three different ways of recycling plastics.

1 Thermoplastics can be melted and remoulded. However, because there are so many different types of plastic, they must first be washed and sorted, otherwise the recycled plastics will not have the properties you want. This costs money, and the recycled plastic may be more expensive than new plastic. However, a number of manufacturing plants in Australia now use recycled plastic. For example, milk bottles are recycled to make products such as garbage bins and detergent bottles, and plastic banknotes are recycled to make compost bins.

2 Mixed plastic waste can be crushed and moulded into a range of products such as plastic posts, plant pots and park benches. It can also be mixed with wood to make a composite material. For these uses the lower quality product is not a problem.

3 Because plastics burn, they can be used as fuel. So far this has proved difficult because of the toxic gases produced and the sticky nature of many plastics as they burn. However, technologists have found a way of converting waste plastics into oil. In the system shown in Fig 32, some of the gases formed as the plastic decomposes are condensed to give valuable oil products. The rest of the gases are used to heat the plastic waste. Such a system can handle 8000 tonnes of plastic waste in a year. It is an expensive process but a useful way of saving our non-renewable oil reserves.

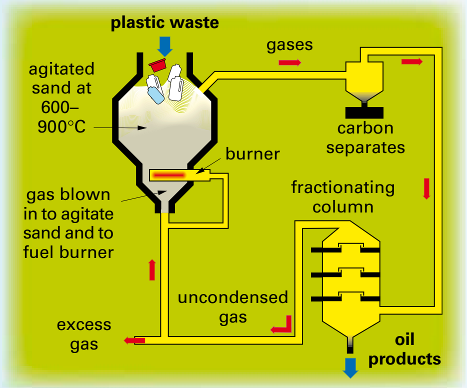


Fig 32 Recycling plastic waste into oil

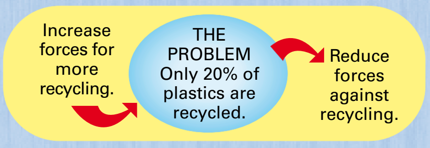
Activity

At present we recycle only about 20% of the plastics we use. How can we increase the proportion recycled? Discuss this problem in a group using the steps below.

1 Brainstorm all the forces in favour of more plastics recycling. For example, most people are environmentally conscious at present.

2 Brainstorm the forces opposed to recycling. For example, it's too much trouble to separate plastics from other rubbish.

3 Decide which of the forces could be changed. Is it easier to strengthen the 'for' forces or weaken the 'against' forces?



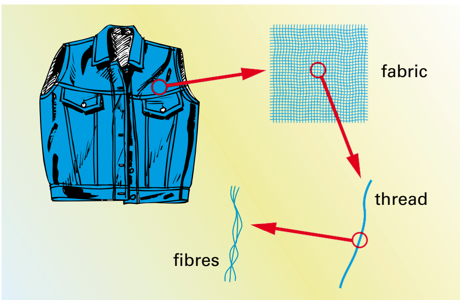
4 On the basis of Step 3, write out a plan to solve the problem.

Learning experience

If the school does not already have a plastics recycling program, organise a keen group of students to head up a team. An authentic task like this promotes self-awareness, ownership, mutual respect and respect for the environment, and has leadership opportunities. The scope of this activity is almost limitless in what can be achieved, so make sure there is an action plan and goals are set along the way.

Fibres

Clothes are made from fabrics which, in turn, are made from threads spun from fibres.

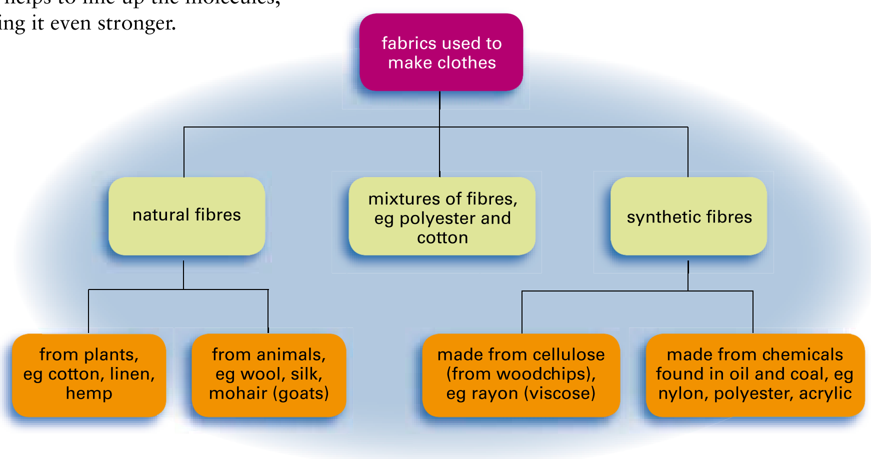


All fibres are polymers, and they may be natural or synthetic. Cotton and wool are natural materials obtained from plants and animals. Cotton is made of cellulose polymers, and wool is made of protein molecules. Synthetic fibres such as nylon and polyester are polymers made from chemicals obtained from oil and coal. The key below shows the different types of fibres.

Properties of fibres

The polymer chains in fibres are very long. They are lined up close to each other and attract each other strongly. This makes the fibre very strong and difficult to break. Stretching the fibre helps to line up the molecules, making it even stronger.

Fig 35 Synthetic fibres like nylon are made by forcing the melted material through holes in a metal plate called a spinneret, named after the organ through which a spider spins the silk for its web.



Hints and tips

- Nylon is considered to be a high-performance engineering plastic. The name of the polymer is polyamide and it was introduced in the 1930s. Nylon became famous in World War II because of its use in parachutes and women's stockings. An interesting fact to tell students is that 'denier', the unit used to measure the fineness of stockings, is the mass (grams) of 9 km of thread. For example, 10 denier stockings are made from a fibre that weighs 10 g per 9 km.
- Discuss with the class why synthetic fibres can be dangerous to wear if they are exposed to an open flame or high temperatures. (Synthetic fabric tends to melt and stick to the skin, causing serious burns.)

Homework

Ask students to use the key at the bottom of page 209 as a model to construct their own chart for classifying their clothes. They should list items they own or wear that are made from each fabric type. For example, a school jumper is made from wool so in the box labelled 'from animals, eg wool, silk, mohair (goats)', write down 'school jumper'. Each item of clothing can be added in this way.

Learning experience

Create a table on the board about fibres. Divide the board into parts as shown below. As a class, fill it in and discuss any relevant points while it is being filled in.

	Advantages	Disadvantages
Natural		
Synthetic		
Blends		

Hints and tips

Fishing line, toothbrush bristles and surgical suturing thread are synthetic fibres. Have you ever wondered what dissolving stitches are made from? Research some additional information in the form of fascinating facts to give to the class.

Stretchy fibres like nylon or wool have molecules that are normally closely curled like a telephone cord. When you pull on the fibre, it stretches by straightening out the loops, but when you release it, the molecules curl up again.

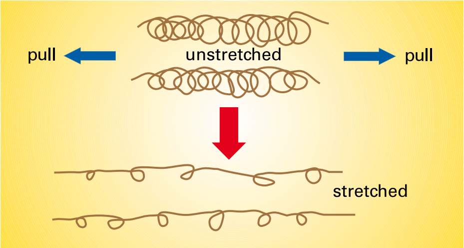


Fig 36 How a fibre can be stretched

Many of the properties of synthetic fibres are different from those of natural fibres. Cotton absorbs moisture and allows sweat to evaporate. It is therefore comfortable to wear on hot days. Synthetic polyester does not wear out as easily as cotton, but does not absorb moisture. This makes it sticky and uncomfortable on hot days. By making clothes from a *mixture* of cotton and polyester, you have the properties of both fibres. For example, 65% polyester and 35% cotton is a common mixture. Clothes made from this blend are hard-wearing, comfortable in summer and drip-dry (non-iron).

Perming hair and creasing wool

Each strand of your hair contains many long chains of the protein keratin. These long polymer chains are held together by different types of chemical bonds. The strongest of these bonds is made up of two sulfur atoms.

If you have a permanent wave (perm), solutions are added to your hair that break and re-form the S–S bonds between the protein polymer chains, as in Fig 37.

In Step 1 the hair is moistened, causing some of the bonds between the protein chains to break. The hair is then wrapped around curling rods, causing it to become stressed because the outer chains are stretched more than the chains next to the curlers.

In Step 2 the permanent wave solution is added. This causes a chemical reaction in which the S–S bonds are broken. Because the cross-links have been broken, the hair is relaxed and takes the shape of the curler. Unfortunately, the permanent wave solution combines the sharp smell of ammonia and the 'rotten egg' smell of sulfur compounds.

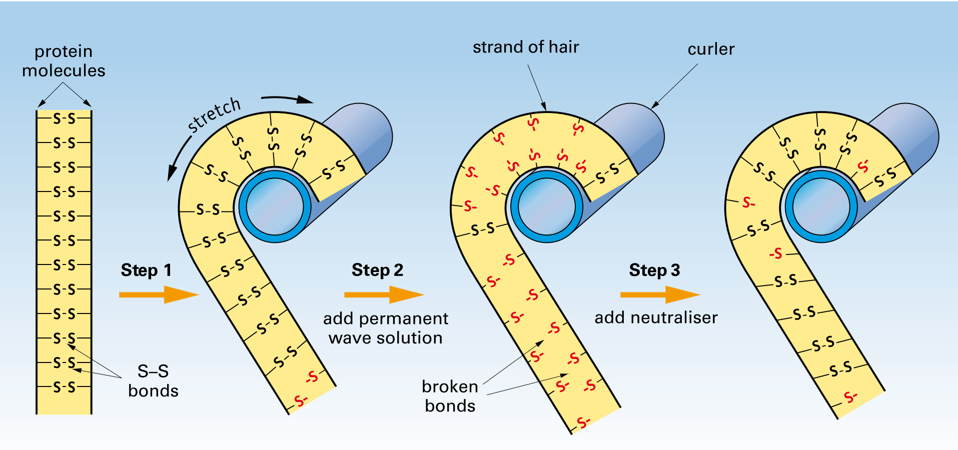


Fig 37 How the permanent wave process works

Learning experience

Ask the students to develop a summary chart for polymers. You may need to help them with their headings. Include properties and characteristics, uses, advantages and disadvantages.

Learning experience

The students could devise a practical investigation on the tensile qualities of some natural and synthetic fibres. Remind them about fair tests and controlling variables. Check their proposal before allowing them to start.

In Step 3 a neutraliser is added to reverse the reaction and re-form the S–S cross-links. As the hair dries it becomes strong again but in a different shape, because the cross-links are in different places.

Wool fibres are also made of protein polymer chains. Australian scientists from CSIRO developed a process to make permanent creases in wool. It works in much the same way as permanent waving of hair. Permanent crease trousers don't lose their crease when worn or washed.

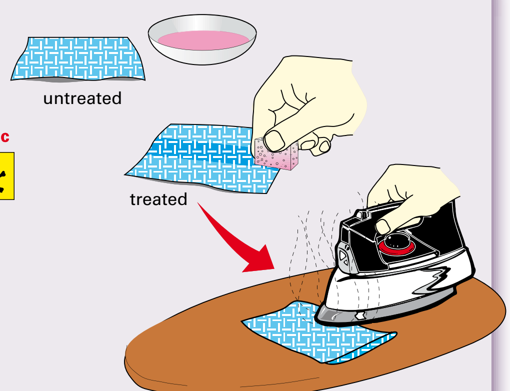
Investigate 21 PERMANENT CREASE

Aim

To make a permanent crease in a piece of woollen fabric.

Materials

- permanent crease solution (3% **sodium hydrogen sulfite** or **sodium metabisulfite** solution containing a little detergent) Toxic
- 2 pieces of woollen fabric
- sponge
- evaporating basin (or similar container)
- container for washing wool samples
- detergent
- steam iron



Planning and Safety Check

Read the investigation carefully.

What safety precautions will be necessary?

Method

1 Pour some of the permanent crease solution into the flat dish. Sponge a line of solution down the centre of one of the wool samples.

2 Crease the sample along the sponged line and press the crease in with the steam iron for about 30 seconds. Using the steam iron again, press a similar crease in the untreated sample.

3 Wash both samples in hot water (about 70°C) containing a small amount of detergent.

4 Take the samples out of the water and allow them to dry.

Compare the two samples.

Write a conclusion for the investigation.

try this

Design an experiment to answer one of these questions.

1 Does the temperature of the washing water in Step 3 have any effect?

2 Does this permanent creasing method work for other fabrics, eg polyester?

3 What effect do different washing solutions have? Some you could try are: liquid and powder detergent, ammonia solution, vinegar, wool wash and fabric softener.

Hints and tips

A biotechnology company in America (Monsanto, formerly Agracetus Inc.) has managed to genetically modify a cotton plant to produce PHB (a thermoplastic called polyhydroxybutyrate) in the centre of its cotton fibres. The PHB appears as granules rather than fibres. The company is doing this to try to make wrinkle-resistant cotton.

Lab notes

- Check that you have access to an iron as you may need to borrow one from another part of the school. A dissecting board could be used instead.
- Due to the safety concerns and lack of availability of irons, it may be better to do this as a demonstration and pass around 'before' and 'after' samples.
- If students are doing the investigation themselves, make sure to emphasise how to position a hot iron when it is not being used. The heating element should NOT be face down on the board. Also consider safety issues with students using hot irons near others.

Hints and tips

- During this reading task, make sure you monitor ESL students and those who have learning difficulties. Allow them extra time if required.
- If the students wrote down some questions at the beginning of the chapter that they would like answered (Starting point page 191), now is the best time to give them the opportunity to answer them.

Science in action

Goodyear and rubber

Rubber is a natural polymer consisting of long tangled molecules. Over the years scientists have learnt how to modify its properties and to make synthetic rubbers. But this process has not been straightforward, as this story shows.

For many centuries the native people of Central and South America used a milky liquid (latex) from certain trees to make elastic, bouncing balls. The early European explorers used this latex to waterproof their clothes. This worked well until the sun melted the rubber, making it soft and sticky. And during cold weather the rubberised material became hard and brittle.

Charles Goodyear, an American inventor, became interested in finding a process to make rubber that would have the same properties in hot and cold weather. However, his experimenting soon used up the little money he had and he was put in prison more than once for owing people money. At one time he sold to the government a large order of mailbags that had been coated with his modified rubber to make them waterproof. But the mailbags turned sticky and shapeless from heat even before they left the factory.

Centuries ago, South American natives discovered the essential properties and uses of the rubber tree.

After 10 years of unsuccessful experimenting, Goodyear accidentally spilt a mixture of rubber and sulfur on a hot stove. To his surprise the rubber didn't melt, and when he scraped it off and let it cool he found that it was not sticky. To test the rubber he left it outside in the cold overnight, and in the morning it hadn't become hard and brittle.

Goodyear continued experimenting and found the right amounts of rubber and sulfur to use and the best conditions for heating. He applied for a patent for a process he called *vulcanisation* after Vulcan the Roman god of war.

Goodyear didn't live happily even after his discovery. He had to defend his patent many times against people who wanted to steal his process. He was a poor businessman and never recovered from his huge debts. Not long before he died he said:

Life should not be estimated exclusively by the standard of dollars and cents. I am not disposed to complain that I have planted and others have gathered the fruits. A man has cause for regret only when he sows and no one reaps.

Questions

1 What was wrong with the first rubber made from rubber trees?

2 What did Charles Goodyear mix with rubber to vulcanise it?

3 What is a patent?

4 Suggest how Goodyear could have avoided the disaster with the mailbags.

5 Read carefully what Goodyear said before he died. Rewrite this more clearly in your own words.

6 Using what you have learnt about polymers, explain why rubber is so elastic.

Learning experience

Revise the chapter by getting the students to develop a concept map around the theme 'Everyday substances'. Ask them to generate a list of words and put them on the board. Alternatively, if the students constructed a graffiti wall at the beginning of this chapter, they can use words from this list. Circle the words/terms for the students to include on their map.

Check! solutions

1 'P' stands for 'poly–' which means that plastics are made up of long chains of the same units joined together.

2 The reasons why so much plastic is now used in cars include its relatively low cost, its light weight and the fact that it can be easily moulded, coloured and given different textures to look appealing.

3 Suitable properties include:
   a Plastic is an insulator for heat and electricity, is lightweight and is easily coloured.
   b Polystyrene is very light and able to absorb shocks if the object is dropped.
   c This plastic is strong enough to sit on and able to be moulded so that the chairs are exactly the same shape and stack together.

4 Advantages are that they are light, cheap and can be discarded without washing. Disadvantages are that they don't weigh very much and can be blown off a table with a very light wind. They get hot when holding hot liquids, and they are very difficult to recycle, causing damage to the environment.

5 The monomer for these molecules is glucose which has the formula $C_6H_{12}O_6$.

6 Thermosets are not able to be recycled

Check!

1. Why is it that the names of so many plastics start with P?
2. In some cars about 30% of the components used are made from plastics. Why do car manufacturers use so much plastic?
3. For each of the items below list the properties of plastic that make it suitable for making that particular object.
   - a hand-held hair dryer
   - b packaging foam
   - c stackable chairs
4. List the advantages and disadvantages of making drinking cups from plastic.
5. What is the monomer for the natural polymers cellulose and starch?
6. It is possible to recycle thermoplastics but not thermosets. Why is this?
7. a Look at Fig 32 on page 208. Explain in your own words how this process works.
   b How could this process be used to generate electricity?
8. Give at least one example of each of the following:
   - a a natural fibre from a plant
   - b a natural fibre from an animal
   - c a synthetic fibre made from oil or coal
9. Which properties would be particularly important in choosing a fibre for each of the following uses?
   - a fishing line
   - b laboratory coat
   - c non-iron shirt or blouse
   - d swimwear
   - e towel
10. How are the permanent creasing of wool and the perming of hair similar?
11. Most synthetic fibres are thermoplastic. What does this mean? Why must a cool iron be used on clothes made from synthetic fibres?
12. Some people think that the cost of plastics will rise as the world's oil resources diminish. Why?

challenge

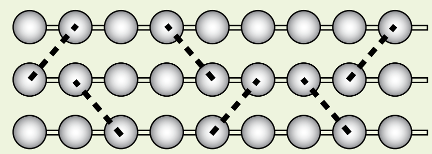
1. The casein polymer you made in the activity on page 205 is soft at first, but it hardens if you leave it for a day or so. Infer what causes this hardening. Draw a diagram.
2. Why do curls in hair tend to disappear when the hair becomes wet?
3. The table opposite compares the properties of wool and polyester (a synthetic competitor).
   - a Make a list of the properties in which wool is clearly superior to polyester.
   - b If you were employed by the wool industry to find ways to improve some of the properties of wool, which ones would you choose to work on? Why?
   - c Design an experiment which could be used to measure a fabric's resistance to shrinkage.
   - d How would you expect the crease resistance of wool to change in humid conditions? Why?
   - e Suggest why polyester is so much better than wool at resisting insect attack.

Property	Wool	Polyester
strength	★★	★★★★
ability to accept a dye	★★★★	★
ease of use	★★★	★★
crease resistance	★★	★★★
resists insect attack	★	★★★★
low flammability	★★★★	★
resists shrinking	★	★★★★
does not show dirt	★★★★	★
moisture absorbency	★★★★	★
takes permanent crease	★	★★★
feel	★★★★	★

★ poor ★★★ good
★★ fair ★★★★ best

Challenge solutions

1 The hardening occurs as bonds form between polymer chains as shown below. This reaction takes several days to happen.



2 The curls disappear when the hair becomes wet because some of the bonds between the protein molecules are broken.

3 a Wool is clearly superior because it will accept a dye, has low flammability, does not show dirt and has good moisture absorbency and feel.
b The most obvious properties to work on are the resistance to insects and the shrinkage.
c A simple way to do this would be to accurately measure a piece of cloth and then wash and dry it. You would then measure it again and calculate the percentage decrease in size.
d In humid conditions moisture may cause the cross bonding to be weakened and the wool will therefore be less crease-resistant (ie will crease more easily).
e Polyester is a synthetic fibre and the insects are not adapted to produce the chemicals to digest it.

because when heated they do not melt but blacken and start to decompose. This makes it impossible to re-use them in different shapes or products.

7 a Waste plastic objects are tipped into a furnace and mixed with sand at a temperature of 600–900°C. The plastic vapour is drawn off and the carbon particles separate out. The vapour is then passed through a fractionating column where several oil products are removed. Excess gas is then removed and the remainder is recycled by being burnt in the furnace.
b This process could be used to generate electricity by burning some of the gases and oil products. These can then be burned to produce heat to form steam that can be used to turn a turbine and generator.

8 Examples of fibres are:
a cotton and linen
b wool, silk and fur
c nylon, polyester and acrylic

9 Important properties would be:
a transparent, thin and strong
b strong, light and resistant to chemicals
c hard-wearing and does not allow creases to form
d resistant to chlorine and stretchy
e absorbs water and dries quickly

10 Permanent creasing (or perming) is caused by bonds between amino acids in the proteins in the hair or wool molecules. In wool this occurs naturally but with hair it can be done artificially.

11 Thermoplastics consist of long tangled chains of polymers which tend to soften, stretch and bend when heated. This explains why fabrics which consist of thermoplastics should not be heated in the process of ironing.

12 It is likely that prices will rise because plastics are made from materials that are obtained from petroleum. Thousands of tonnes of plastics are wasted in our society every year. One example of this wastage is plastic shopping bags.

Challenge solutions

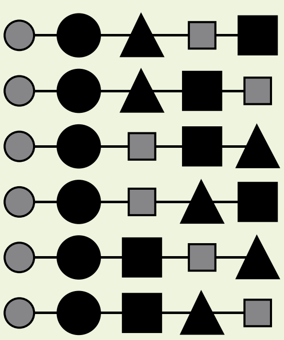
4 Some other uses for this plastic include shopping bags which will dissolve in the rain if disposed of thoughtlessly, and as a protective layer on roofing materials when they are packed which will dissolve and wash away after the first rain. No doubt you can think of more.

5 Yes it does. In South Australia it has been found that even if the user does not return it to collect the deposit other people will and the amount of litter is greatly reduced. Other states should do the same.

6 Using each of these only once and making a chain of 5 amino acids, the number of possible proteins is calculated as follows:

There are 5 possibilities in the first position and for each of these 4 possibilities in the second position and then 3 and so on, so the total number of combinations is 5 × 4 × 3 × 2 × 1 = 120.

It will take some time to work them all out but here are 6 to show you the pattern to get you started.



4 A new plastic called polyvinylalcohol is soluble in water. It is used to make laundry bags that dissolve in the wash and packages for detergents, insecticides etc. Suggest some other uses for this plastic.

5 In South Australia they have a returnable deposit on plastic drink bottles. Do you think this would significantly reduce the litter created by these items in your state? Explain.

6 Suppose you have five different amino acid units:

How many different protein fragments could you make by putting these five units together, using each one only once? Draw them.

try this

1 a Various processes are used to shape plastics, eg injection moulding, extrusion and blow moulding. Use library resources to find out about these processes. To get you started go to www.scienceworld.net.au and follow the links to **Fantastic plastic tour**.

b The photo below shows how thin plastic film is made. Explain how you think this is done, starting from solid pellets of plastic.

2 Stretch a rubber band around a block of wood and put it in the freezer of a fridge for about 10 minutes. Predict what you think will happen when you remove the rubber band from the block. Do it and observe what happens. Then try to explain what happened.

3 Check plastic containers on supermarket shelves or at home. Use the recycling symbols in the table on page 206 to identify the type of plastic in each.

a Add more uses to the right-hand column.

b Which are the most common plastics?

c Are plastics recycled in your area? Which types?

4 Use the internet to research one or more of the following:

- What are conducting plastics? When were they first discovered? How are they different from normal plastics? What can they be used for?
- What are bulletproof vests made of? Go to www.scienceworld.net.au and follow the links to **How body armor works**.
- How do shampoos and conditioners keep your hair soft and shiny?
- What research is being done into spider web fibres?

5 When you add hardener to a resin, it sets to form a thermosetting plastic. Use a resin kit to embed an insect in resin, like the mosquito in amber in *Jurassic Park*.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

alloys
corrodes
detergents
distillation
hydrocarbons
moulded
polymerisation
rusting
synthetic
thermoplastics
thermosets

1 The properties of metals can be changed by making ______, which are mixtures of two or more different metals.
2 A metal ______ when it reacts with the air and with water.
3 To prevent iron from ______ you must cover it with some other material, eg paint, oil or another metal.
4 Crude oil is a mixture of ______ (compounds containing hydrogen and carbon) which can be separated by fractional ______.
5 Soaps and ______ both contain long molecules with a water-loving end and a grease-loving end.
6 Polymers are very large molecules made by joining many small molecules together in a process called ______.
7 Plastics are synthetic polymers that can be ______ into various shapes.
8 ______ melt when heated, but ______ do not (due to cross-links between the polymer chains).
9 Fibres consist of natural or ______ polymers. Their properties depend on the type of polymer they contain.

Try doing the Chapter 9 crossword on the CD. Working with technology

Main ideas solutions

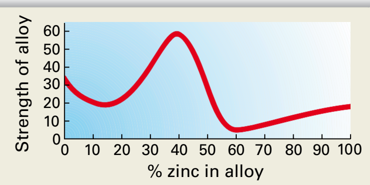
1 alloys
2 corrodes
3 rusting
4 hydrocarbons, distillation
5 detergents
6 polymerisation
7 moulded
8 thermoplastics, thermosets
9 synthetic

REVIEW

1 Soap works as a cleaning agent because:
A it has long chain-like molecules.
B it is made from grease.
C it dissolves in water.
D its molecules have a water-loving end and a grease-loving end.

2 A polymer is a substance that is:
A made up of many small molecules linked together.
B formed when two or more chemicals react together.
C made soft by heating.
D like Bakelite.

Questions 3 and 4 refer to the graph on the right which shows how the strength of a zinc–copper alloy varies with the percentage of zinc in the alloy.



3 At which percentage of zinc is the alloy strongest?
A 20
B 40
C 60
D cannot tell

4 Which is the weakest substance?
A pure copper
B 40% zinc and 60% copper
C 60% zinc and 40% copper
D pure zinc

Review solutions

1 D
2 A
3 B
4 C

5 a true
b false—Hydrocarbons contain carbon and hydrogen only.
c true
d true
e false—Petrol has a *lower* boiling point than diesel fuel (see Fig 12 on page 198).

6 a The plastic pellets are forced along by the turning screw and melted by the heaters. The molten plastic is then forced into the nozzle where it cools and takes the shape of the mould, in this case a pipe.
b B

7 a Acetone would distil first, because it has the lowest boiling point. Acetic acid would distil last.
b Propanol and water are difficult to separate. They distil together because their boiling points are very close.

8 a bridge—by painting
b bicycle chain—by coating with oil
c food cans—by coating with a thin layer of tin
d cutlery—by coating the steel with nickel or silver, or alloying it with chromium and nickel (stainless steel)

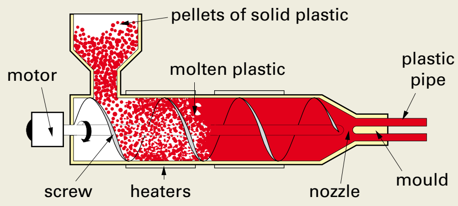
9 a A is a thermoplastic since there are no cross-links between the chains (see page 205).
b B would not melt on heating since it is a thermoset.
c B would be stronger because of all the cross-links.
d A—since only thermoplastics can be recycled
e A is likely to be polythene (see page 204).

10 a The holes in the elbows are caused by rubbing rather than stretching. The fact that the thread is strong is not relevant in this situation.
b You would need to test the different fabrics by rubbing them, eg pulling strips of fabric backwards and forwards across the edge of a bench 100 times. You could then compare the wear in the different fabrics.

REVIEW

5 Which of the following statements are true and which are false? Rewrite the false ones to make them correct.
a Carbon atoms form four chemical bonds.
b Hydrocarbons contain carbon, hydrogen and oxygen atoms.
c Only thermoplastics can be recycled.
d Hair and wool are both protein polymers.
e Petrol has a higher boiling point than diesel fuel.

6 The diagram shows how plastics are shaped by the process of extrusion.
a Use the diagram to explain how this process works.



b Which one of the following products could *not* be produced by this method?
A PVC pipes
B detergent bottles
C roof guttering
D biro casings

7 The boiling points of four liquids are as follows:

	Boiling point (°C)
acetic acid	118
acetone	56
propanol	97
water	100

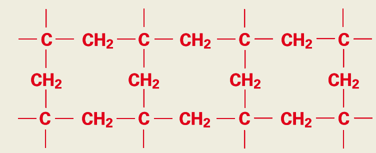
Suppose you had a mixture of these liquids, and you distilled it.
a Which would be the first substance to distil? Which would be the last?
b Two of the liquids are very difficult to separate by fractional distillation. Which are they, and why are they difficult to separate?

8 How are the following iron or steel objects usually protected from rusting?
a bridge
b bicycle chain
c food cans
d cutlery

9 Polymer A consists of carbon atoms bonded like this:

$$-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$$

Polymer B consists of carbon atoms bonded like this:



a Which polymer, A or B, is a thermoplastic? Give a reason.
b Which polymer would not melt on heating?
c Which polymer would be stronger? Why?
d Which polymer could be recycled?
e Which polymer is polythene?

10 A major manufacturer of school uniforms is concerned by reports that their windcheater jackets develop holes in the elbows after only a few weeks' wear. They insist that threads of the fabric used are able to support very large loads without breaking.
a Write a short explanation of why the breaking strength of the thread is not the problem.
b Describe a test that could be used to decide whether the jackets were any better or worse than those of their competitors.

Check your answers on pages 322–323.