27 Macromolecules

Introduction

The focus in this chapter is on polymers which are organic compounds consisting of macromolecules. Students study the structure, formation and uses of a variety of addition and condensation polymers. In addition, by studying pollution problems caused by the disposal of plastics, students can develop a concern for the environment and a sense of shared responsibility for a sustainable development of our society.

Chapter Opener (page 434)

1. Begin the chapter by discussing the following question. Precise answers are not needed at this stage.

   Plastics are made of macromolecules. What is a macromolecule?

   Answer: A macromolecule is a large molecule made by joining together many small molecules.

   What properties of plastics make them useful materials?

   Answer: Plastics can be easily moulded into different shapes; they are strong but light; they are corrosion resistant; they do not rot and are not eaten by inserts; they are good insulators of heat and electricity; they can be made in different forms (e.g. films, fibres, rigid solids, solid foam) and they are relatively cheap. Refer also to Section 27.2.

   What are some of the problems associated with the disposal of plastics? How can these problems be solved?

   Answer: The disposal of plastics causes pollution problems. They produce poisonous gases when burnt and are non-biodegradable. Plastic waste can kill animals. Greenhouse gases such as chlorofluorocarbons (CFCs) are released from plastic foam into the atmosphere and this contributes to global warming. These problems can be solved by using alternative materials instead of plastics and to re-duce, re-use and re-cycle plastics.

2. Carry out an 'Inquiry Preview.'

Learning Outcomes

After completing this chapter, the students should be able to:

- describe the term macromolecule
- describe the formation of poly(ethene) as an example of addition polymerisation
- state some uses of poly(ethene) as a typical plastic
- deduce the structure of a polymer from a given monomer and vice versa
- describe nylon and terylene as condensation polymers
- state some typical uses of man-made fibres such as nylon and terylene
- describe the manufacture of margarine
- describe pollution problems caused by the disposal of non-biodegradable plastics

Teaching pointers

27.1 How Common are Plastics in Daily Life? (page 435)

Stimulation

Show the class some several objects made of plastics together with similar objects made of traditional materials, such as wood, metals and glass that the plastic objects have replaced (refer to Figure 27.1). Discuss the disadvantages of the traditional materials and the advantages of the plastics.

1. Following the stimulation. lead students to appreciate that because of their advantageous properties, the amount of plastics used has increased dramatically in the last 50 – 60 years.
2. The word *plastic* comes from the Greek *plastikos* = to form or to mould. Students should appreciate that the term plastics is a collective term embracing many kinds of polymers.
3. The first plastic — celluloid — was developed in the 1860s from cellulose (hence its name) as a substitute for elephant ivory. Celluloid was used as film in early movies, but has the disadvantage of being highly flammable.
4. Introduce the idea a macromolecule and compare it with simple molecules. Perhaps show a space-filling model of part of a macromolecule and compare it with a small hydrocarbon molecule but do not discuss the details of the structure at this stage.
5. Show some of the articles shown in Figure 27.2 to demonstrate the different forms and useful properties. Do not mention the names of the individual plastics at this stage.

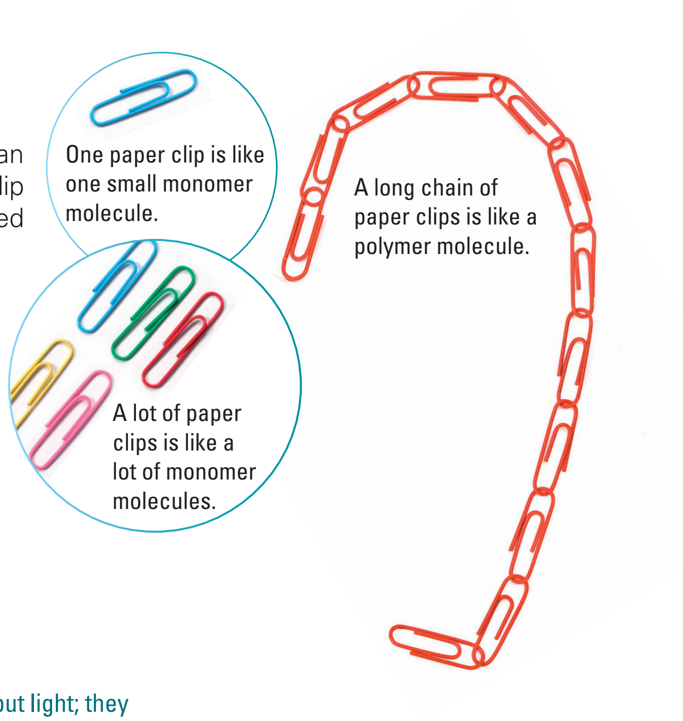
Skills Practice (page 436)

1. **(a)** For example: Wood, metal, glass and clay containers; metal electrical switches; paper or cloth bags; wooden/bamboo brooms; leather for shoes.
   (b) For example: Wood rots while plastics do not; glass breaks easily while plastics do not; metals corrode (especially iron) while plastics do not.
2. **(a)** Perspex is transparent, hard and cheap.
   (b) Advantages: Perspex does not break easily and can be moulded into different shapes.
   Disadvantage: Perspex scratches easily.
3. **(a)** Plastic bags are stronger than paper bags and are not affected by water. However, they are non-biodegradable.
   (b) Plastic bottles are lighter than glass bottles, are less likely to break and can be dyed. However, they are more difficult to recycle and are non-biodegradable.
   (c) Plastic water pipes are lighter and cheaper than iron pipes and do not corrode/rust. However, they are more difficult to recycle.

Teaching pointers

27.2 How are Plastics Formed? (page 436)

1. A simple analogy to show how a polymer is formed can be demonstrated with a box of paper clips. Each paper clip represents a monomer molecule. The clips can be joined together in a long chain to make a flexible polymer molecule.
2. It might be useful to mention that polymers can be natural as well as man-made. See "Notes for Teachers" below. Perhaps get students to look at the label on a shirt made from a mixture of cotton and polyester and identify the natural polymer (cotton) and the man-made polymer (polyester).



Skills Practice (page 437)

1. **(a)** Six atoms
   (b) M_r of ethene = 28
2. **(a)** 6000
   (b) M_r of poly(ethene) = 28 000
3. Plastics can be easily moulded into different shapes; they are strong but light; they are corrosion-resistant; they do not rot and are not eaten by insects; they are good insulators of heat and electricity; they can be made in different forms (e.g. films, fibres, rigid solids, solid foam); they are relatively cheap and many plastics are flexible and can often by stretched.

Notes for Teachers

Natural and man-made polymers
Polymers may be natural or man-made (synthetic). Plastics are man-made polymers. Thus plastics such as poly(ethene), PVC and nylon are examples of man-made polymers.

Many natural substances are also polymers. For example:
- Proteins found in wool, silk and animal tissue.
- Carbohydrates, such as starch and cellulose. Cellulose is found in wood, cotton and the walls of plant cells.
- Rubber

All plastics are polymers. But the opposite is not true, that is, not all polymers are plastics. Only synthetic (man-made) polymers are plastics. Natural polymers, such as cellulose and proteins found in wool and cotton, are not plastics.

Teaching pointers

27.3 What is Addition Polymerisation? (page 438)

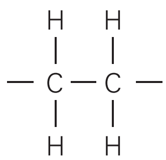
1. The paper clip 'polymer' demonstrated in the previous section is actually an addition polymer.
2. The topic of alkenes as unsaturated compounds which can be obtained from the cracking of heavy petroleum fractions, was studied in Chapter 25. Relate this work to the importance of alkenes for the manufacture of addition polymers.

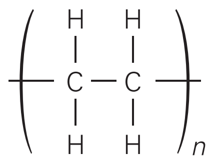
3. Here are two similar analogies that can be used to demonstrate the polymerisation of ethene.

(a) Each student represents an ethene molecule. Students should place their arms across their chests to represent the double bond in ethene. Get the students to hold hands to form a 'polymer' chain. In doing this, they 'break' the C = C double bonds and form a chain with just – C – C – single bonds as in poly(ethene).

(b) In pairs, get students to hold hands. Each student represents a carbon atom, while the pair of arms represents the double bond between the carbon atoms. Students 'break' the C = C double bond and link hands with other pairs to form a poly(ethene) chain.

4. The structure of a repeat unit and that of a polymer are represented in ways that look similar and this can cause confusion for students. Ensure that students are able to distinguish between the two.

Thus  is a repeat(ing) unit,

whereas  is a polymer.

5. Show examples of the common addition polymers listed in Table 27.1 on page 439 of the Textbook.

6. Polymers have a molecular structure. Compare polymers, which are giant molecules, with simple molecules, which have only a small number of atoms. Emphasise also that in polymers, unlike small molecules, the number of atoms (and hence the relative molecular mass) is not fixed.

7. Students must be able to work out the structure of a polymer from a given monomer, and vice versa. Give students to practise doing this using the examples in Table 27.1 on page 439 of the Textbook.

8. In Experiment 27.1 of the Practical Workbook, students are required to make perspex. The perspex monomer has a bad smell and can be irritating to the skin. The experiment must be carried out in a fume cupboard or a well-ventilated laboratory. This experiment could be carried out as a demonstration. You may also demonstrate the preparation of polystyrene. For details on how to do this, refer to 'Notes for Teachers' on page 454.

9. Refer back to the three major components of a petrochemical plant (see the 'Chemistry in Society' in the textbook, Chapter 24, page 393). Then discuss the production of monomers and polymers at the petrochemical plants in Singapore (at Jurong Island and Pulau Bukom). Poly(ethene), poly(propene) and poly(butene) are three addition polymers produced. These are used to manufacture various products, such as those listed in Table 27.1 for poly(ethene).

10. Students could then carry out the additional exercise on petrochemical plants on Jurong Island, which is found at the end of this chapter. The worksheet may be photocopied and distributed to students.

11. An additional 'Chemistry in Society' on plastics that conduct electricity is provided at the end of this chapter. This may be photocopied and distributed to students. Refer to the notes on page 454.

Chemistry Inquiry (page 440)

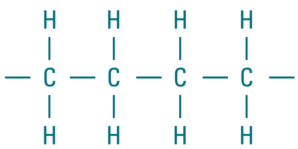
Group Discussion

1. The C = C double bond allows the monomers to form the long polymer chains. When the C = C bonds break, each monomer can then combine with two other monomers.
2. PAN is formed by the addition polymerisation of acrylonitrile monomer molecules. The C = C double bond in each monomer breaks and the open units join together to form the addition polymer. The steps in this process are just the opposite to those shown on the same page for working out the structural formula of the acrylonitrile monomer.

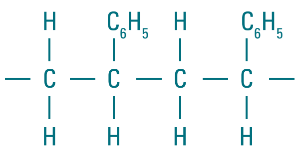
Skills Practice (page 441)

1. Structure of part of the polymer molecule:

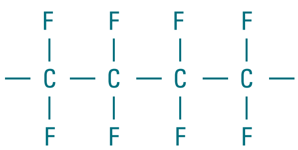
Polythene

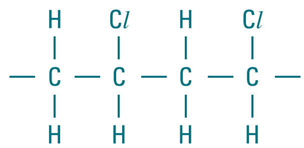


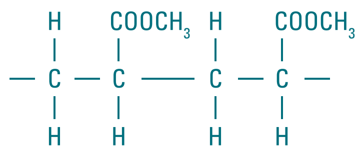
Polystyrene



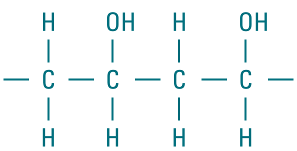
PTFE



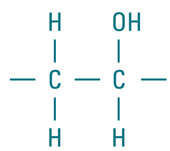




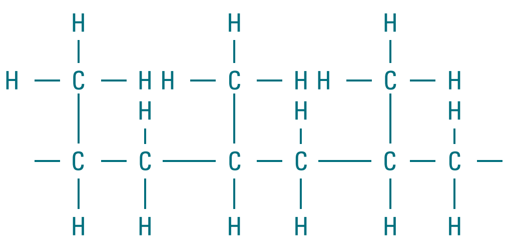
2. (a) Structure of part of the polymer:



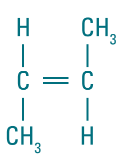
(b) Repeat unit:



3. (a) Structure of part of the polymer:



4. Structural formula of the monomer:



or $CH_3-CH=CH-CH_3$

Notes for Teachers

Laboratory preparation of polystyrene

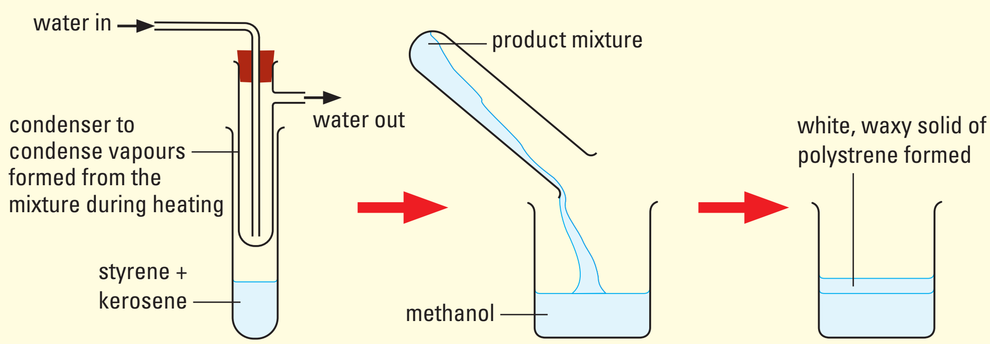
Method 1:

1. Add 6 cm^3 of the monomer polylite 449 (a commercial type of styrene) to a dry test-tube. Then add 6 drops of initiator to the tube and stir well with a glass rod. Finally, add 6 drops of a hardener. Again stir well.
2. Shake the test-tube. On sitting, the mixture hardens into a colourless, transparent solid. Remove the solid by wrapping the test-tube in a plastic bag and breaking it with a hammer inside a bucket. Use forceps to remove any glass sticking to the solid.

   Note: The 'polylite' used here is a group of reactive resins dissolved in styrene and other monomers. For simplicity, the reaction can be regarded as the polymerisation of styrene. The polylite 449, initiator and hardener can be obtained cheaply from local chemical shops.

Method 2:

1. Place equal volumes of styrene and kerosene in a boiling tube. Reflux gently for about one hour using a set-up such as that shown below. (The kerosene acts as a solvent and as a catalyst.)
2. Allow the mixture to cool before pouring it into methanol. A white, waxy layer of solid polystyrene forms on the surface of methanol.



Chemistry in Society

Plastics that Conduct Electricity

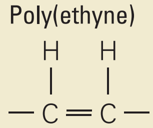
Three chemists — a Japanese chemist, Hideki Shirakawa and two American chemists, Alan J. Heeger and Alan G. MacDiarmid — were awarded the Nobel Prize in Chemistry in 2000 for discovering that plastic can, under certain circumstances, behave like a metal.

For conduction of electricity to occur, electrons need to be free to move and not bound to the atoms in the material. For this to happen, a polymer must first have conjugated double bonds, that is, alternating single and double bonds. An impurity can be added to enable the electrons to move (a process called doping).

Exercise

1. (a) Poly(ethyne)

   (b)



2. For other examples, get students to play the game in Extension Activity 3 on page 450 of the Textbook.

IT Link

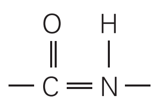
The following websites provide more information on conductivity of plastic and the chemists who discovered the phenomenon.

http://nobelprize.org/chemistry/laureates/2000/illpres/

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2000/press.html

Teaching pointers

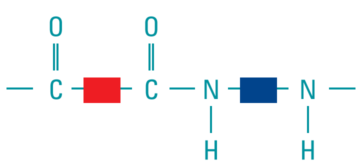
27.4 What is Condensation Polymerisation? (page 441)

1. Introduce this topic by showing the class some examples of products made from nylon and polyester.
2. To show the concept of condensation polymerisation, a set of paper/cardboard models can be used. Refer to the 'Notes for Teachers' on the next page. The advantage of using these block models is that they focus students' attention on the reactive ends of the monomer that form the small molecules being eliminated during the polymerisation.
3. If possible, carry out the demonstration of the preparation of nylon. This is a very dramatic experiment which students enjoy. If a demonstration is not possible, show the class a video of the process. Notes on the experiment together with a website for the video are given in 'Notes for Teachers' on the next page.
4. In the industrial manufacture of nylon, hexanedioic acid is used as it is cheap. Hexanedioyl dichloride is used for laboratory preparation of nylon as it reacts faster (see the question in the Skills Practice on page 444 of the Textbook).
5. A stretched nylon thread is almost as strong as a steel wire of the same diameter.
6. Nylon was first made in 1933 and first marketed in 1938. The origin of the name, nylon is often believed to be a combination of 'Ny' (New York) and 'lon' (London) as it was introduced at about the same time in these two places. However, this story is not true!
7. There are many varieties of nylon. The most common type is nylon 6.6, in which each monomer has six carbon atoms. Another type of nylon is nylon 6.10 which is formed from monomers with different chain lengths.
8. In nylon, the  unit is repeated in the polymer. This unit is called the peptide link and is the same link that occurs in protein molecules.
9. The term polyester means 'many esters' as the polymer contains the linkage which occurs in esters (see page 428 of the Textbook).
10. Again, ensure that students can work out the structures of the monomers, the polymers and the repeat units for condensation polymers.

Skills Practice (page 444)

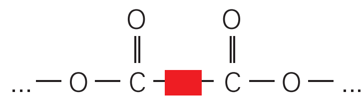
1. **(a)** Monomer 1 (the monomer on the left) has a –COC*l* group whereas for the industrial manufacture of nylon, it has the –COOH group. Monomer 2 (the monomer on the right) is the same for both the laboratory preparation here and in the industrial preparation.

   (b) Hydrogen chloride, HC*l*.



Mystery Clue

The monomer is lactic acid. The structure of part of the polymer chain is:



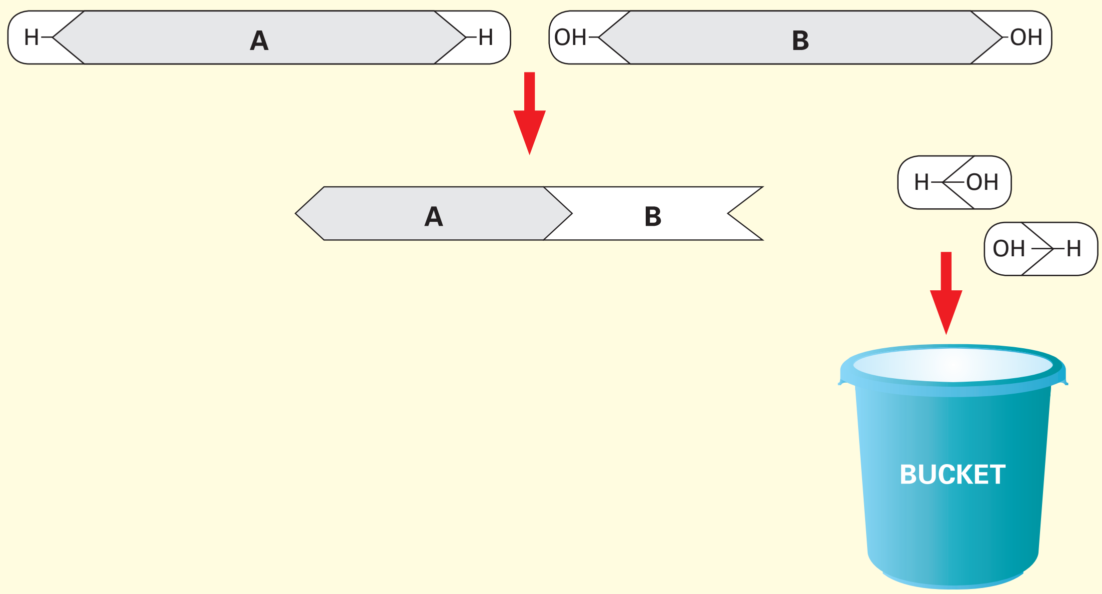
Condensation polymerisation is involves as a H- and an -OH are removed from each monomer molecule to form H_2O.

Note: Additional Exercise 2, located at the end of this chapter, discuss how the PLA polymer is formed.

Models for condensation polymerisation

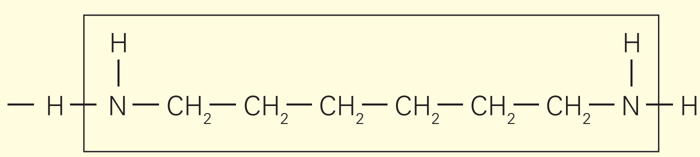
A set of templates to make the models is found at the end of this chapter. They can be photocopied for teacher and/or student use. Templates **A** and **B** correspond to two monomers suitable for forming condensation polymers. Here is how they might be used:

1. The ends of each monomer model may be coloured, one colour for A, another for B. If desired, the endings in monomer **B** could be –C*l* instead of –OH.
2. Cut out the models and cut off the coloured ends. Join them together using tape. (Alternatively, if pieces of magnetised rubber can be stuck on the back of the models, a magnetic board can be used.)
3. Join the …**ABABAB**… pieces together to give a model of the condensation polymer.
4. Join the H– and –OH pieces together. The formation of simple water molecules can be reinforced by collecting the water models in a bucket. See the diagram below.

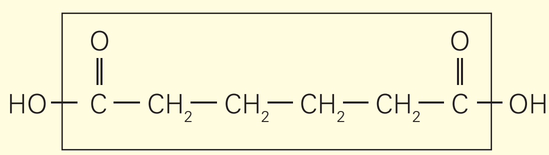


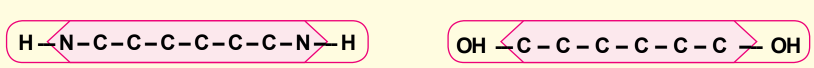
5. For more able classes, you could develop the above models by including the following steps: On other templates, or on the back of the templates provided, draw carbon skeletons or structural formulae for the monomers. Join the pieces together as in Steps 3 and 4. See the example below for nylon:

   Monomer A: hexane-1,6-diamine



   Monomer B: hexanedioic acid





   Note: Monomer B could also be used with –C*l* endings (to represent hexanedioyl dichloride) instead of –OH endings. In this case, HC*l* molecules and not water molecules will be eliminated.

6. The equation for the polymerisation could then be written without using the model.

Additional Experiment 1: Preparing nylon

A worksheet for the preparation of nylon is found at the end of this chapter. You can photocopy and distribute the worksheet to the class.
Comments on the experiment:

- Prepare Solution A by dissolving 5 g of the monomer in 100 cm^3 of water (or dilute sodium hydroxide solution).
- Prepare Solution B by dissolving 5 g of the monomer in 100 cm^3 of an organic solvent such as 1,1,1-trichlorethene or one of the Volasil range of silicone-based solvents, e.g. Volasil 244.
- The chemicals used to make nylon are harmful. Avoid skin contact and breathing in fumes. Carry out the experiment in a well-ventilated laboratory or a fume cupboard.
- Ask students to wind the nylon thread onto the glass rod. Then get them to unwind the thread to see how long it is.

IT Link

Synthesis of nylon
The following websites provide more information on conductivity of plastic and the chemists who discovered the phenomenon.

http://nobelprize.org/chemistry/laureates/2000/illpres/

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2000/press.html

Chemistry in Society (page 444)

The Discovery of Plastics — The Part Played by Chance and Curiosity

In the introductory chapter, the use of the scientific method to acquire knowledge was discussed. However, scientists have also made important discoveries by chance as well as by the deliberate application of the scientific method. The accidental discovery of two polymers described in this Chemistry in Society is an example of a discovery made by chance.

IT Link

For more on the discovery of nylon:

http://wayback.archive-it.org/2118/20100924225844/http://64.251.202.97/EducationalServices/nylon/nylon.html

Exercise

1. Curiosity, creativity, perseverance
2. Curiosity and creativity allows us to seek for new knowledge and be resourceful, flexible and adaptable. Perseverance helps us to not give up during difficult situations but instead learn to solve problems in life.

Teaching pointers

27.5 What Problems Does Disposal of Plastics Cause? (page 445)

1. Millions of plastic bags are used in Singapore every day. Most of these bags are non-biodegradable. An interesting activity is to ask students to count the number of plastic bags used in their homes in a week. Collect the results for the class and estimate how many bags are used in Singapore in a year. According to the NEA, Singaporeans use about 2.5 billion plastic bags a year; on average, this is 2500 bags per family, per year or about 48 bags per week. Compare students' answers with these figures.
2. The use of non-biodegradable plastics leads to waste disposal problems and 'non-rotting' litter around the environment. Much of this litter is collected and buried in landfill sites or burnt in incinerators. As Singapore has only 715.8 km^2 of land (as at 2012, according to Singapore Department of Statistics website), it cannot afford to have many landfill sites. All landfill sites on the mainland have been closed; the only site now in use is that at Pulau Semakau which is 8 km away from the mainland. The government plans to abolish landfill sites altogether by minimising the amount of waste generated and by recycling as much of the waste as possible.
3. An additional exercise on the issue of pollution problems caused by non-biodegradable plastics and the development of a new biodegradable plastic made from lactic acid is provided at the end of the chapter. This exercise can be linked with the Mystery Clue on page 443 of the Textbook. The worksheet can be photocopied and distributed to students.
4. Solving the problem of waste disposal includes the '3-Rs,' i.e. Reuse, Reduce (which can include Replace) and Recycle. These are the basis of the discussion in Additional Exercise 3 at the end of the chapter. For a suggestion on how to carry this activity could be carried out, refer to the suggested lesson plan below.
5. The development of plastics that are more biodegradable or can be recycled may reverse the trend towards the use of paper bags and other alternative packaging to plastics.
6. Around the world, people are coming up with ideas to solve the problem of plastic waste disposal. For example, in England, a company collects waste plastic, shreds it and then compresses it into porous pads. These porous pads make good 'underground' drainage layers for footpaths, golf greens, etc.

Mystery Clue

Something that is biodegradable is capable of being decomposed by bacteria or other micro-organisms. As bioplastics are biodegradable, they will not accumulate when buried in landfills. They will not solve pollution problems if burnt nor harm to animals is disposed of in the environment.

Skills Practice (page 446)

1. **(a)** Examples where plastics do not need to be used to make things:
   - Plastic drink containers (use glass, aluminium or treated cardboard containers instead).
   - Plastic rulers (use wood or metal rulers instead).
   - PVC as artificial leather (use real leather instead).
   - Plastic bags (use paper or cloth bags instead).
   - Plastic food trays (use cardboard or aluminium trays instead)

   (b) Examples where plastics cannot be easily replaced by other materials:
   - Plastic windows for aircraft and spacecraft (glass would crack too easily).
   - Artificial plastic body parts (metal parts may corrode or may not be flexible enough).
2. For example, I can write a letter to a newspaper, call a radio talk show, prepare a poster to put up on the school notice board, talk to my friends, family and relatives about the issue, volunteer to pick up rubbish at a beach, pick up bags thrown away by others at a barbeque (and perhaps make comment to those people who throw them away by asking them to re-use the bags for other purposes).

Additional Exercise 3: Plastics and the Three R's

Suggested teaching and learning sequence (2 periods)

1. Introduction and Part A (1 period)
   (a) The teacher introduces the activity then helps students to form groups of six to seven.
   (b) Groups begin Part A of the activity by discussing the meaning of the 3 R's when applied to solving the problem of plastic waste disposal. They then carry out the survey. Group results can be pooled to complete the survey.
2. Part B: Discussion (1 period)
   (a) In groups, students discuss the questions in Step 1 and record their findings.
   (b) Groups spend a few minutes organising the discussion findings. Each group is then given a few minutes to make an oral presentation of their findings and to answer questions from the floor. During the presentations, students write down ideas from other groups that their group did not think of.
3. Part C: Follow-up activity (optional)
   Using the materials from the discussions, groups write a short essay on the environmental problems associated with the disposal of plastics and how these problems might be overcome.

Notes for Teachers

Hazards of burning plastics

Many plastics produce toxic fumes when burnt. Nitrogen-containing plastics, such as nylon and polyurethane, produce fumes of hydrogen cyanide and other cyanides when burnt. These fumes are extremely toxic and have probably caused many deaths in fires where victims may otherwise have escaped.

Plastics which contain chlorine, such as PVC, produce hydrogen chloride and other toxic chlorine compounds. And, according to Greenpeace, the burning of PVC also releases dioxins into the air and soil. Dioxins are carcinogenic compounds.

Modern furniture contains many plastic materials. A lot of furniture is now labelled to indicate the fire hazards involved with the materials used.

Reuse of plastics

One way to reduce the problem of plastic waste disposal is to find ways to reuse plastics. Here are examples of some ways that have been suggested by primary school students to reuse plastics:

- Plastic bags as liners for small rubbish bins
- To keep food in the refrigerator
- As shopping bags
- To keep clothes and shoes clean
- Use squashed bags to protect breakable items when moving them in boxes
- To use as a glove for cleaning
- To keep clothes dry when at the beach
- As a backpack liner on a wet day
- To be used as a rubbish bag in a car
- As containers for plants before/after putting into a pot
- To put on a wet seat before sitting

IT Link

Good overall site

http://www-g.eng.cam.ac.uk/impee/topics/RecyclePlastics/files/Recycling%20Plastic%20v3%20PDF.pdf

The 3 R's – uses of plastic bags

http://www.highcountryconservation.org/reduce_reuse_recycle.htm

http://www.factmonster.com/ipka/A0775891.html

http://dnr.mo.gov/env/swmp/pubs-reports/threers.htm

http://www.nrdc.org/thisgreenlife/0802.asp

Recycling process of plastic bags

http://earth911.com/news/2009/06/15/360-recycling-plastic-bags/

http://answers.yahoo.com/question/index?qid=20081023203547AAHkPXT

http://www.statusclean.com/waste-management/recycling/plastic-recycling.aspx

Recycling plastics and code for sorting plastics

http://www.lotfi.net/recycle/plastic.html#1n1

http://www.matweb.com/reference/plastic_recycling.aspx

Solving the Mystery (page 447)

Go green! How can we drive environmentally-friendly cars?

Infer

$5CO(g) + 11H_2(g) \longrightarrow C_5H_{12}(l) + 5H_2O(l)$

Connect

When the green petrol burns, carbon dioxide is formed. Through photosynthesis, other plants can recycle this carbon dioxide.

Further thought

For example, instead of importing petroleum, Singapore would import plant material from other countries (we do not have enough land to grow plants). The petrochemical plants on Jurong Island and Pulau Bukom would have to be modified or replaced in order to produce green petrol and plastics from this plant material.

Notes for Teachers

Additional Experiment 2: Make Your Own Compostable Bioplastic

With just a few materials that are easily available, students can make a corn-based plastic. This will share the same corn base as manufactured bioplastics, but the product in this experiment will be much softer (Weak bonds cause the sample to dissolve quickly in water, something manufacturers hope not to happen to their bioplastic products.) The worksheet for this experiment is found at the end of the chapter.

How it works

Before heating, the starch and water molecules combine physically in a liquid mixture, but do not permanently attach. Heating causes the water molecules to move fast enough to penetrate and break up the starch granules, which then tangle together to form polymers. Because the polymers are weaker than commercial bioplastics, they readily break apart in water. Durable commercial bioplastics need heat, microbes, and much more time to biodegrade, which is just fine with manufacturers. After all, who would buy a bottle that dissolves in water?

IT Link

Green petrol from plants

http://portal.acs.org/portal/PublicWebSite/education/resources/highschool/chemmatters/archive/CNBP_023993

http://www.forbes.com/2009/04/28/biofuels-ethanol-virent-technology-breakthroughs-biofuels.html

http://www.virent.com/BioForming/difference.html

Plastics go green

http://portal.acs.org/portal/PublicWebSite/education/resources/highschool/chemmatters/archive/CNBP_024548

http://green-plastics.net/news/47-education/103-chemmatters-qplastics-go-greenq

http://science.howstuffworks.com/environmental/green-tech/sustainable/eco-plastic2.htm

Plastic cars

http://www.fastcompany.com/1183909/toyotas-seaweed-cars-take-green-design-whole-new-level

http://reviews.cnet.com/4520-13529_7-6740435-1.html

http://pjlighthouse.info/2007/09/hyundai-qarmaq-concept-cars-skin-made-from-plastic-bottles/

27 Chapter Review

Self-Management

Misconception Analysis (page 303)

1. **False** Glucose has only 24 atoms. Many macromolecules, such as polymers, have hundreds or thousands of atoms in one molecule.
2. **True** Oil fractions, such as naphtha, are cracked to produce small alkenes such as ethene and propene. These small alkenes are used to make plastics.
3. **False** In addition polymerisation, there is only one product. In condensation polymerisation, small molecules, such as water, are eliminated as the polymer is formed.
4. **True** This is true most of the time. Occasionally, more than one monomer can be used. For example, ethene and propene can be combined to form an addition polymer.
5. **False** Many plastics produce harmful substances when burnt. Most produce poisonous carbon monoxide. PVC gives off chlorine and nylon gives off hydrogen cyanide.

5. **False** Most plastics are non-biodegradable, that is, they cannot be decomposed by bacteria and other micro-organisms.

Practice

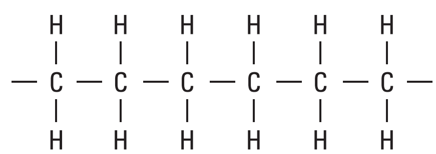
Structured Questions (pages 449 – 450)

1. (a)

Object	Natural material	Advantage of using plastic over the natural material
Shopping bag	paper	E.g. Cheaper, stronger, does not break when wet.
Drink container	Glass	E.g. Lighter (lower density), does not break.
Clothes	Cotton	E.g. Stronger, does not rot, not eaten by insects.

2. (a) $C_{17}H_{36}(l) \longrightarrow 3C_2H_4(g) + C_{11}H_{24}(l)$

(b) (i)

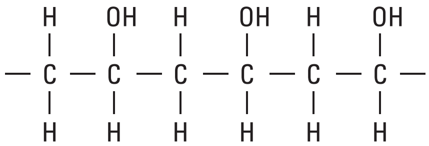


Note: Always draw a polymer showing at least three of the monomer molecules.

(ii) This is because all the ethene molecules are incorporated into poly(ethene).

3. (a) An alcohol

(b) (i)



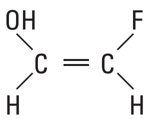
(ii) Poly(ethenol)

(iii) The polymer can be used in baby nappies and to keep objects such as electrical appliances dry.

(c) (i) Polyester such as terylene.

(ii) Poly(ethene)

4. (a)



(b) Percentage yield of the reaction = 18 ÷ 20 × 100%

= 90% yield

5. (a) $nC_3H_6(g) \longrightarrow (C_3H_6)n(s)$

(b) Poly(propene) is an addition polymer, as propene monomers join or add together to form a single polymer.

(c) (i) This means that bacteria do not break poly(propene) down naturally in the ground.

(ii) It can be used as fishing nets so that they will last for a long time.

(d) Poly(propene) objects do not rot/decay. Thus disposing them causes land pollution. Also, they give off poisonous carbon monoxide gas when burnt.

6. (a) Polymerisation

(b) (i) Water

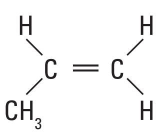
(ii) Ester linkage

(iii) Alcohols

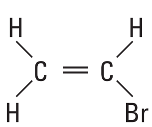
(iv) Carboxylic acids

7. (a) (i) E and F

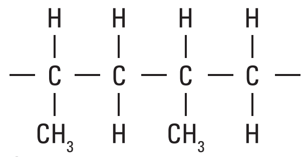
(ii) Structural formula of monomer E:



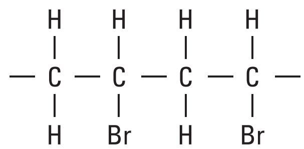
Structural formula of monomer F:



(iii) Structure of part of the addition polymer formed from monomer E:



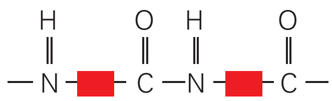
Structure of part of the addition polymer formed from monomer F:



(b) (i) B and D

(ii) Nylon

(c) Structure of part of the polymer formed from monomer C:

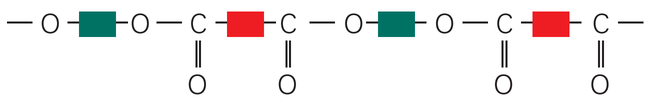


8. (a) (i) Organic/Carboxylic acids

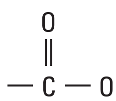
(ii) Alcohols

(b) Water

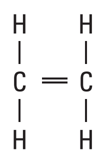
(c)



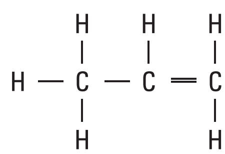
(d) This means that it contains many ester linkages, i.e.



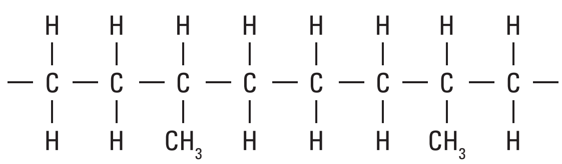
9. (a) Structure of ethene:



Structure of propene:



(b)



Free Response Questions (pages 450)

1. (a) Responses to this question may include the following points:
    - Examples of using plastics in place of natural materials:
    1. Plastic carrier bags are used instead of paper bags.
    2. Many drink containers are made of plastic instead of glass or metal.
    - There are many different kinds of plastics. Different plastics have different properties. Plastics are chosen because they have useful combinations of these properties. Advantages of using plastics include the following:
        – They are relatively cheap.
        – They are strong but also flexible.
        – They are light in weight.
        – They are resistant to attack by chemicals and to living things such as insects.
        – They are good insulators of heat and electricity.

    - Disadvantages of using plastics include the following:
        – Many plastics burn easily and so are a fire hazard.
        – Most plastics are non-biodegradable and so pollute the environment.
        – Plastic waste kills animals that try to eat it.
        – Plastics produce poisonous gases when burnt.

   (b) Most monomers used to make plastics come from petroleum. Petroleum will begin to run out in a few years which will result in fewer plastics and increased prices.

2. Responses to this question may include the following points:
    - The production of poly(ethene) at the petrochemical plants involves three basic steps:
        (i) The separation of petroleum into fractions by fractional distillation.
        (ii) Naphtha, one of the fractions obtained from the cracking of petroleum, undergoes (steam) cracking to produce small alkene molecules including ethene.
        (iii) Ethene molecules are then polymerised to form poly(ethene).
    - Uses of poly(ethene): Examples are plastic bags and plastic film for wrapping food.
    - Characteristics of poly(ethene) that make it suitable for these uses: Strong, light in weight and cheap to produce.

3. Responses to this question may include the following points:
    - Problems caused by the disposal of plastics:
        (i) Land pollution as many plastics are non-biodegradable.
        (ii) Burning plastics can produce toxic gases.
        (iii) Plastic waste can kill animals that swallow it or get tangled by it.
    - Measures taken to deal with the problem of plastic waste disposal: Making biodegradable plastics, disposing of plastics in landfills instead of burning them, using alternative materials to make objects, recycling of waste plastics.

Extension (page 450)

1. **Use of Alternative Materials**
   Here are some points you may consider:
    - The pollution problems caused by the disposal of plastic waste, e.g. burning plastics produces toxic gases, most plastics are non-biodegradable.
    - Most plastics are made using petroleum as a raw material. As petroleum reserves are limited, alternatives to plastics should be used wherever possible.
    - Materials such as glass and metals are more easily recycled than plastics.
    - Aesthetic values, e.g. ceramic crockery is often more beautiful than plastic crockery.
    - Cost: Plastics are usually very cheap.

2. **Plastics and Environmental Issues**
   –

3. **Play the Conductive Plastic game**
   This game can be used in connection with the material in "Chemistry in Society: Plastics that conduct electricity" at the end of this chapter.

Chemistry in **Society**

Plastics that Conduct Electricity

Metals conduct electricity but plastics do not. One of the properties of plastics is that they are good insulators. Therefore, plastics are used to make electrical sockets and plugs and as insulation around the copper wires in electrical cables (Figure 1).

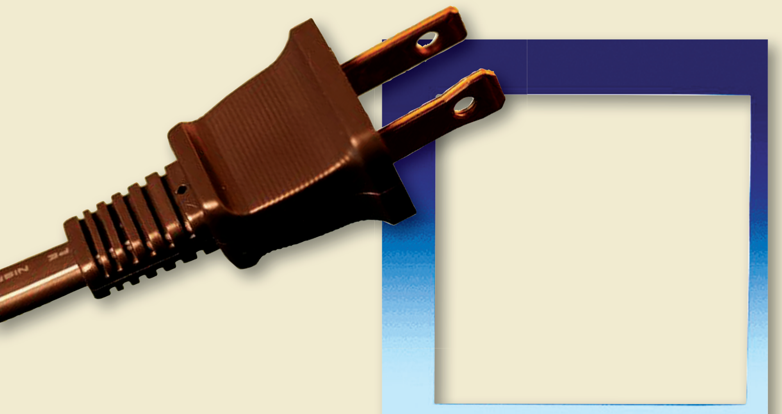


Figure 1 Plastics are used for electrical insulation in wires and for making electrical sockets.

However, chemists have now discovered that under certain conditions, plastics can be made to behave like metals.

In the 1970s, a Japanese chemist named Hideki Shirakawa was studying the polymerisation of the compound ethyne, C_2H_2. The ethyne molecule, CH ≡ CH, has a triple bond between the two carbon atoms. During polymerisation, one of the bonds between the carbon atoms breaks as the ethyne molecules join together:

```
     H   H   H   H   H   H
     |   |   |   |   |   |
... + C ≡ C + C ≡ C + C ≡ C + ...

     H   H   H   H   H   H
     |   |   |   |   |   |
... – C = C – C = C – C = C – ...
  \_________________________/
            polymer
```

The polymer he made had the shiny appearance of a metal but did not conduct electricity. However, working with two chemists in the United States, it was soon discovered that by adding small amounts of iodine, the polymer was able to conduct electricity like a metal.

Soon after this discovery, other plastics that could conduct electricity were made. In addition, it was also discovered that some of these conductive polymers exhibit electro-luminescence, that is, they glow when an electric current passes through them.

Applications

Advantages of plastics over metals are that they can be moulded into different shapes, are flexible, light weight and can be made easily and cheaply. And with the ability to conduct electricity and emit light, conductive plastics have many potential uses. Here are some of them:

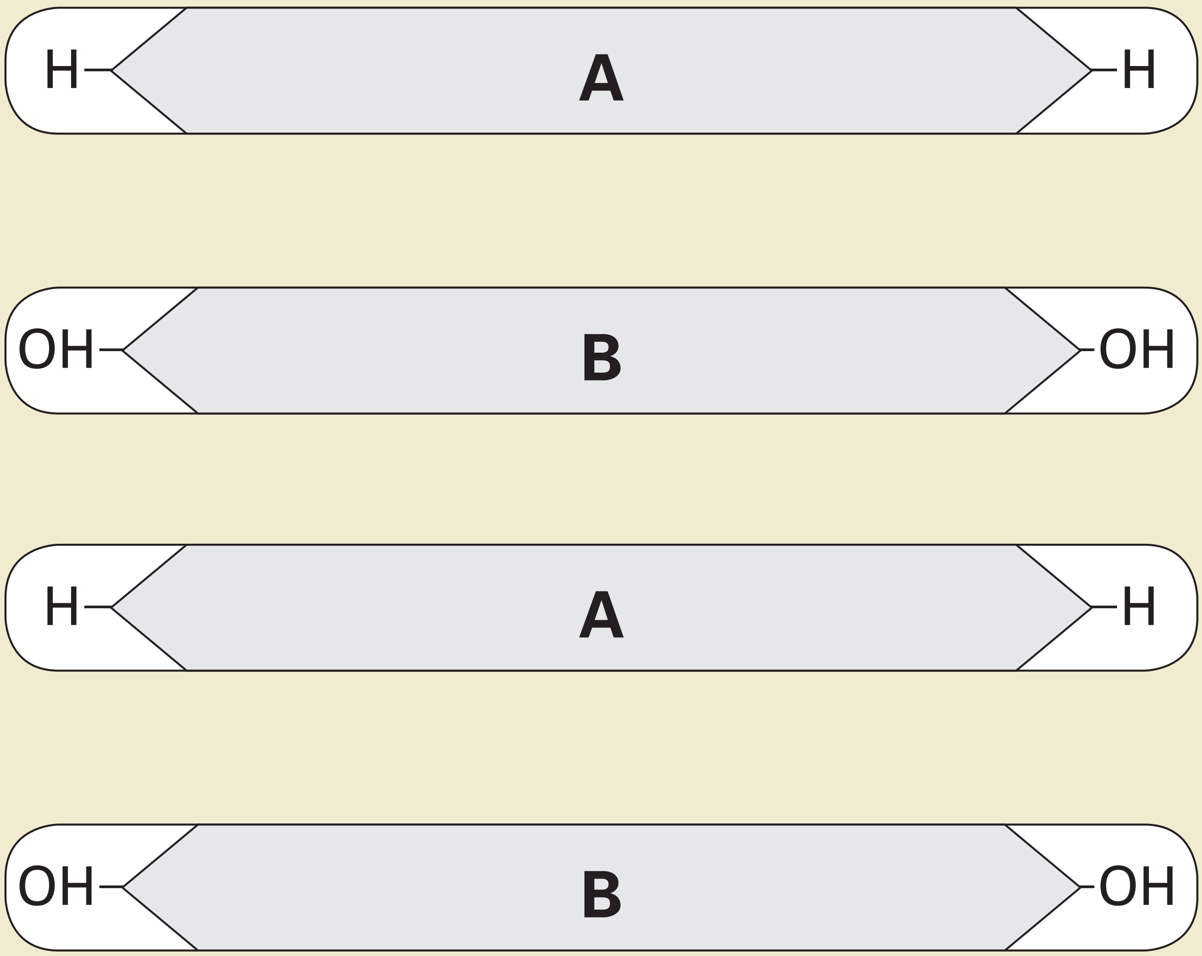
- plastic batteries,
- plastic TV screens,
- plastic wallpaper that can show images or change colours and be used as a source of light instead of conventional lamps,
- light displays in mobile phones and information boards, and
- solar cells to convert sunlight into electricity. Solar cell plastic could be spread out over large areas to generate environmentally-friendly electricity.

Exercise

1 (a) What is the name of the polymer formed from ethyne?
  (b) Write the repeat unit for the polymer.
  [*elaborating*]

2 Suggest other possible uses in the home for plastics that conduct electricity and emit light.
  [creating: generating ideas]

Templates for Condensation Polymers



Additional Teaching Material

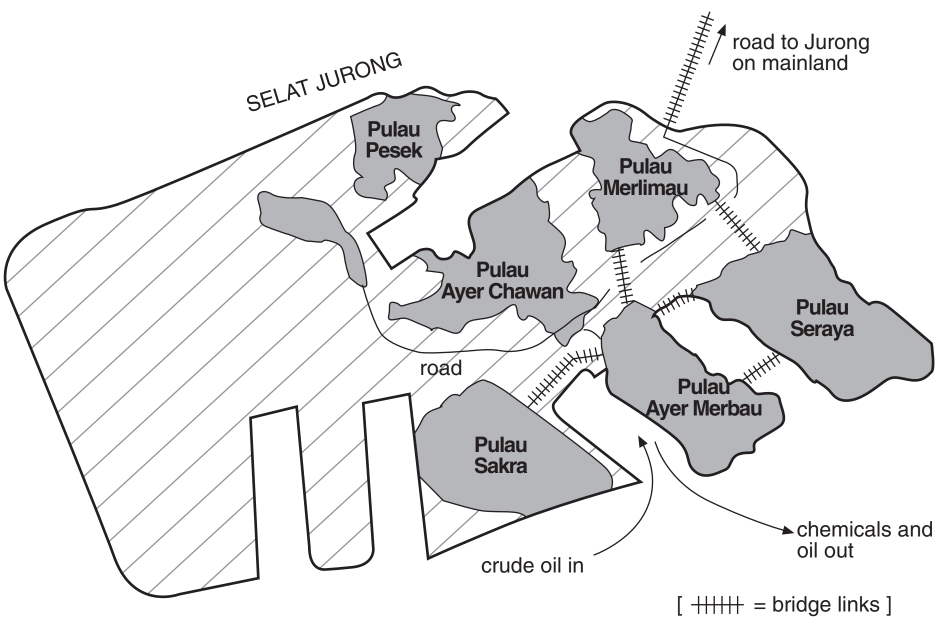
Additional Exercise 1: Petrochemical Plants on Jurong Island

Objective
- To obtain information on Jurong Island and the Singapore petrochemical industry
- To appreciate the benefits of the industries on Jurong Island to Singapore

Strategies
- Doing a case study
- Information searching

This activity is about Jurong Island and the Singapore petrochemical industry. To obtain information for the activity, use your textbook and the Internet.

Jurong Island
Singapore is one of the biggest regional producers of polymers and chemicals for making polymers. Most are produced at petrochemical complexes on Jurong Island, which is situated on the south-west side of Singapore. Less than 30 years ago, the island was just a group of seven small islands that were home to a few fishing villages. The land area of Jurong Island was extended by filling in the sea between the small islands. The map shows how Jurong Island has been formed from these small islands.



Questions

1. Today, four petrochemical plants are located on Jurong Island. Where are they?

____

____

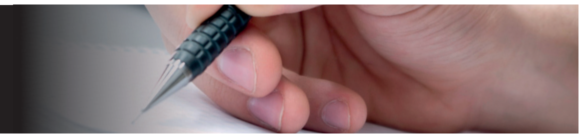
2. Singapore has one other petrochemical complex that is not on Jurong Island. Where is it located?

____

Part of a petrochemical plant in Singapore

A petrochemical plant consists of three main parts. Name these parts and state the main process that takes place in each.

Part	Process
1.	
2.	
3.	



Additional Exercise 2: Biodegradable Plastics

Objective

- To appreciate how pollution problems caused by the disposal of non-biodegradable plastics can be overcome

Strategies

- Doing a case study

Most plastics polymers, such as poly(ethene), are non-biodegradable. When products made of these plastics are dumped in landfills (Figure 1), they can remain there without significant change for perhaps thousands of years.

Figure 1 Pollution caused by plastic waste

As a response to the pollution caused by this plastic waste, biodegradable plastics are being developed.

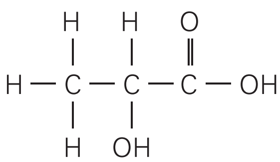
One promising biodegradable plastic is polylactic acid (PLA). It can be made from lactic acid, which is found in living things. Lactic acid can also be made using petrochemicals but it is very expensive. An environmentally friendly process is to obtain lactic acid from starch in plants and even food waste (e.g. corn, wheat, potatoes, sorghum, cheese whey). Figure 2 shows the steps involved.

starch → sugars → lactic acid → PLA

Figure 2 Obtaining PLA from starch

PLA is a suitable alternative to poly(ethene), a cheaper oil-based polymer. Future uses of PLA may include food packaging, yoghurt containers, plastic bags and disposable plastic bottles, cups, plates and cutlery. After use, products made from PLA are rapidly broken down by a variety of micro-organisms to water and carbon dioxide.

Figure 3 shows the structure of lactic acid:



lactic acid

or simply

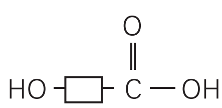


Figure 3 Structure of lactic acid molecule

Questions

1 What is meant by the term ‘non-biodegradable’?

____

2 Name two natural sources of lactic acid.

____

3 The conversion of sugar to lactic acid is brought about by bacteria. What is the general name given to this process?

____

4 Give two advantages of making PLA from natural materials instead of crude oil.

5 At present, PLA is much more expensive to produce than poly(ethene). Suggest two or more factors that may help to reduce the price gap.

6 Using block diagrams of lactic acid, write part of the polymer chain in PLA.

Find out more on how PLA is made from the Internet. An example of a website that you can go to is:

http://www.cargilldow.com/corporate/natureworks.asp

Additional Teaching Material

Additional Exercise 3: Plastics and the Three R's

Objective

- To appreciate the pollution problems caused by the disposal of plastic waste
- To show concern for protecting the environment

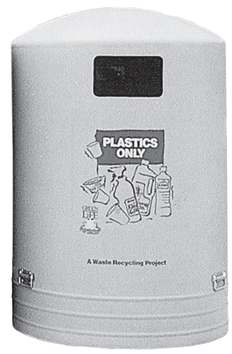
Strategies

- Doing a survey
- Discussing

Plastics are important materials in the modern world. They have many uses both in the home and in the world. The plastics industry is large, producing millions of tonnes of plastics every year. However, the disposal of plastic waste is causing pollution problems.

To overcome these problems, people are being encouraged to use the 3 R's — **Reuse**, **Reduce** (which can include *Replace*) and **Recycle**. For example, bins for the collection of plastic waste for recycling can be seen in many parts of Singapore.

In this activity, you are to carry out a survey and participate in a discussion on the impact of the disposal of plastic waste.



A recycle bin for plastic waste in a housing estate

A. Survey

1 In your groups, discuss what is meant by the 3 R's when applied to the problem of plastic waste.

2 Carry out a class survey to find out (a) how many families practice the 3 R's, and (b) examples of how they do this. Record the findings in the table below.

Total number of homes surveyed: ____________

	Number of homes	**Number of homes**
Reuse		
Reduce		
Recycle		

3 Share reasons why people practise the 3 R's and why they do not.

B. Discussion

1 In your groups, discuss the following questions:

(a) How does plastic waste cause pollution?

(b) How does the practice of the 3 R's help to overcome these problems?

(c) What ways can you suggest to encourage people to practise the 3 R's?

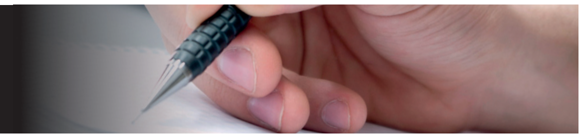
In the space below, or in a notebook, record ideas from the discussion.

2 Present the results of your discussion to the class. Be prepared to answer any questions from other groups. During the presentations, write down ideas from other groups that your group did not think of.

C. Follow-up assignment (optional)

Take some of the points from the group discussions to write a short essay on pollution problems caused by the disposal of plastics and how these problems might be overcome.

Additional Teaching Material



Additional Experiment 1: Preparing Nylon

Aim

- To prepare the condensation polymer, nylon

Apparatus and chemicals

- The teacher will need: beaker (1000 cm^3) Solution A: hexane-1,6-diamine solution (5 cm^3 Solution B: hexanedioyl dichloride solution (5 cm^3)measuring cylinder (10 cm^3) pair of tweezers glass rod

Key Competencies

CIT: sound reasoning

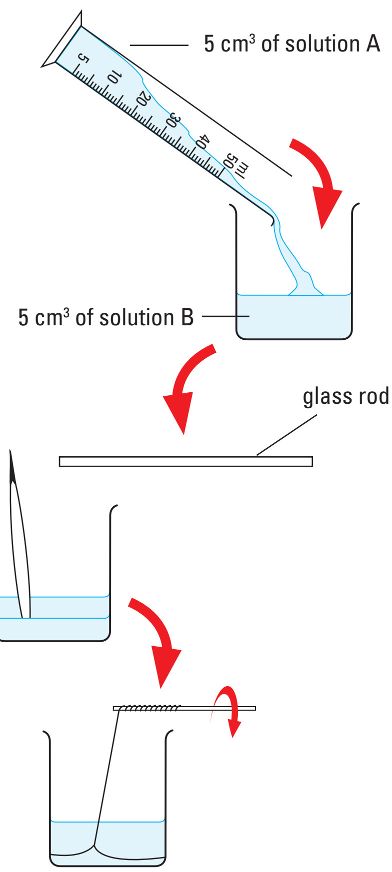
Safety warnings

Nylon is made from solutions of two monomers:
Solution A: Hexane-1,6-diamine in water (5 cm^3)
Solution B: Hexanedioyl dichloride in a non-aqueous solvent (5 cm^3)

- The chemicals used to make nylon are harmful. Avoid skin contact and breathing in fumes.
- The experiment must be carried out in a fume cupboard.

Procedure

1. **(a)** Pour Solution B into a small beaker.
   (b) Very carefully, pour Solution A down the side of beaker containing Solution B.
   Note: Do not reverse the order — Solution A must be added to Solution B.
2. Nylon forms where the two layers meet. Do not mix the layers. Use tweezers to pick up the nylon. Place the nylon on a glass rod.
3. Slowly turn the glass rod to get more nylon from the beaker. Wash the nylon with water before you touch it.
4. Pull the nylon. Is it strong or weak?



Questions

1. Describe the appearance of the nylon.

____

____

2. Is the nylon you made strong or weak?

____

____

3. In the space below, write the structure of a short length of the nylon molecule.

hexane-1,6-diamine (monomer A)

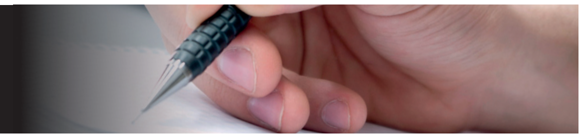
hexanedioyl dichloride (monomer B)

nylon (polymer) + ______________________

4. During the polymerisation reaction, what small molecule is eliminated?

____

____



Additional Experiment 2: Make Your Own Compostable Bioplastic

Aim

- To make a compostable bioplastic

Apparatus and Materials

- 1 tablespoon corn starch
- 2 drops corn oil
- 1 tablespoon water
- food colouring
- zip-sealing plastic bag
- microwave oven

Key Competencies

CIT: sound reasoning
ICS: communicating effectively (*collaborating with others*)

Safety warnings

Procedure

1. **(a)** Place the cornstarch in the plastic bag. Add corn oil and water.
(b) Seal the bag and mix the contents by rubbing outside the bag with your fingers.
(c) Add two drops of any colour food colouring to the mixture, seal and mix again.

2. **(a)** Open the zip seal just a little and put the bag in a microwave oven.
(b) Microwave on high for 20–25 seconds.

3. Carefully remove the bag. While the plastic is still warm, shape it into a ball.
You have now made a biodegradable plastic.

4. If you want to see your ball degrade, just immerse it in water.

> ! Be careful removing your plastic. It will be hot!

Answers

Additional Exercise 1:

1. Pulau Pesek, Pulau Merlimau, Pulau Ayer Chawan and Pulau Ayer Merbau

2. It is located on Pulau Bukom.

Part	Process
1. Oil refinery	fractional distillation of petroleum
2. Cracking units/plants	steam cracking/converting petroleum fractions into small alkenes
3. Polymer plants	polymerisation/converting small alkenes into polymers

Additional Exercise 2:

1. E.g. They are not able to be decomposed into simpler substances by the action of bacteria.

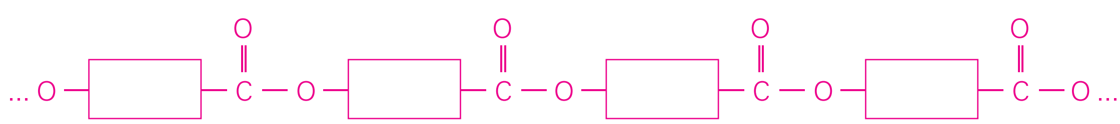
2. E.g. Yoghurt and sour milk.

3. Fermentation

4. E.g. PLA made this way will save large quantities of crude oil./Food waste can be used instead of being thrown away./Plants, unlike crude oil, are renewable.

5.
1. As petroleum reserves decrease, the cost of poly(ethene) will increase.
2. More research will lower the cost of PLA.
3. Government may require poly(ethene) to be recycled, forcing costs to increase.
4. A larger PLA market derived from its ‘green’ label may help reduce its cost.

6.



Additional Exercise 3:

A. Survey

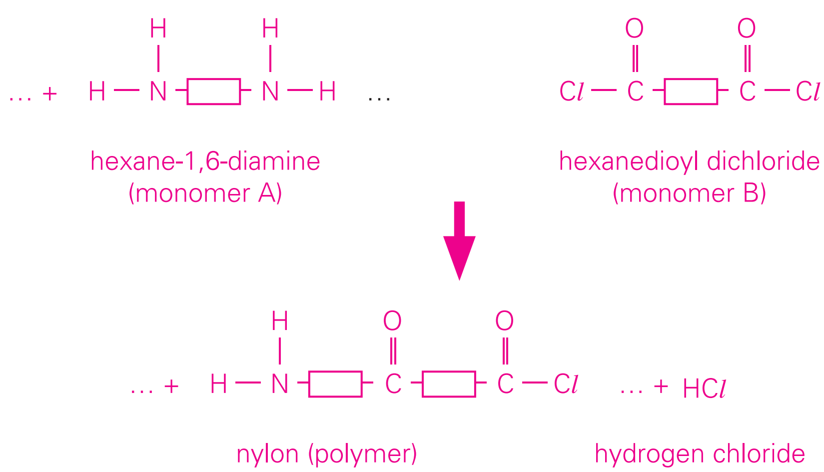
	Number of homes	Number of homes
Reuse		E.g. Supermarket bags are used as home rubbish bags.
Reduce		E.g. Reduce use of plastic bags from shops by using cloth bags for shopping.
Recycle		E.g. Deposit waste plastic containers in the recycle bins in the housing estate.

Additional Experiment 1:

1. The nylon is a white, solid thread.

2. It is strong.

3.



4. Hydrogen chloride, HC*l*, is eliminated.