Mastering Chemistry

- Book 3B
- Topic 8 Chemistry of Carbon Compounds

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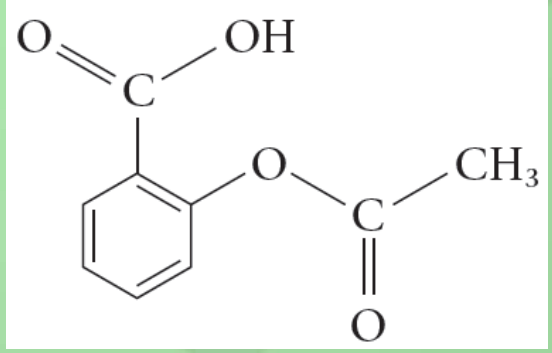
33.1 Aspirin (p.189)

- **Aspirin (亞士匹靈)** is one of the most frequently used painkillers in the world. It is also able to reduce inflammation and fever. People with a high risk of heart attack can use aspirin long term in low doses.
- The active ingredient of aspirin is **acetylsalicylic acid (乙酰水楊酸)**. It has a carboxyl group and an ester functional group.



Analysing aspirin tablets using back titration

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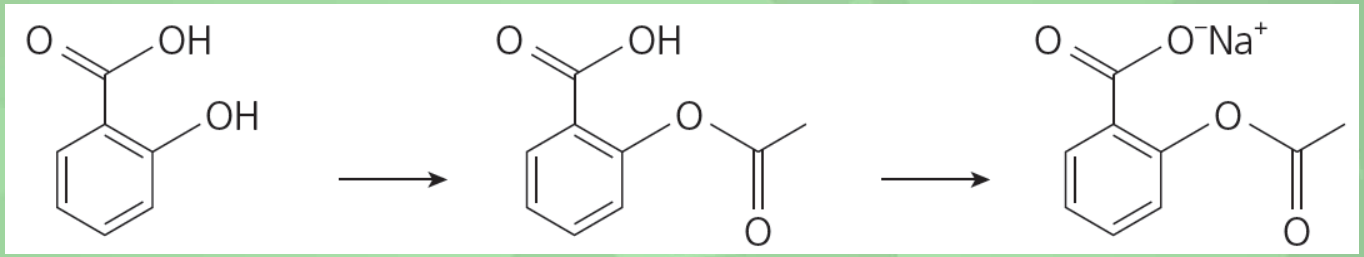
33.1 Aspirin (p.189)

Practice 33.1

Aspirin and its derivatives are made from salicyclic acid.



salicyclic acid aspirin soluble aspirin

a) Identify a reagent that could be used under appropriate conditions to convert aspirin into soluble aspirin. $NaOH$ / Na_2CO_3 / $NaHCO_3$

b) Suggest why aspirin has a low solubility in water.

The large benzene ring leads to low solubility.

c) Explain why soluble aspirin is more soluble in water than aspirin.

Soluble aspirin is ionic.

There are strong interactions between water and ions.

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33.2 Soaps (p.191)

- Both grease and oil are insoluble in water. Hence you can not cleanse grease and oil by water alone. Soaps can improve the cleansing property of water. They are made from natural fats and oils.

Fats and oils—examples of ester

- Most oils and fats are esters of propane-1,2,3-triol (commonly called **glycerol (甘油)**) with long-chain carboxylic acids (often called **fatty acids (脂肪酸)**).
- A glycerol molecule has three alcohol groups, which can form ester linkages with three carboxylic acid molecules to form a triester (often called a **triglyceride (甘油三酯)**)

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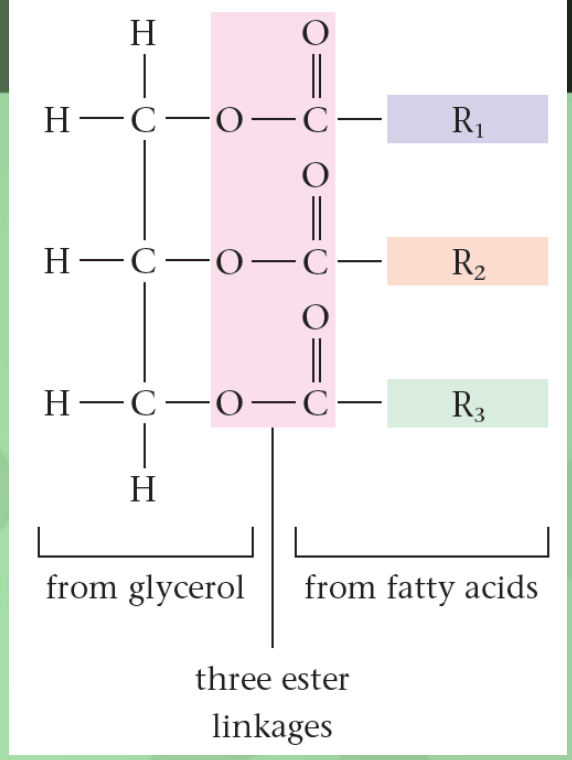
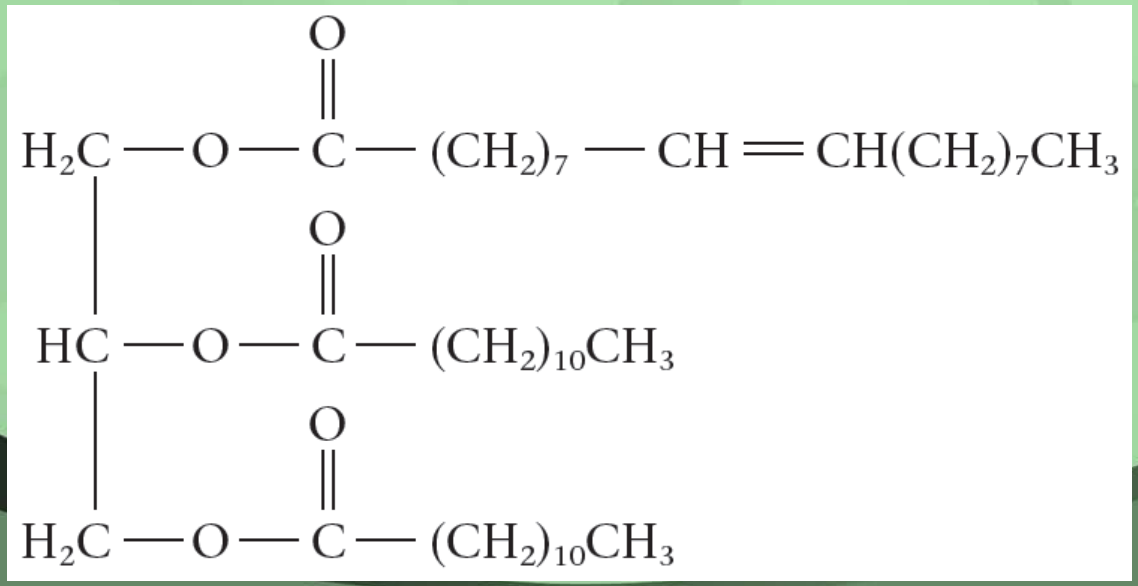
33.2 Soaps (p.191)

- The triglycerides found in natural oils and fats often contain triglycerides made from different long-chain carboxylic acids.





Coconut oil contains this triglyceride

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33.2 Soaps (p.191)

Saponification

- **Saponification (皂化作用)** means ‘soap making’.
- Heating fats with concentrated sodium hydroxide solution causes hydrolysis of the triglycerides.
- Conc. NaCl(aq) is added to lower the solubility of the soap. This process is called **salting-out (鹽析)** of soap. The soap separates from the mixture and floats on the surface.

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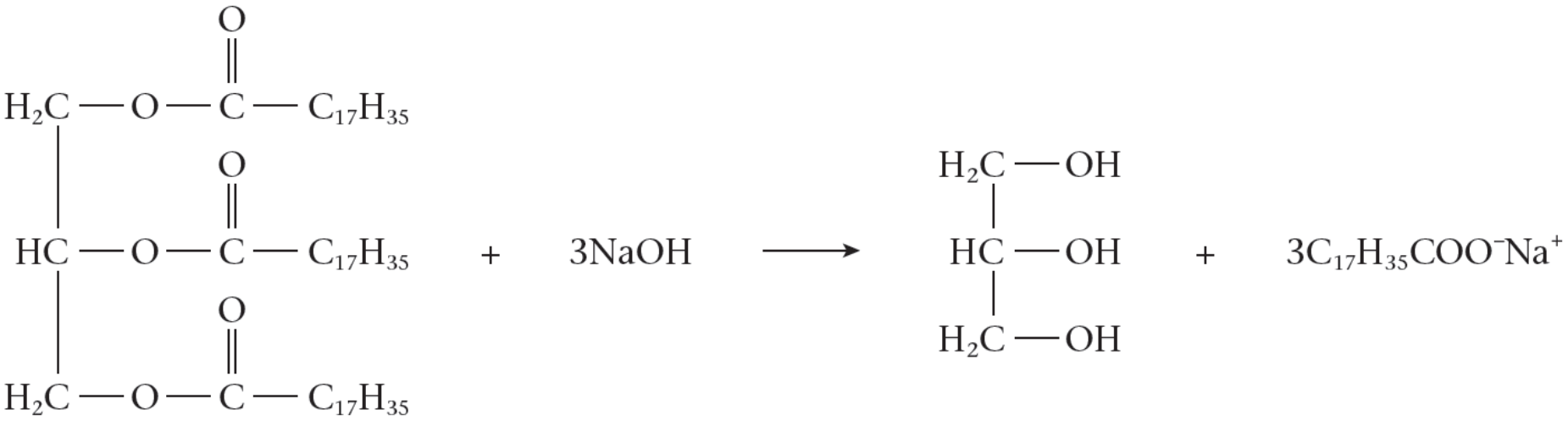
33.2 Soaps (p.191)



propane-1,2,3-triol (glycerol)

sodium octadecanoate (sodium stearate)

fat + alkali ⟶ alcohol + soap

Preparing a soap and testing its properties ***Ref.***

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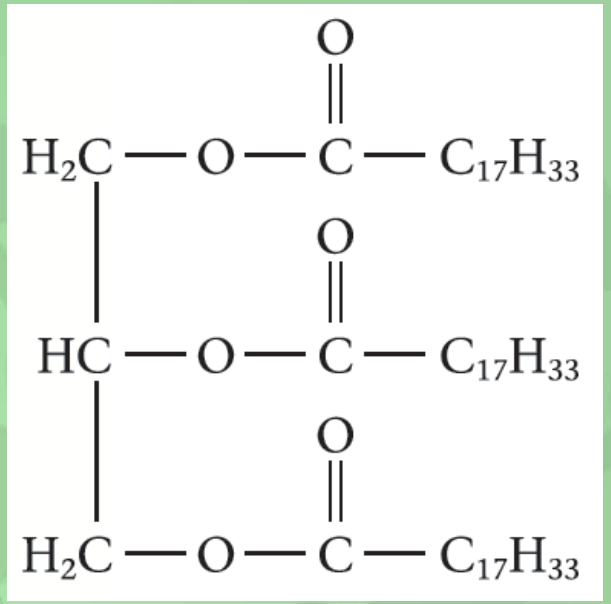
33.2 Soaps (p.191)

Q (Example 33.1)

An unsaturated fat F is a component of a vegetable oil. The structure of F is shown:



a) State the reagents needed for converting F to a saturated fat.
b) Vegetable oils can be used to make soap. Write the chemical equation involved for the formation of soap from F.
c) In the presence of an acid, the soap formed in (b) can react with methanol to give compound X, which can be used as a biodiesel. The structure of X is shown: $C_{17}H_{33}COOCH_3$
With reference to their properties, explain why X can be used as fuel for cars, but F CANNOT.

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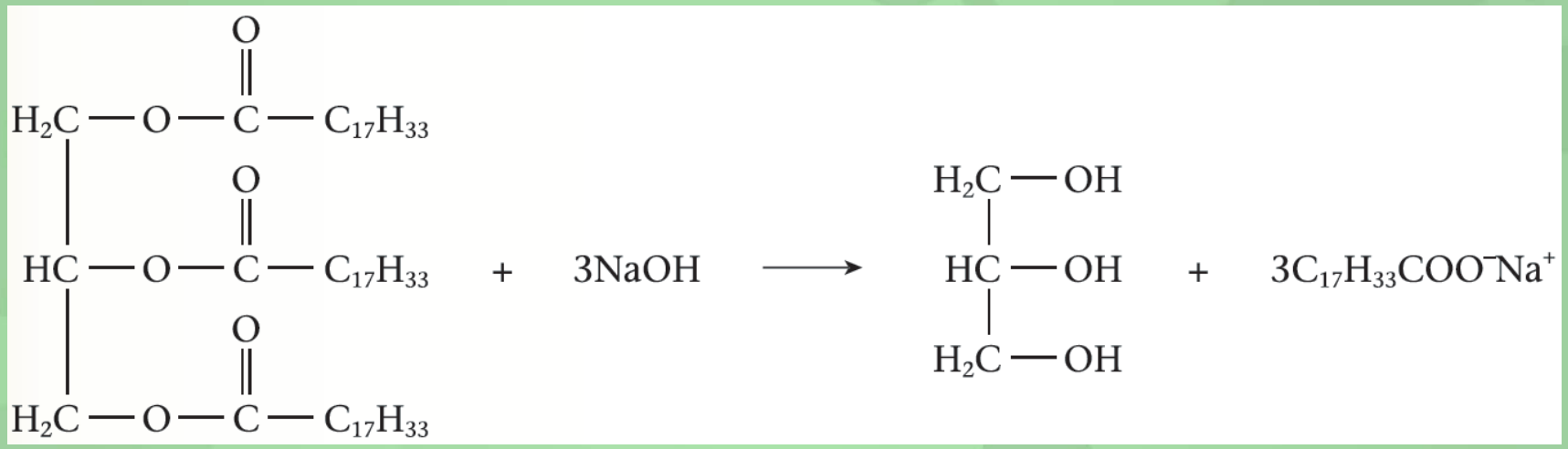
33.2 Soaps (p.191)

A

a) Hydrogen and Ni / Pt catalyst

b)



c) The molecular size of X is smaller than that of F.
The van der Waals' forces between molecules of X are weaker than those between molecules of F. Hence X can be vaporised more easily than F.
X burns more completely than F.

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33.2 Soaps (p.191)

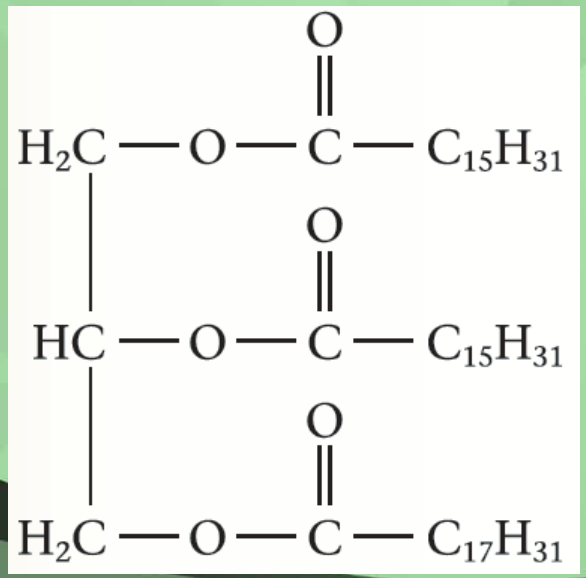
Q (Example 33.2)

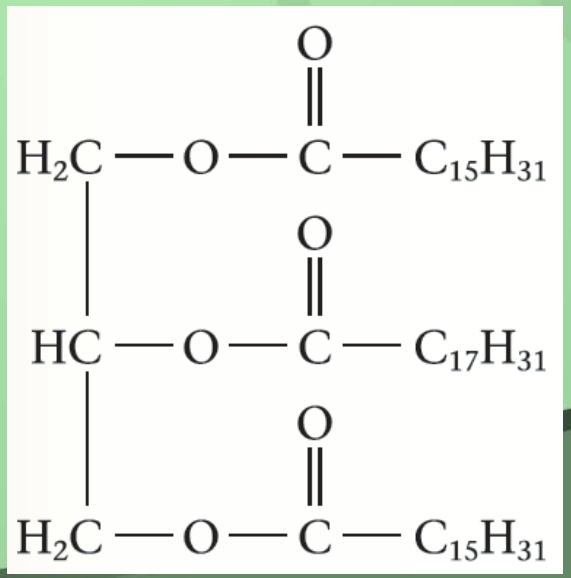
One mole of a triglyceride in an oil, when hydrolysed, produced one mole of glycerol, one mole of linoleic acid ($C_{17}H_{31}COOH$) and two moles of palmitic acid ($C_{15}H_{31}COOH$).

a) Draw TWO possible structures of the triglyceride.
b) Explain whether any of the triglyceride is optically active.

A

a)





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33.2 Soaps (p.191)

b) The first triglyceride is optically active. There are four different atoms / groups around the central carbon atom.

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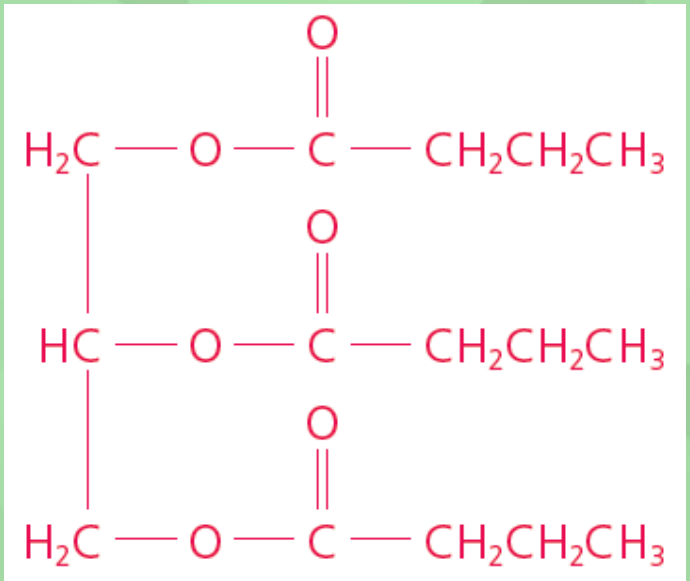
33.2 Soaps (p.191)

Practice 33.2

1 Butter contains a small amount of the triglyceride of butanoic acid. Draw the structure of the triglyceride of butanoic acid.



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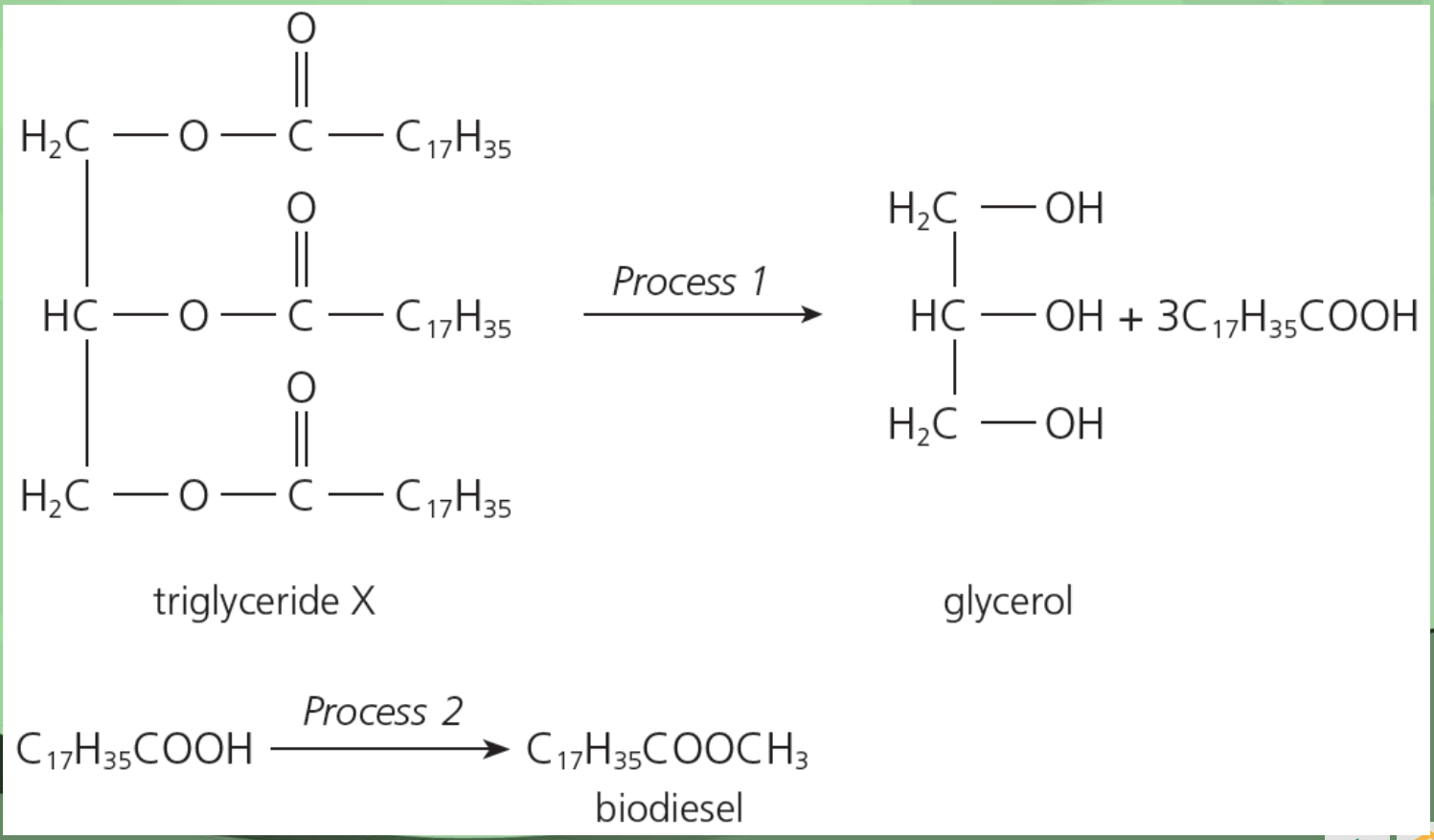
33.2 Soaps (p.191)

2 Recently much interest has been shown in the production of biodiesel from algae. Dried algae contain many triglycerides.
To convert triglyceride X found in dried algae to biodiesel, the following processes are carried out.



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33.2 Soaps (p.191)

a) Suggest the reagents and reaction conditions for

i) *Process 1*;

Any one of the following reagents:

- HCl / H_2SO_4
- NaOH (followed by H^+)

Heat / heat under reflux

ii) *Process 2*.

CH_3OH

Heat with concentrated H_2SO_4

b) Give the structure of the compound formed when glycerol reacts with excess hot acidified $K_2Cr_2O_7$(aq). HOOCCOCOOH

c) Suggest why the development of biodiesel as an alternative to fossil fuels is important. Any one of the following:

- Saving diminishing resources
- Economic argument — e.g. petroleum will become increasingly more expensive as it runs out.
- No net increase in carbon dioxide or less global warming
- Renewable

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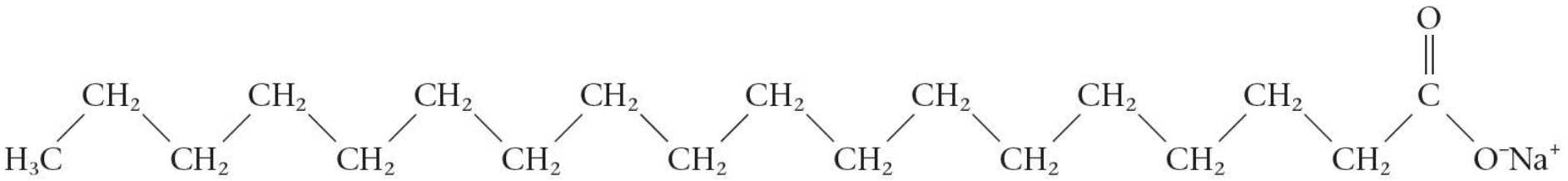
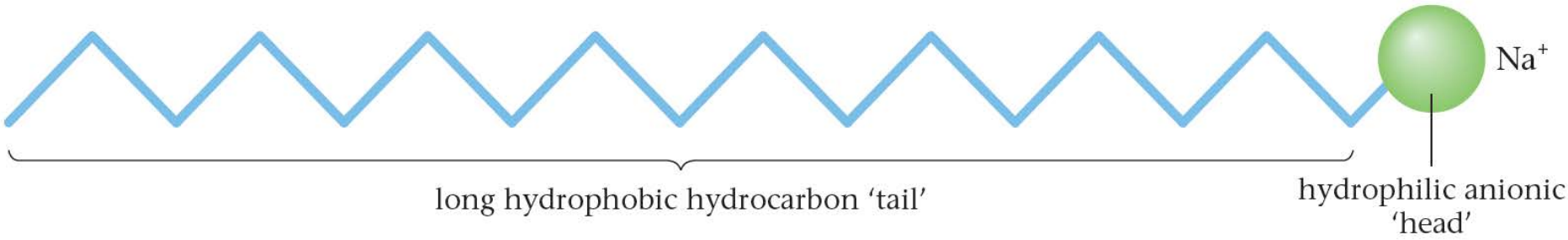
33.3 Structure of a soap molecule (p.196)

- **Sodium stearate** ($C_{17}H_{35}COO^-Na^+$) **(硬脂酸鈉)** is a typical soap.



sodium stearate $C_{17}H_{35}COO^-Na^+$

(a)



(b)

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33.3 Structure of a soap molecule (p.196)

- A soap molecule has two parts with different properties:
  - a long hydrocarbon 'tail' which is soluble in grease and oil (i.e. **hydrophobic (疏水性)** — water-rejecting); and
  - an anionic carboxylate 'head' which is soluble in water (i.e. **hydrophilic (親水性)** — water-seeking).

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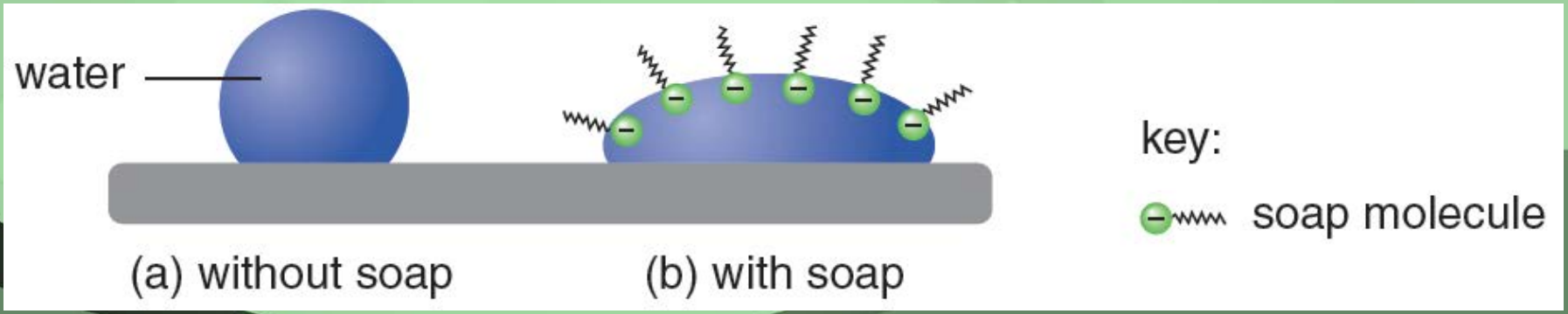
33.4 Wetting and emulsifying properties of soap (p.196)

- The cleansing action of a soap results from its
  - wetting property; and
  - emulsifying property.

The emulsifying process of a detergent *Ref.*

Wetting property of soap

- Water has a high surface tension. This tension causes water to bead up on a piece of fabric. When soap is added to the water, the water spreads out. Soap can reduce the surface tension of water.



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33.4 Wetting and emulsifying properties of soap (p.196)

- A large number of soap molecules tend to stay at the surface, with their hydrophobic hydrocarbon ends sticking out. The soap molecules disrupt the cohesion between the water molecules, causing the water bead to spread and covering a wider surface area of the fabric. This process is called **wetting (濕潤)**.

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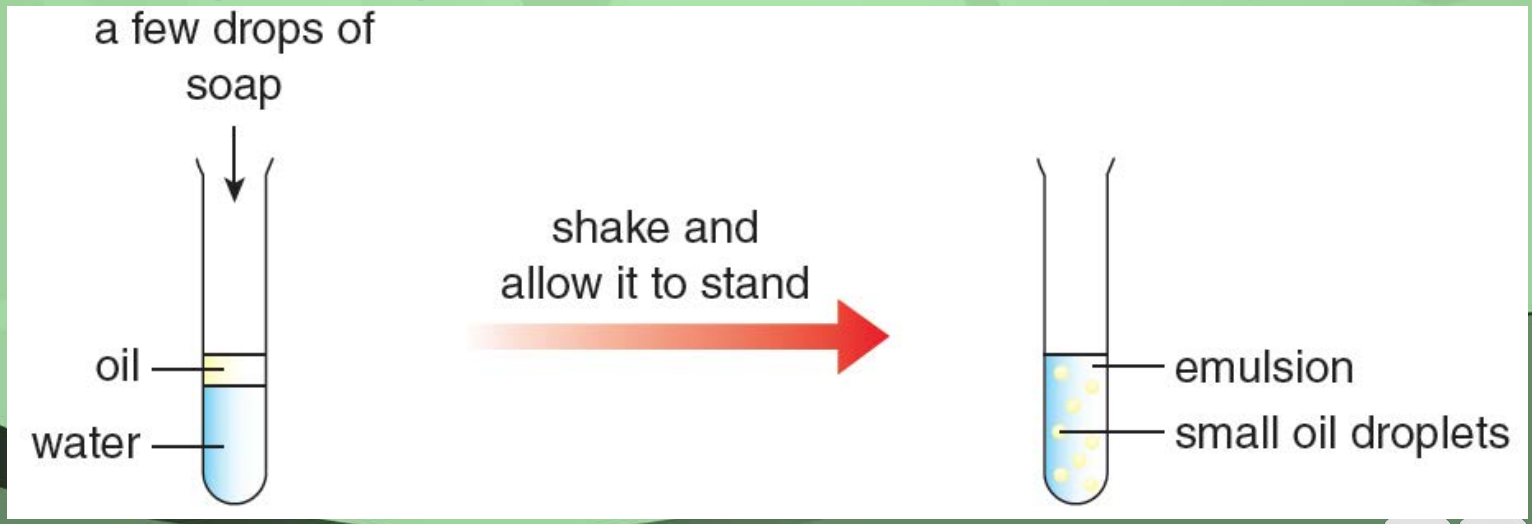
33.4 Wetting and emulsifying properties of soap (p.196)

Emulsifying property of soap

- Oil and water do not mix. When you shake an oil-water mixture and allow it to stand, the oil and water separate.
- However, when you add some soap to an oil-water mixture, shake and allow it to stand, small oil droplets appear. An **emulsion (乳狀物)** of oil in water forms.



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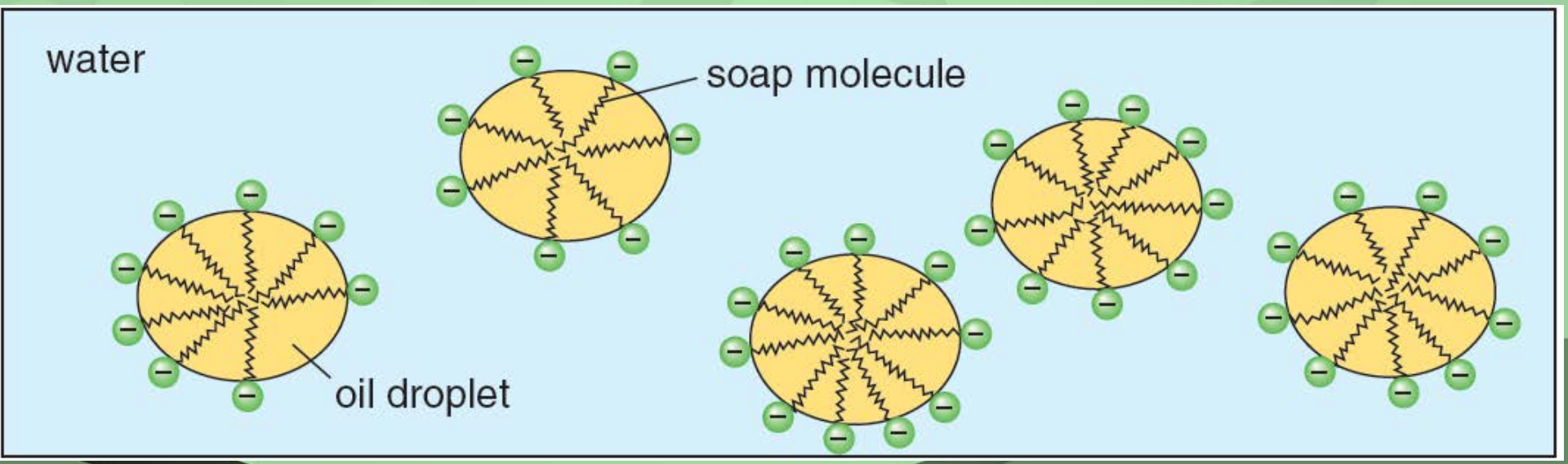
33.4 Wetting and emulsifying properties of soap (p.196)

- When you add some soap to an oil and water mixture and shake, oil droplets form. Each oil droplet is surrounded by soap molecules with the anionic 'heads' in water. The oil droplets cannot come together again due to the repulsion between the anionic 'heads'.



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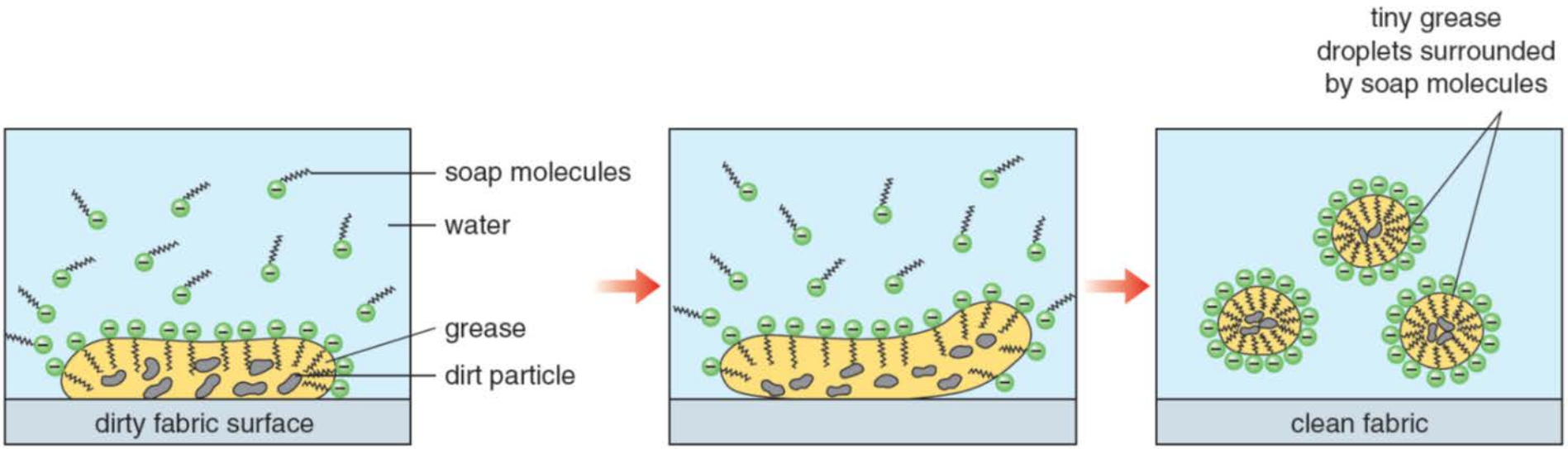
33.5 The cleansing action of soap (p.198)

- When you add a soap solution to the fabric, the hydrocarbon 'tails' of the soap molecules dissolve in the grease, leaving the anionic 'heads' sticking out.
- The surrounding water molecules attract the anionic 'heads' and lift the grease off the surface.



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33.5 The cleansing action of soap (p.198)

- The grease breaks up into tiny droplets when stirred. These tiny droplets cannot come together again due to the repulsion between the anionic ‘heads’ of the soap molecules.
- Rinsing washes away the tiny droplets and leaves the fabric clean.

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33.5 The cleansing action of soap (p.198)

Practice 33.3

The procedure of an experiment are listed below:

Step 1 A mixture of palm oil and concentrated sodium hydroxide solution is heated gently with stirring for 15 minutes.

Step 2 After cooling, concentrated sodium chloride solution is added to the reaction mixture.

Step 3 A white solid X separates out from the mixture.

a) Name the type of reaction involved when the mixture of palm oil and concentrated sodium hydroxide solution is heated.
Saponification / alkaline hydrolysis

b) What is the purpose of adding concentrated sodium chloride solution in *Step 2*?
Salting-out of soap

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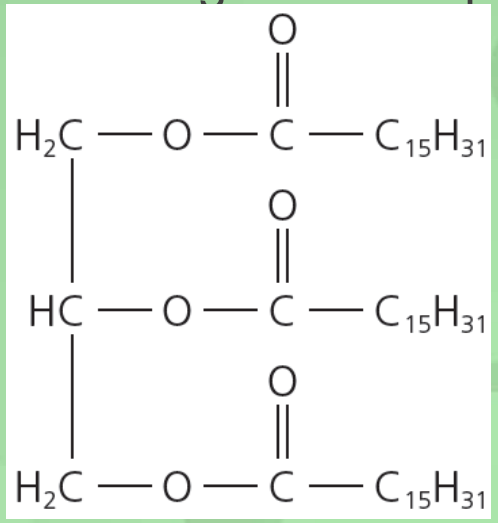
33.5 The cleansing action of soap (p.198)

c) The structure of a main ingredient of palm oil is shown below. Draw a structure of X.



$C_{15}H_{31}COO^-Na^+$

d) A small amount of X is added to a test tube containing a mixture of water and oil. The test tube is shaken. State the expected observation upon shaking the test tube. Explain your answer.

An emulsion forms.
X contains a hydrocarbon 'tail' which is hydrophobic and an anionic 'head' which is hydrophilic.
Each oil droplet is surrounded by soap molecules with the anionic 'heads' in water.
The oil droplets cannot come together due to the repulsion between the anionic 'heads'.

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33.6 Soapless detergents (p.200)

- Soaps are not effective cleansing agents in hard water which contain calcium ions and magnesium ions. These ions form water-insoluble precipitates with soap molecules and hinder the cleansing process.

$$2C_{17}H_{35}COO^-(aq) + Ca^{2+}(aq) \rightarrow (C_{17}H_{35}COO^-)_2Ca^{2+}(s)$$

- Soapless detergents (also known as synthetic detergents) are synthetic substances that are widely employed as cleansing agents these days. Unlike soaps, soapless detergents can be used satisfactorily in hard water since they do not form any precipitate in such water.

Investigating the properties of detergents ***Ref.***

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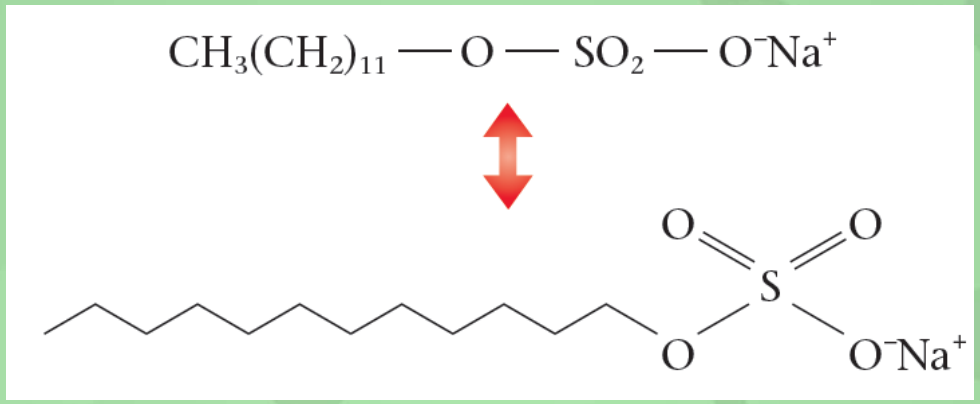
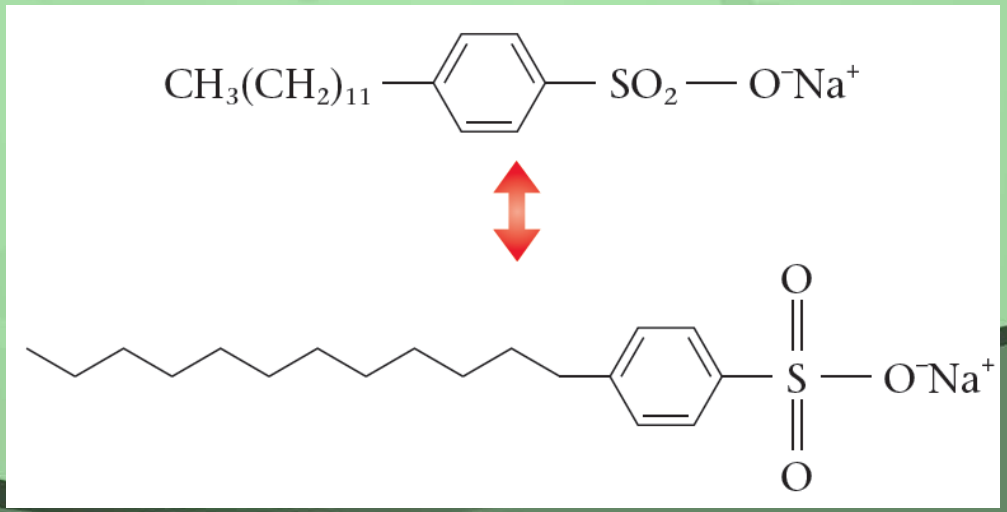
33.6 Soapless detergents (p.200)

A bottle of synthetic detergent

- Soapless detergents are structurally similar to soaps.

Two common examples of soapless detergent molecules





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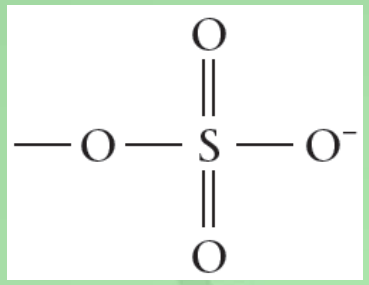
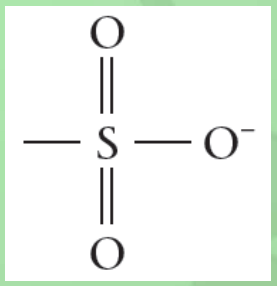
33.6 Soapless detergents (p.200)

- The anionic 'head' of a soapless detergent molecule is usually

a sulphate group () or

a **sulphonate group (磺酸基)** ().

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33.6 Soapless detergents (p.200)

Making soapless detergents

- Soapless detergents are made from chemicals derived from petroleum.
- For example, a long straight-chain alkene, such as dodec-1-ene ($CH_3(CH_2)_9CH=CH_2$), first reacts with benzene. The product then reacts with concentrated sulphuric acid to give a compound known as sulphonic acid. Finally, this acid reacts with the alkali sodium hydroxide to give a soapless detergent.

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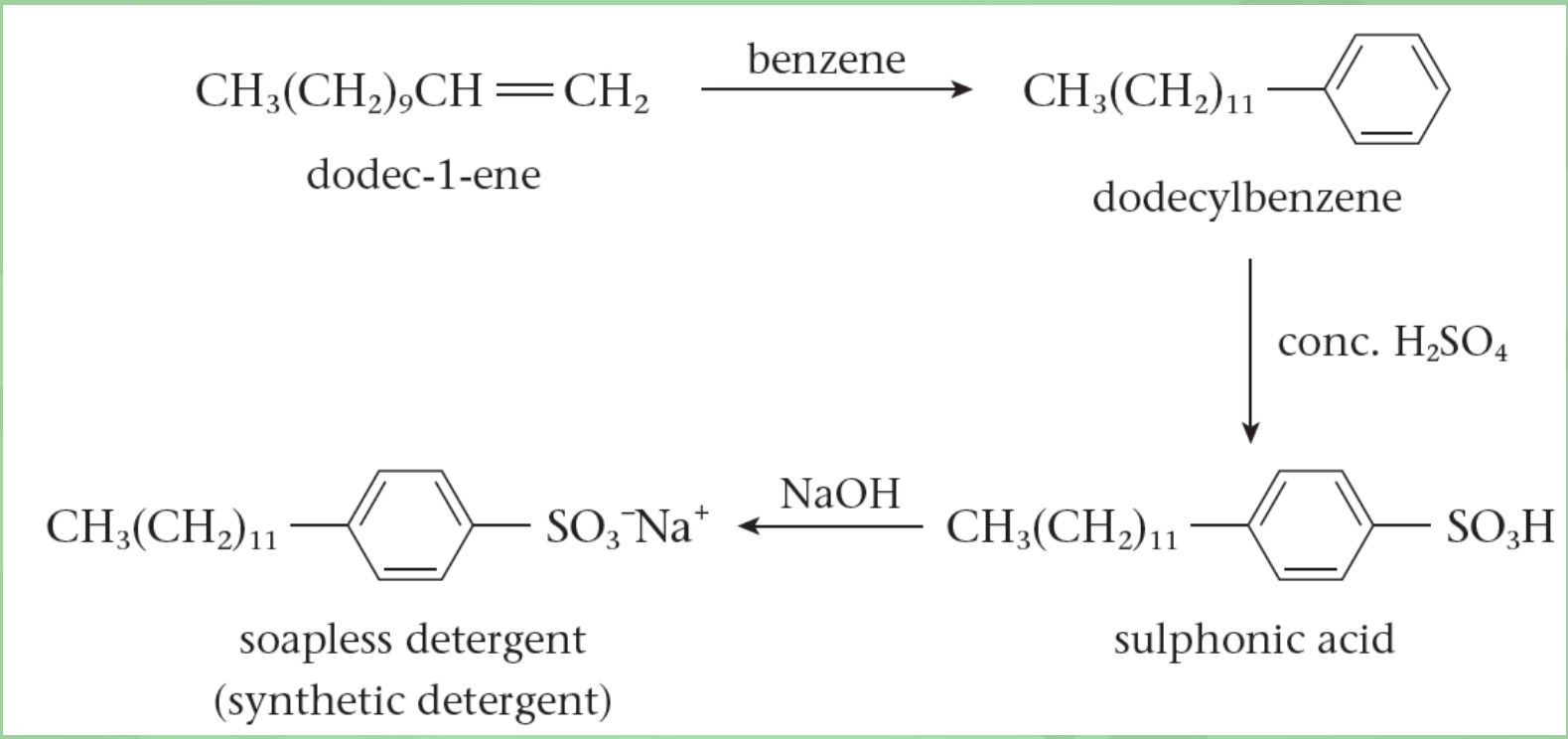
33.6 Soapless detergents (p.200)



- These days, soapless detergents such as this can be found in most washing powders and liquids.

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33.7 Polyesters (p.203)

- **Polyesters (聚酯)** are polymers in which the monomer units are linked together by ester linkages.
- The formation of polyesters involves a series of condensation reactions in which water molecules are lost between the monomer molecules as they react to create ester linkages. So polyesters are a type of **condensation polymer (縮合聚合物)**.
- A condensation polymer is formed when many monomer molecules join together via condensation reactions, with the elimination of simple molecules, such as water.
- The monomers must have at least two suitable functional groups per molecule for a condensation polymer to be produced.

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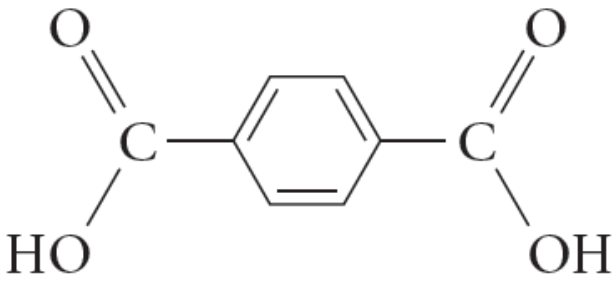
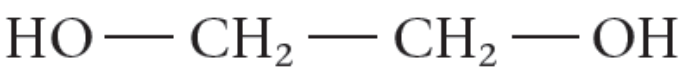
33.7 Polyesters (p.203)

Poly(ethylene terephthalate) (PET)

- **Poly(ethylene terephthalate)** (PET) **(聚對苯二甲酸乙二酯)** is one of the most common polyesters. It is formed from two monomers, a dicarboxylic acid (containing two –COOH groups) and a diol (containing two –OH groups).



benzene-1,4-dicarboxylic acid
or
terephthalic acid



ethane-1,2-diol
or
ethylene glycol

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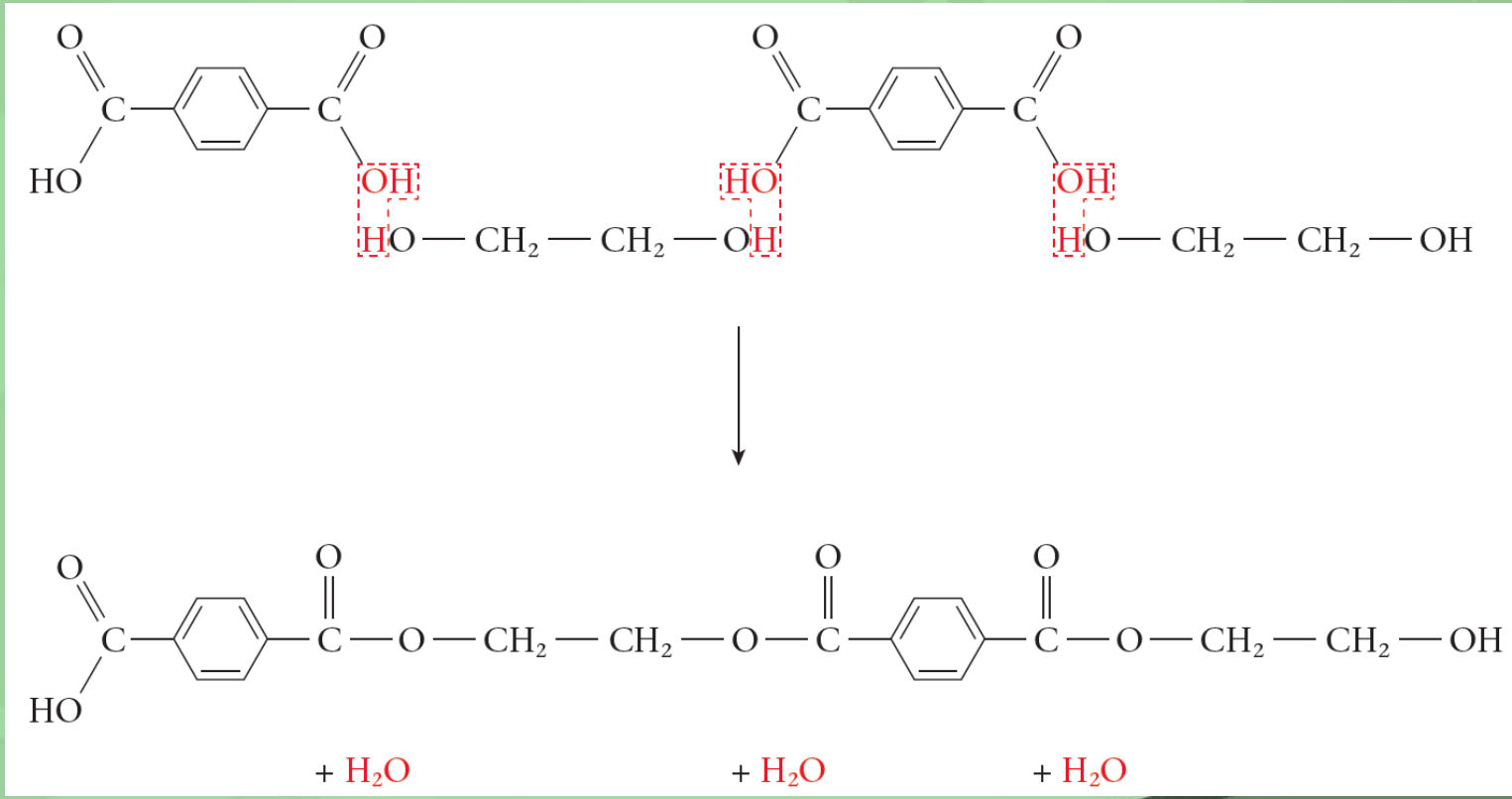
33.7 Polyesters (p.203)

- Formation of a short section of the polyester PET from a dicarboxylic acid and a diol:



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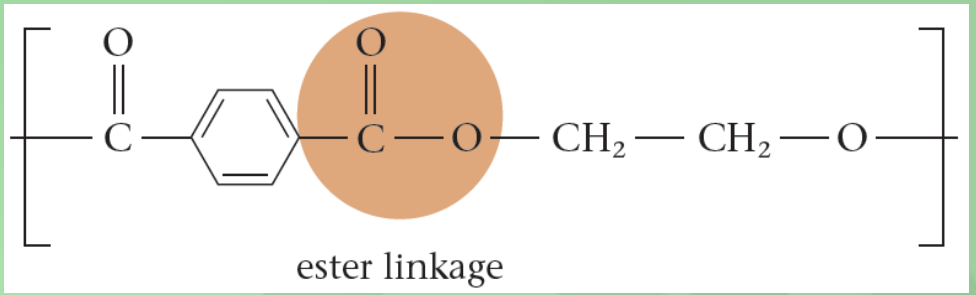
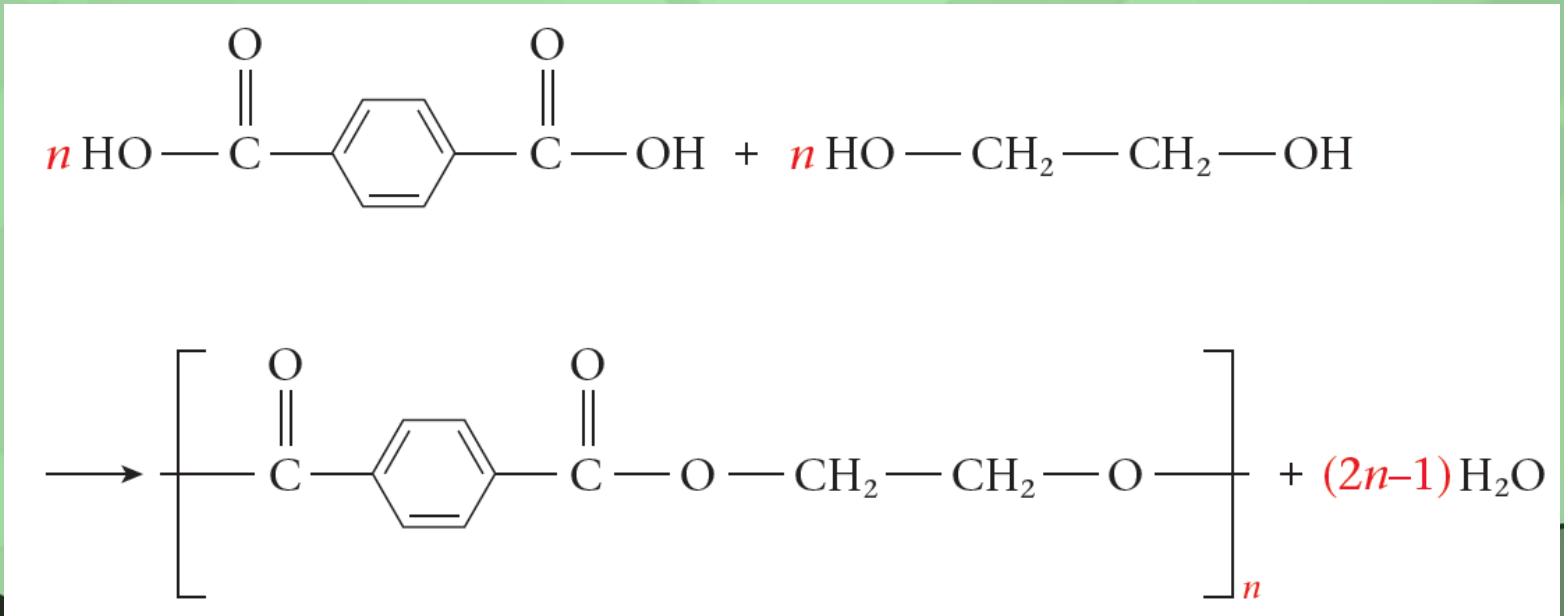
33.7 Polyesters (p.203)

- The repeating unit of PET:



- The chemical equation:



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33.7 Polyesters (p.203)

Uses of poly(ethylene terephthalate)

- The polymer chain of PET has a regular, approximately linear structure. The polymer chains pack closely together, so there are strong intermolecular forces.
- PET is used as fibres to make a kind of clothing which is often called by the commercial name *Terylene (特麗綾)*.
- Some shirts, sheets, socks and trousers are made from mixing PET with a natural fibre such as cotton or wool. The polyester gives the material strength and *crease resistance (防皺)*; the natural fibre gives a softer feel and allows the material to absorb some *perspiration (汗水)* from the wearer.

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33.7 Polyesters (p.203)

- PET is also an excellent thermal insulator and can be used as fillings for *duvets (羽絨被)*.
- PET can be made into different shapes and is used to make bottles for carbonated drinks and water. The bottle does not allow the dissolved carbon dioxide to escape as gas and the material is *shatterproof (防碎的)*, so it will not break if dropped.

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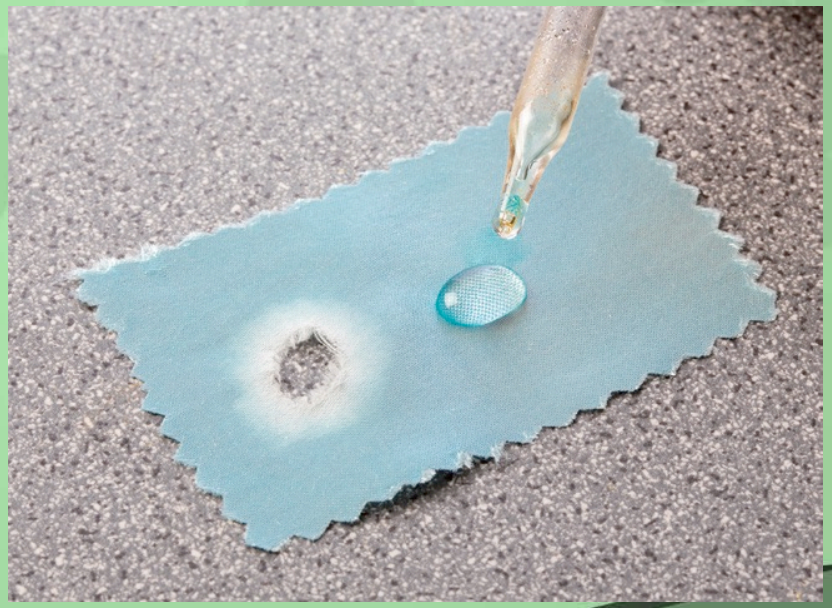
33.7 Polyesters (p.203)

- PET undergoes hydrolysis in acidic and alkaline conditions. The rate of reaction with alkaline hydrolysis is so fast that if a small amount of sodium hydroxide solution is dropped onto a piece of PET fabric, a hole would appear quickly.

Alkalis can easily hydrolyse polyesters and cause holes in clothing



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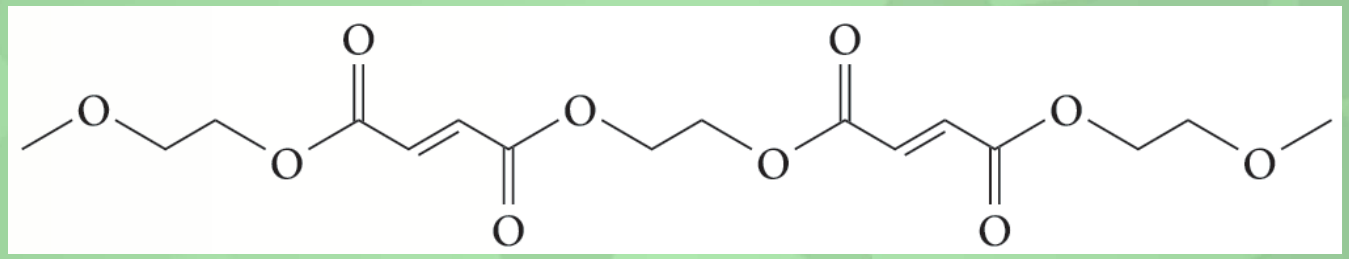
33.7 Polyesters (p.203)

Q (Example 33.3)

Below shows a section of a polymer that can be formed from the reaction between ethane-1,2-diol ($HOCH_2CH_2OH$) and an organic acid X.



a) Identify TWO functional groups in this polymer.
b) Write the structural formula of X.
c) What small molecule would be eliminated during the formation of this polymer?

A

a) Carbon-carbon double bond
   Ester group
b) HOOCCH=CHCOOH
c) Water molecule

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33.7 Polyesters (p.203)

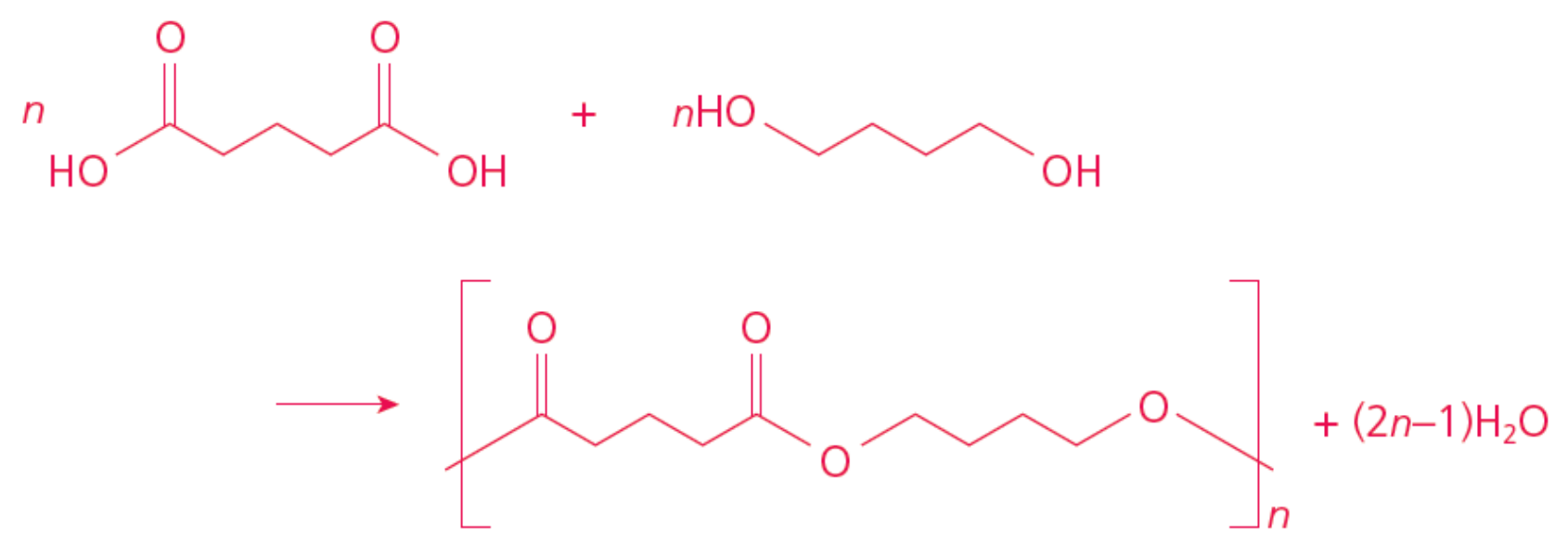
Practice 33.4

1 A polymer can be formed by reacting the two monomers below.

a) Name the functional group made during the formation of the polymer.

Ester group

b) Write the chemical equation for the formation of this polymer.



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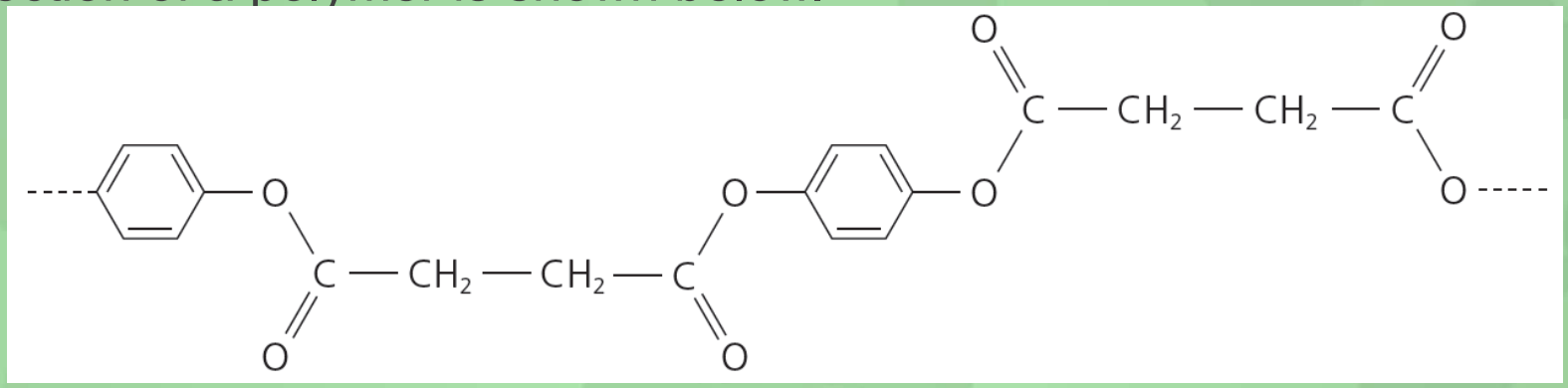
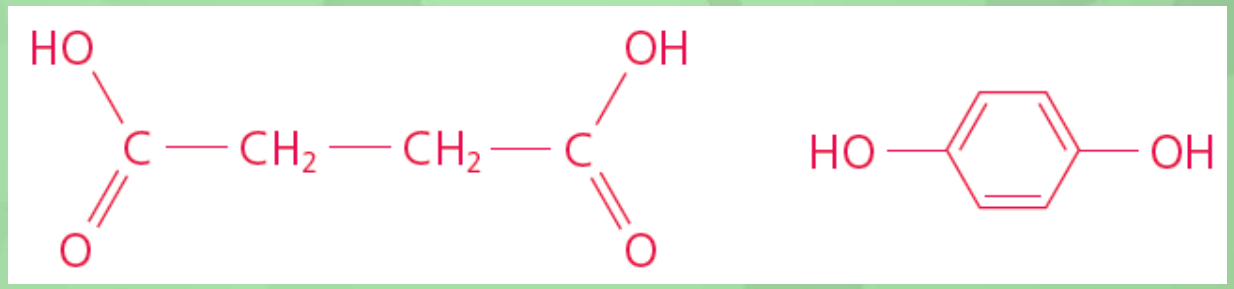
33.7 Polyesters (p.203)

2 A section of a polymer is shown below.



a) Write the structural formulae of the TWO monomers used to form the polymer.



b) What small molecule would be eliminated during the formation of this polymer?

H_2O

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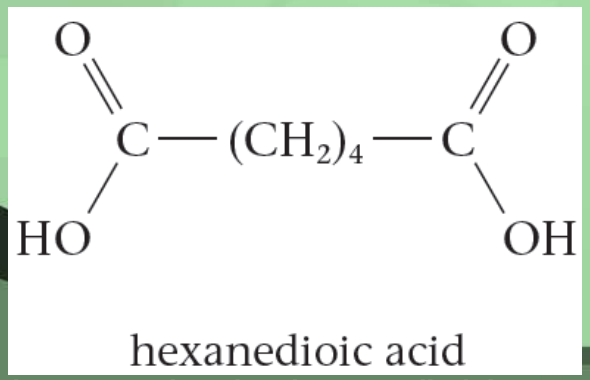
33.8 Polyamides (p.208)

- **Polyamides (聚酰胺)** are condensation polymers in which the monomer units are joined together by amide linkages. As with polyesters, polyamides can be made from two monomers, a dicarboxylic acid (containing two –COOH groups) and a diamine (containing two $–NH_2$ groups).

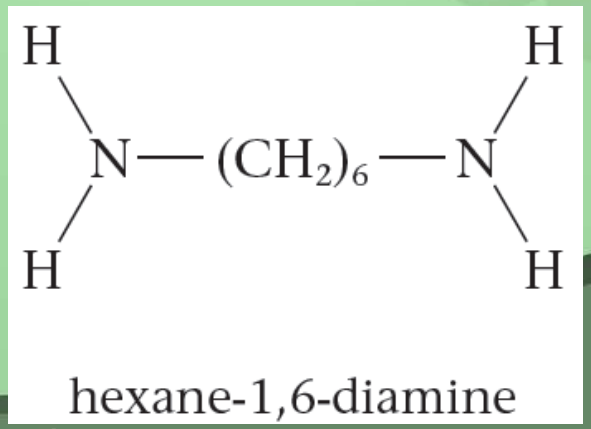
Nylon-6,6

3 Preparing nylon *Ref.*

- **Nylons (尼龍)** are polyamides. A common type of nylon is called nylon-6,6. It is made from hexanedioic acid and hexane-1,6-diamine.



hexanedioic acid



hexane-1,6-diamine

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33.8 Polyamides (p.208)

- The numbers used in nylon-6,6 refer to the number of carbon atoms in each monomer molecule.
- A short section of nylon-6,6 formed by the condensation reaction between hexanedioic acid and hexane-1,6-diamine molecules:

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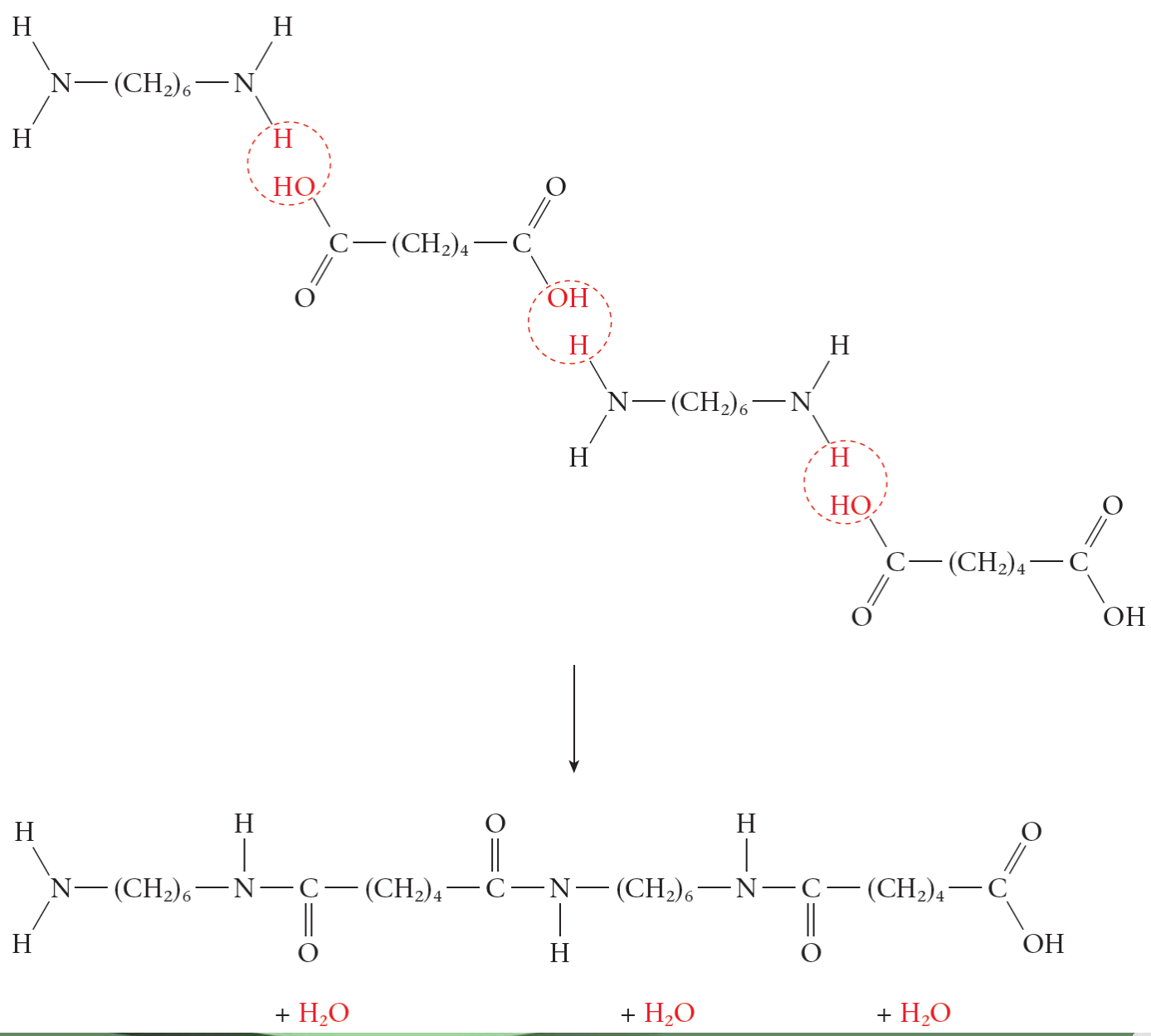

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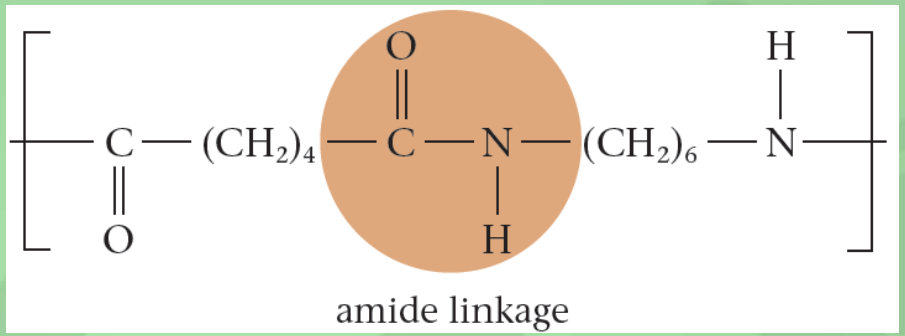
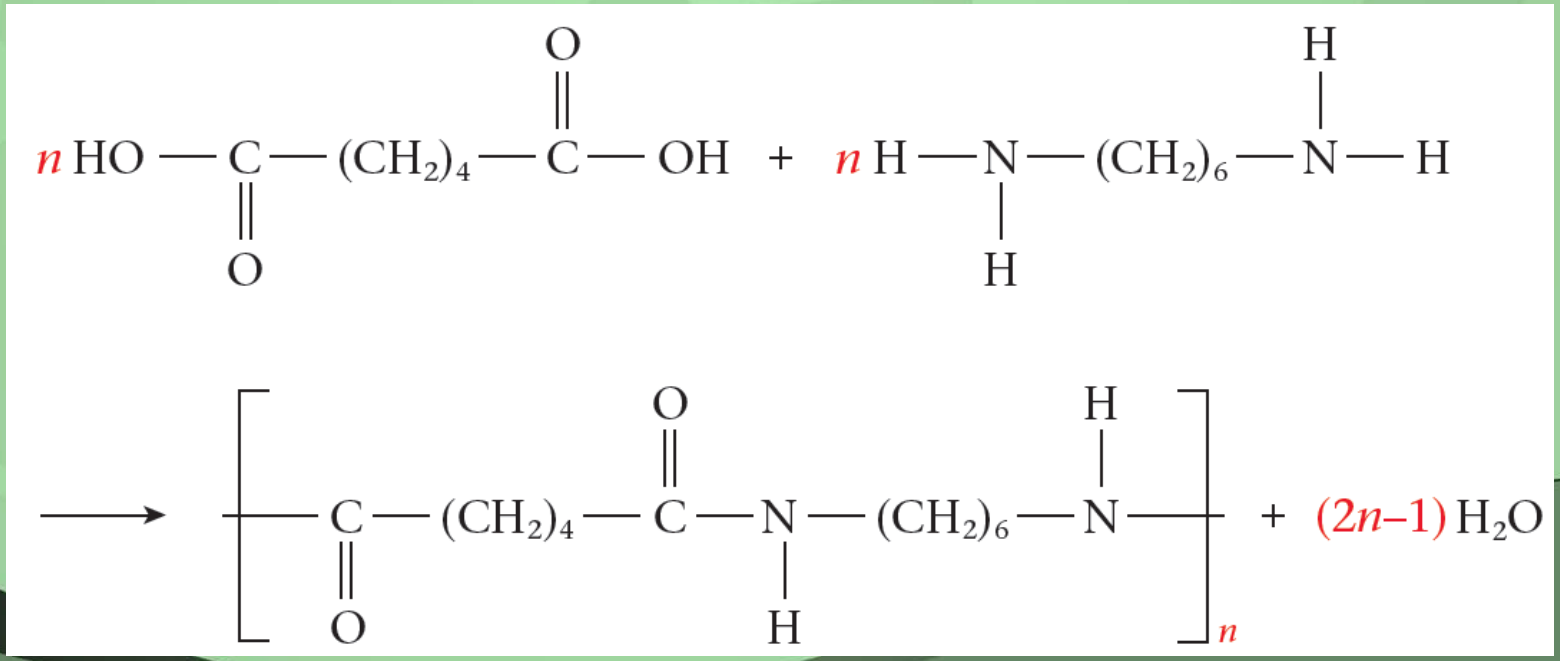
33.8 Polyamides (p.208)

- The repeating unit:



- The chemical equation:



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33.8 Polyamides (p.208)

Uses of nylon

- The low density and high strength of nylon make it a very useful fibre in the clothing industry. Nylon is also used to make climbing ropes and fishing lines.

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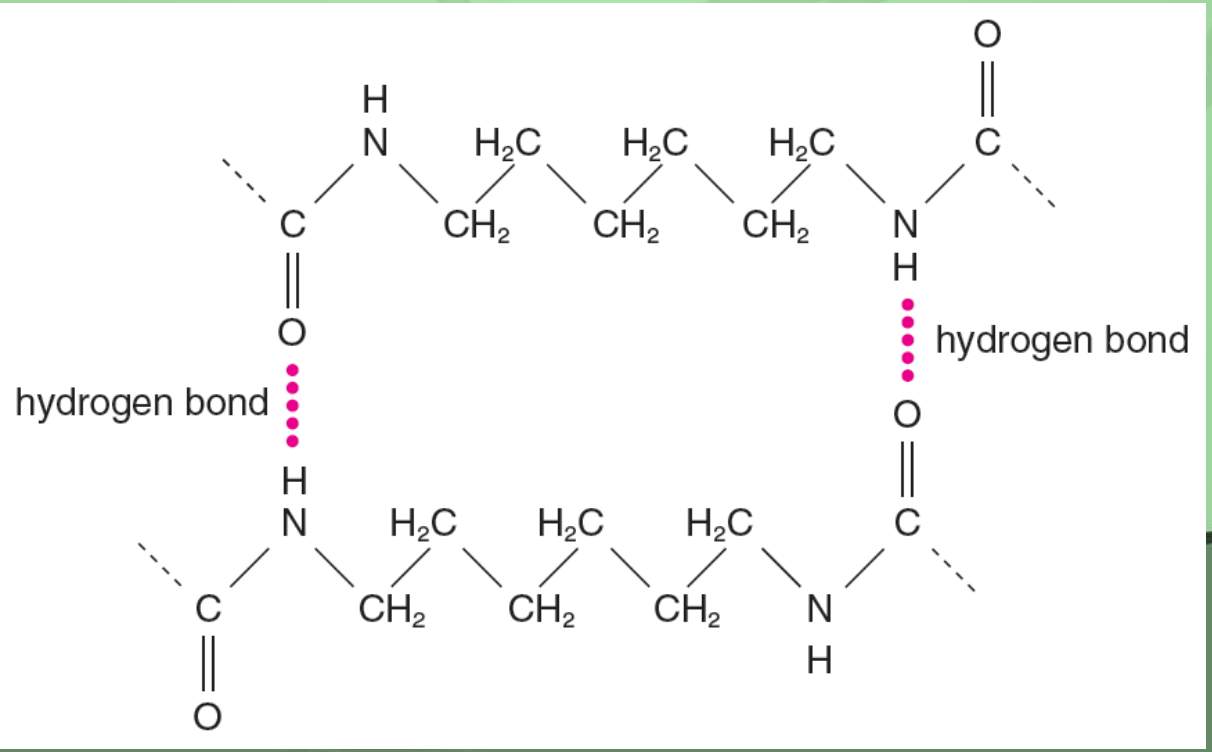
33.8 Polyamides (p.208)

- During the manufacturing process, the nylon is forced out of nozzles and pulled into long fibres. The nylon polymer chains line up along the length of the fibre. Strong hydrogen bonds form between neighbouring polymer chains, accounting for nylon's high strength.



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33.8 Polyamides (p.208)

- Polyamides undergo hydrolysis in acidic and alkaline conditions. The rate of reaction of hydrolysis of polyamides is much faster in acidic condition than in alkaline condition. Acids can easily hydrolyse nylon and cause holes in clothing.

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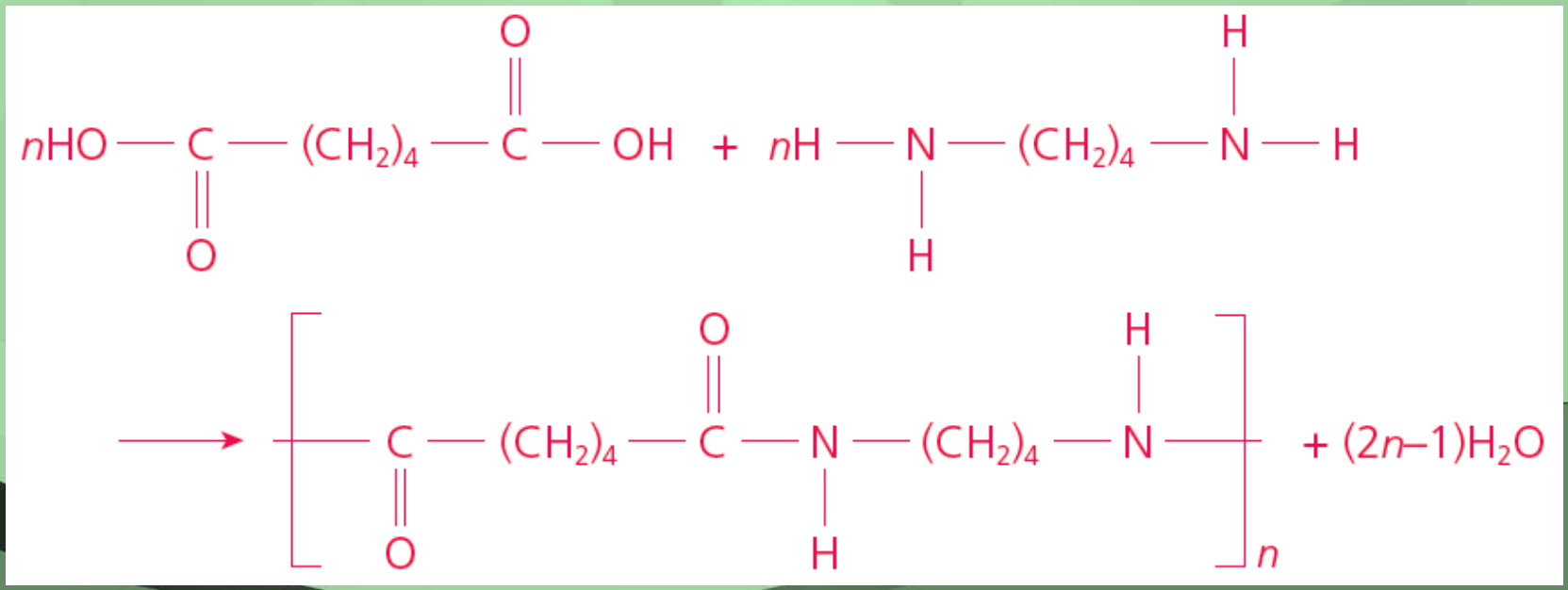
33.8 Polyamides (p.208)

Practice 33.5

Nylon-4,6 can be formed from the reaction between butane-1,4-diamine ($H_2N(CH_2)_4NH_2$) and hexanedioic acid ($HOOC(CH_2)_4COOH$).

a) Name the functional group made during the formation of nylon-4,6.
Amide functional group

b) Write the chemical equation for the formation of nylon-4,6.



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33.8 Polyamides (p.208)

c) Identify the attractive forces between the polymer chains.

Van der Waals' forces
Hydrogen bonds

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Key terms (p.212)

aspirin	亞士匹靈	wetting	濕潤
acetylsalicylic acid	乙酰水楊酸	emulsion	乳狀物
glycerol	甘油	sulphonate group	磺酸基
fatty acid	脂肪酸	polyester	聚酯
triglyceride	甘油三酯	condensation polymer	縮合聚合物
saponification	皂化作用	poly(ethylene terephthalate), PET	聚對苯二甲酸乙二酯
salting-out	鹽析	non-biodegradable	生物不可降解的
sodium stearate	硬脂酸鈉	biodegradable	生物可降解的
hydrophobic	疏水性	polyamide	聚酰胺
hydrophilic	親水性	nylon	尼龍

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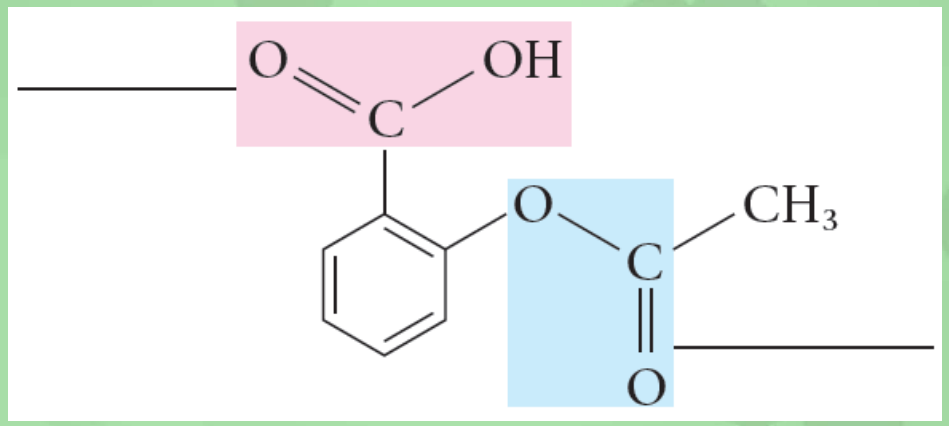
Summary (p.213)

1 The structure of the active ingredient of aspirin tablets, acetylsalicylic acid, is shown below. It contains two functional groups.

carboxyl group



ester group

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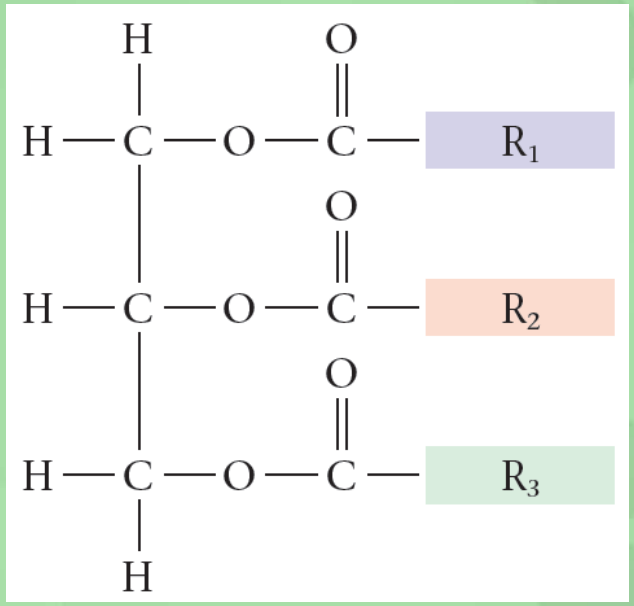
Summary (p.213)

2 a) Most oils are fats are esters of glycerol with long-chain carboxylic acids. Three carboxylic acid molecules can form ester linkages with each glycerol molecule to form a molecule of a triglyceride.



a triglyceride

b) Alkaline hydrolysis of triglycerides (i.e. saponification) produces glycerol and a mixture of salts of long-chain carboxylic acids (i.e. soap).

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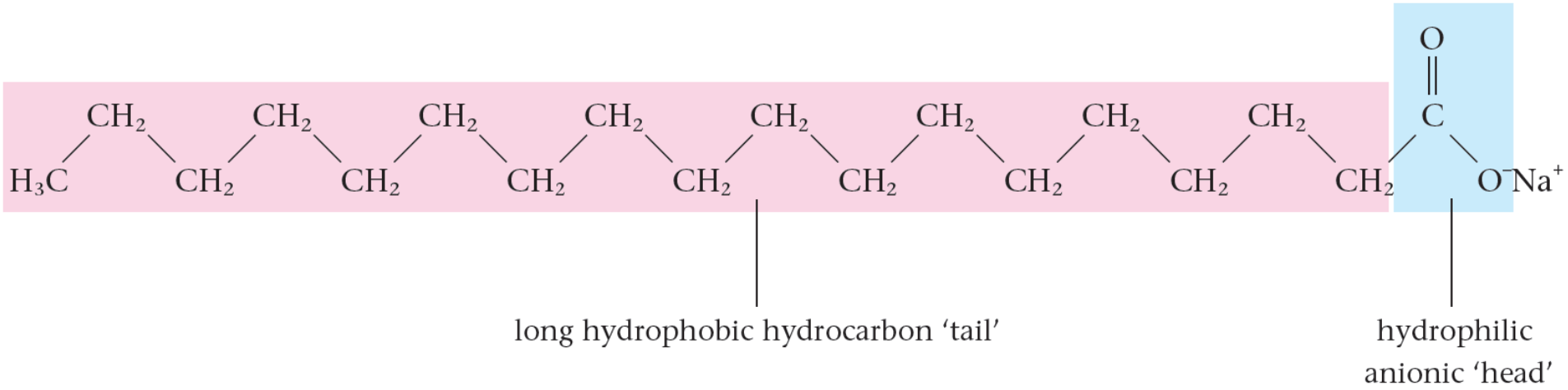
Summary (p.213)

3 The structure of a typical soap, sodium stearate ($C_{17}H_{35}COO^-Na^+$) is shown below:



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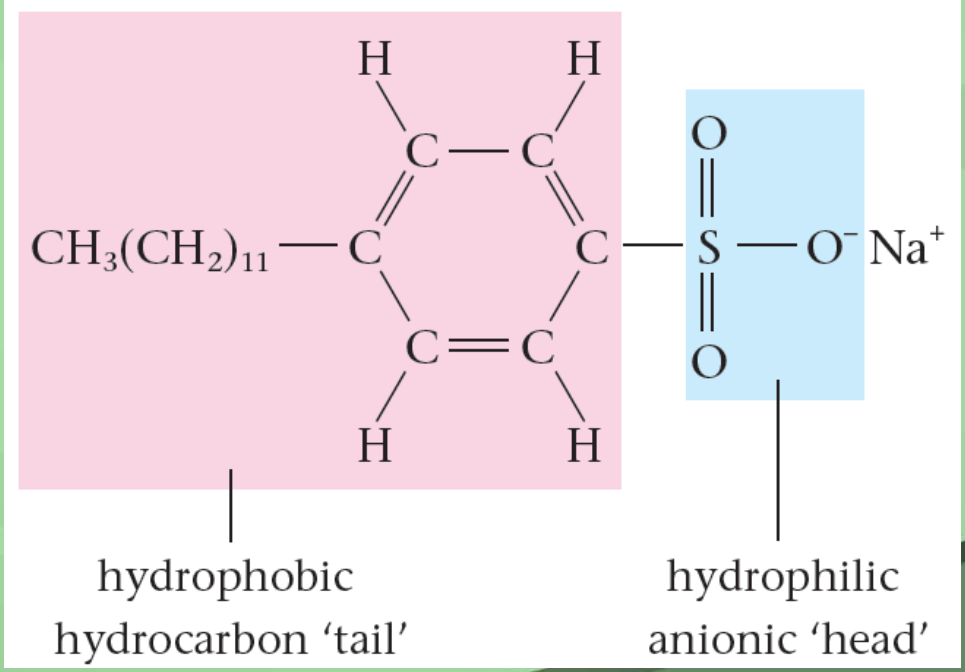
Summary (p.213)

4 The cleansing action of a soap results from its
- wetting property; and
- emulsifying property.

5 The structure of a soapless detergent is shown below:



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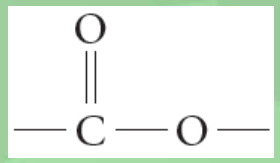
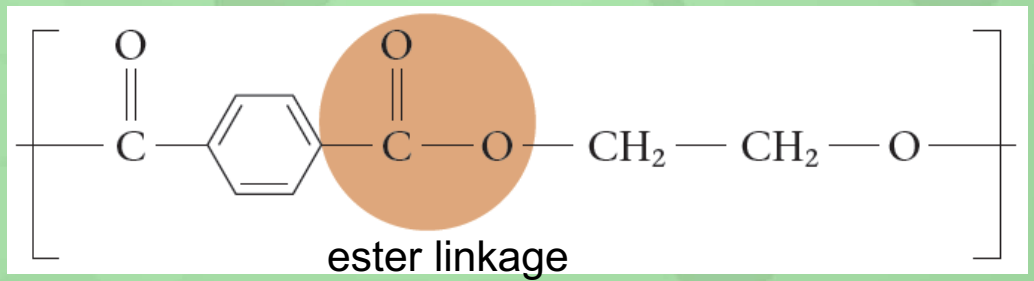
Summary (p.213)

6 A condensation polymer is formed when many monomer molecules join together via condensation reactions, with the elimination of simple molecules, such as water.

7 a) Polyesters contain the ester linkage  .

b) a dicarboxylic acid + a diol → a polyester

c) The repeating unit of poly(ethylene terephthalate) is shown below:



d) Polyesters undergo hydrolysis in acidic and alkaline conditions.

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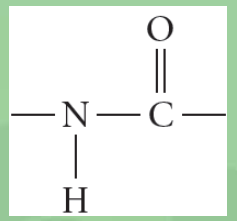
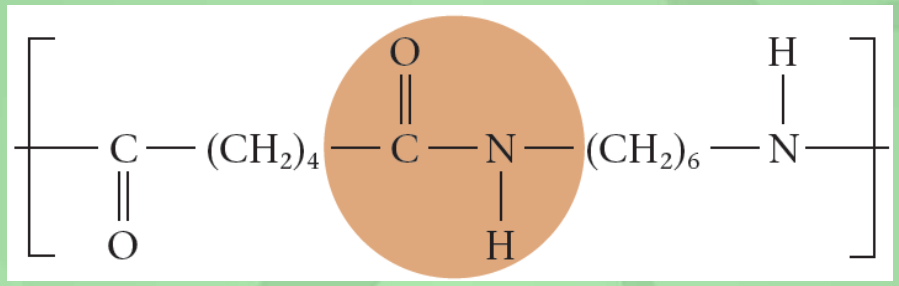
Summary (p.213)



8 a) Nylons are polyamides which contain the amide linkage .

b) a dicarboxylic acid + a diamine a polyamide

c) The repeating unit of nylon-6,6 is shown below:



amide linkage

d) Nylons have high strength due to the hydrogen bonds between the polymer chains.

e) Polyamides undergo hydrolysis in acidic and alkaline conditions.

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Unit Exercise (p.216)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 **question targeted at level 3 and above;**
 **question targeted at level 4 and above;**
 **question targeted at level 5.**
‘ * ’ indicates 1 mark is given for effective communication.

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Unit Exercise (p.216)

PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

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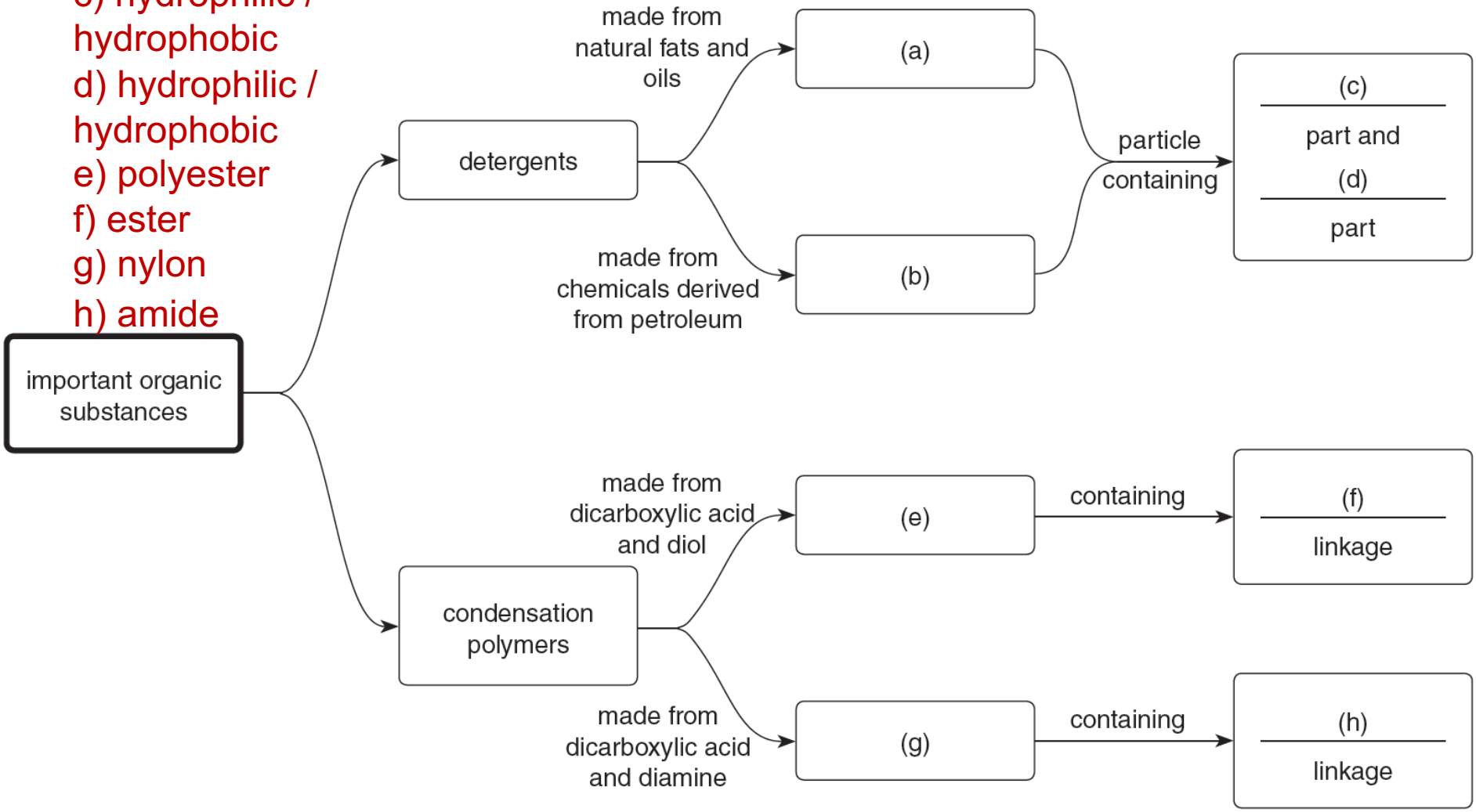
Unit Exercise (p.216)

a) soaps
b) soapless detergents
c) hydrophilic / hydrophobic
d) hydrophilic / hydrophobic
e) polyester
f) ester
g) nylon
h) amide



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Unit Exercise (p.216)

PART II MULTIPLE CHOICE QUESTIONS

2 The structure of a soap is shown below:

$CH_3(CH_2)_5COO^-Na^+$

Which of the following statements concerning this soap is correct?

A It can decrease the surface tension of water.
B It is manufactured from chemicals derived from petroleum.
C The hydrophilic part responsible for its cleansing action is Na^+.
D It has a good cleansing function in hard water.

Answer: A

Explanation:
Option B — Soap is manufactured from fats and oils.
Option C — The hydrophilic part responsible for the cleansing action of soap is –COO–.
Option D — Soap is not an effective cleansing agent in hard water.

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Unit Exercise (p.216)

3 Which of the following two compounds can react together to form a condensation polymer?

A C_2H_4 and C_3H_6
B C_2H_5OH and CH_3COOH
C $H_2N(CH_2)_6NH_2$ and CH_3COOH
D $H_2N(CH_2)_6NH_2$ and $HOOC(CH_2)_4COOH$

Answer: D

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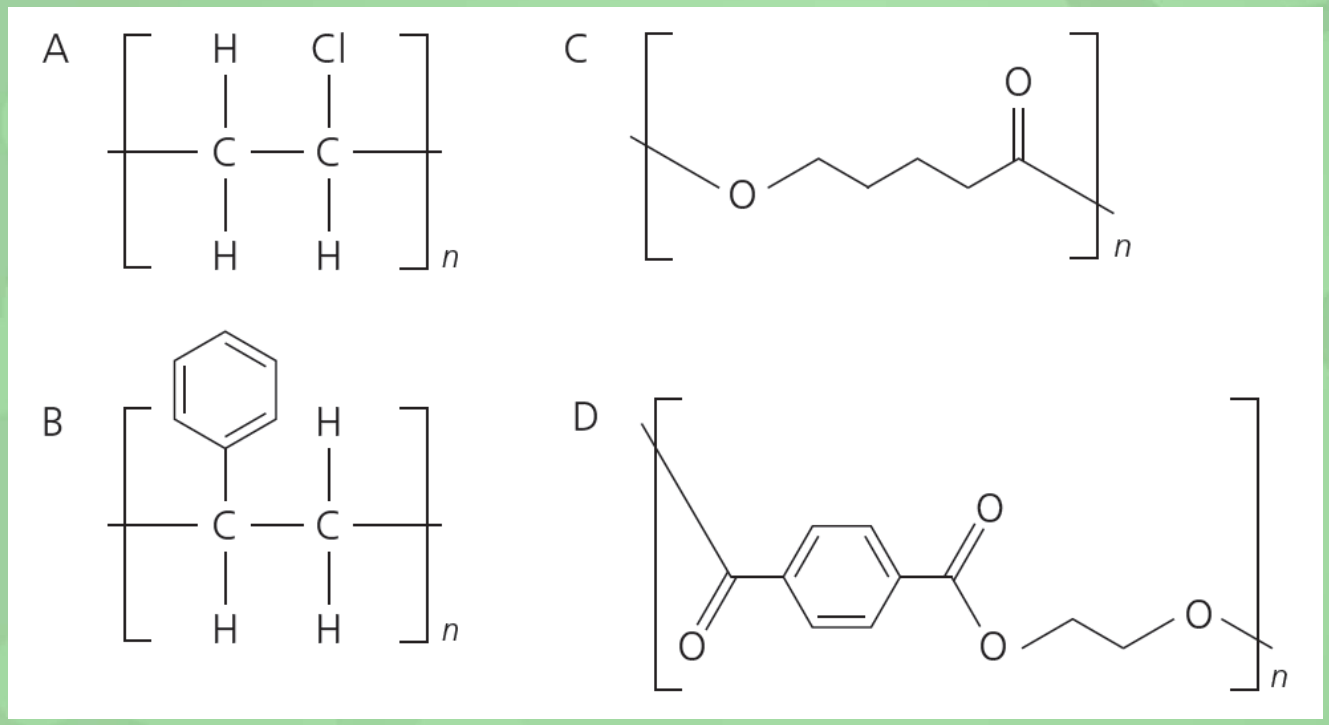
Unit Exercise (p.216)

4 Which of the following polymers is commonly used to make drainage pipes? *(HKDSE, Paper 1A, 2018, 27)*



Answer: A

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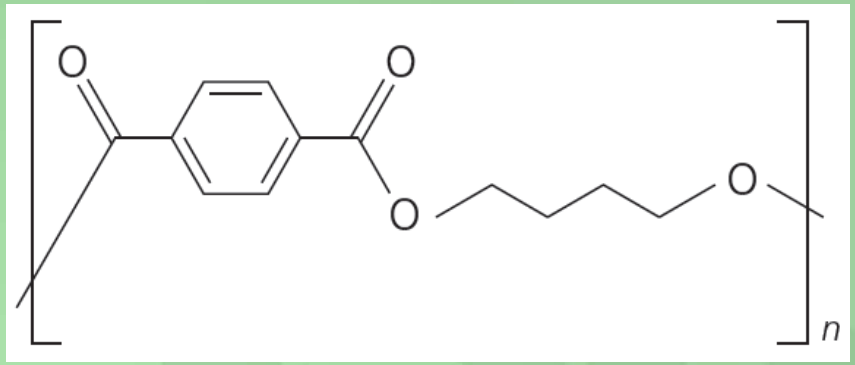
Unit Exercise (p.216)

5 A polymer has the structure shown:



Which of the following statements about the polymer is correct?

A Its intermolecular attraction is predominantly hydrogen bonding.
B The polymerisation in forming it is a hydrolysis process.
C Covalent bonds exist between its polymer chains.
D Its polymer chains can be broken in the presence of dilute sodium hydroxide solution.

Answer: D

Explanation:
The ester linkages are broken down by dilute NaOH(aq) via hydrolysis.

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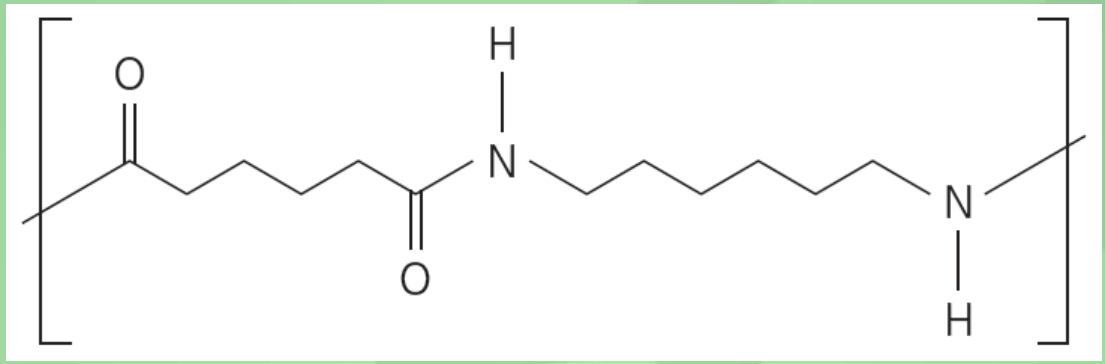
Unit Exercise (p.216)

6 The repeating unit of polymer X is shown below:



Answer: B

Which of the following statements concerning polymer X is INCORRECT?

A It is a condensation polymer.
B It is a polyamine.
C Hydrogen bonds exist between its polymer chains.
D It is hydrolysed by alkalis.

Explanation:
The polymer is a polyamide.

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Unit Exercise (p.216)

7 Which of the following alcohols is produced when olive oil is heated with concentrated sodium hydroxide solution?

A Propan-1-ol
B Propane-1,2-diol
C Propane-1,3-diol
D Propane-1,2,3-triol

Answer: D

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Unit Exercise (p.216)

8 In an experiment, a mixture of castor oil and excess concentrated sodium hydroxide solution is heated for some time. Then, a small amount of concentrated sodium chloride solution is added to the reaction mixture. A solid product is formed. Which of the following statements concerning this experiment are correct?

(1) This experiment involves hydrolysis.
(2) The solid formed is glycerol.
(3) The purpose of adding concentrated sodium chloride solution is to salt out the product formed.

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: B

Explanation:
(1) Castor oil is a mixture of triglycerides. Alkaline hydrolysis of triglycerides produces glycerol and soap.
(2) The solid formed is soap, salts of long-chain carboxylic acids.

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Unit Exercise (p.216)

Answer: D

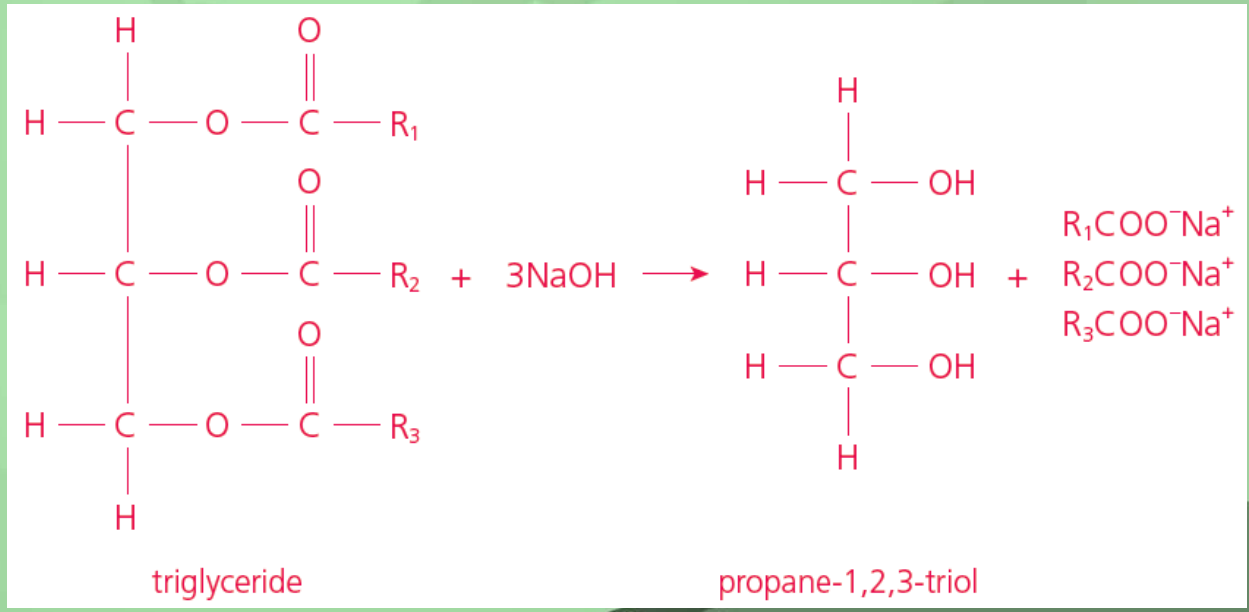
9 Which of the following could be produced by the alkaline hydrolysis of a triglyceride?

(1) $C_{17}H_{35}CH_2OH$
(2) $CH_2OHCH(OH)CH_2OH$
(3) $C_8H_{17}CH{=}CH(CH_2)_7COO^-Na^+$

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Explanation:

Alkaline hydrolysis of a triglyceride results in the production of propane-1,2,3-triol and salts of carboxylic acids of long hydrocarbon chains (saturated or unsaturated).



(1) $C_{17}H_{35}CH_2OH$ is NOT a possible product.

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Unit Exercise (p.216)

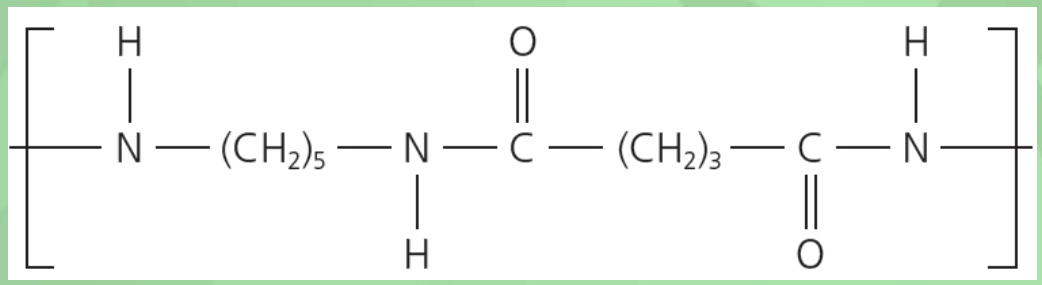
10 Amine X, $H_2N(CH_2)_5NH_2$, and acid Y, $HOOC(CH_2)_3COOH$, react to form polymer Z.

Which of the following statements is / are correct?

(1) The IUPAC name of X is pentane-1,5-diamine.

(2) Polymer Z is an addition polymer.

(3) The repeating unit of polymer Z is shown below:



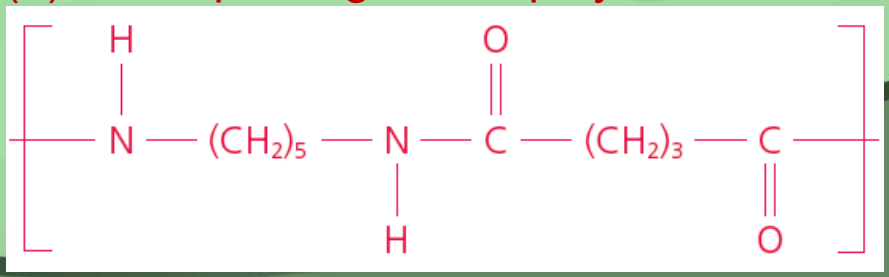
Answer: A

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Explanation:

(2) Polymer Z is a condensation polymer.

(3) The repeating unit of polymer Z is:



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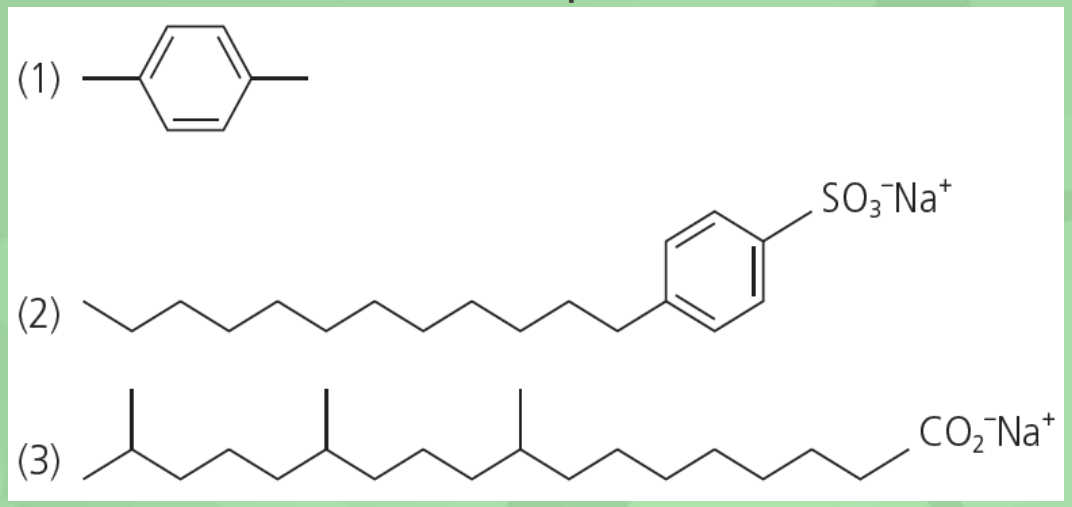
Unit Exercise (p.216)

11 The structures of three compounds are shown below:



Which of them can form a stable emulsion when shaken with oil and water vigorously?

Answer: C

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

(HKDSE, Paper 1A, 2017, 33)

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Unit Exercise (p.216)

12 Which of the following compounds CANNOT form condensation polymers?

(1) $H_2N(CH_2)_5CO_2H$
(2) $CH_3CO_2CH=CH_2$
(3) $CH_3CH(OH)CO_2H$

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: B

(HKDSE, Paper 1A, 2018, 31)

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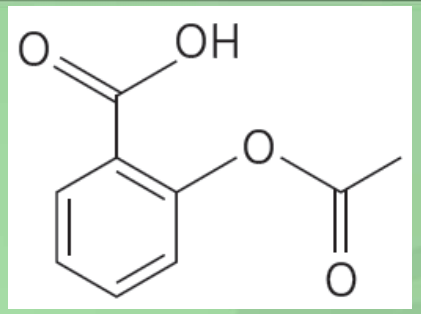
Unit Exercise (p.216)



PART III STRUCTURED QUESTIONS

13 Aspirin is a pain-killer. Its structure is shown:

a) State one medical application of aspirin other than pain-killing.

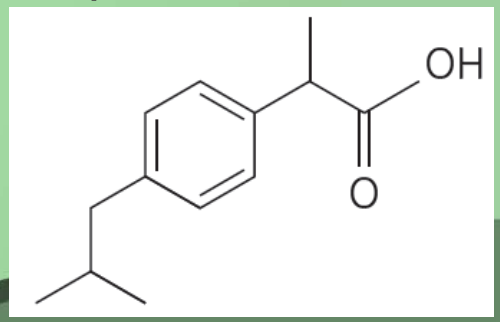
b) Explain why a suspension of aspirin and water can become clear when sodium hydrogencarbonate powder is added.

c) Heating aspirin with excess dilute aqueous acid under reflux will give two organic products.

i) Draw the structures of these two organic products.

ii) Explain why the conversion of aspirin to these two organic products can hardly reach 100% even though the mixture of aspirin and dilute acid is heated under reflux for a long time.

d) Ibuprofen is also a pain-killer. Its structure is shown:



There exists enantiomerism in ibuprofen.

Draw the three-dimensional structures for the pair of enantiomers. *(HKDSE, Paper 1B, 2018, 12)*

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

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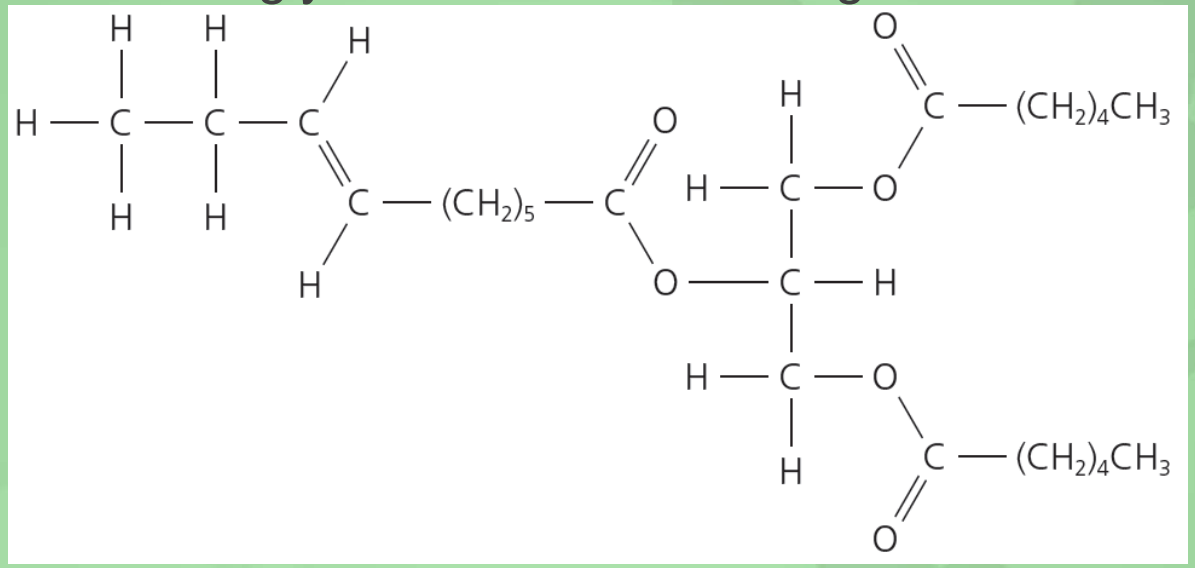
Unit Exercise (p.216)

14 Triglycerides are triesters and are found in fats and oils.
The structure of a triglyceride found in some goats' milk is shown below.



This triglyceride is hydrolysed with hot aqueous sodium hydroxide.

a) Give the systematic name of the alcohol that is formed by this hydrolysis. Propane-1,2,3-triol (1)

b) Draw the structures of the other organic products of this hydrolysis.

(OCR A2 GCE, Chem. A, F324, Jun. 2013, 1(a))

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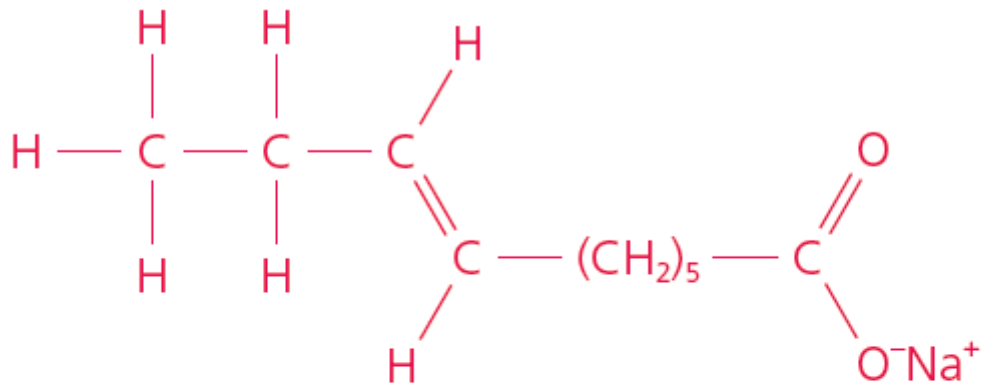
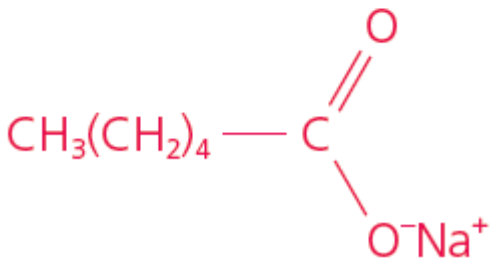
Unit Exercise (p.216)

b)



(1)



(1)

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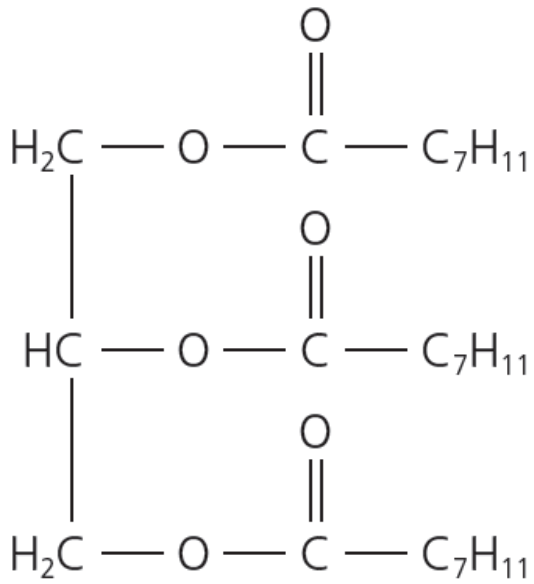
Unit Exercise (p.216)

15 The equation below shows an example of reactions used to make esters from vegetable oils. These esters are suitable for use as biofuels, such as biodiesel.



ester X

$$+ \ 3CH_3CH_2OH \longrightarrow 3C_7H_{11}COOCH_2CH_3 + \text{compound Z}$$

ester Y

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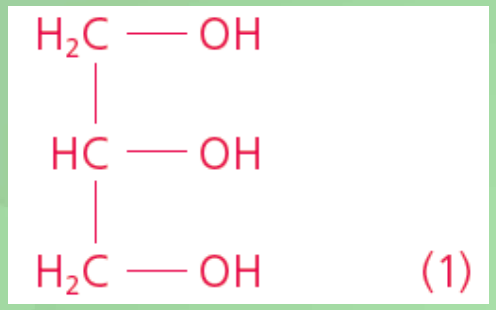
Unit Exercise (p.216)

a) Give the structural formula and systematic name of compound Z.



(1)

propane-1,2,3-triol (1)

b) Ester Y is unsaturated. Give the number of carbon-carbon double bonds in the C_7H_{11} group. 2 (1)

c) Ester Y is more suitable as 'biodiesel' than ester X as it has a lower boiling point. Justify the statement.

Ester Y has a small molecule and hence (1)
weak van der Waals' forces between its molecules. (1)

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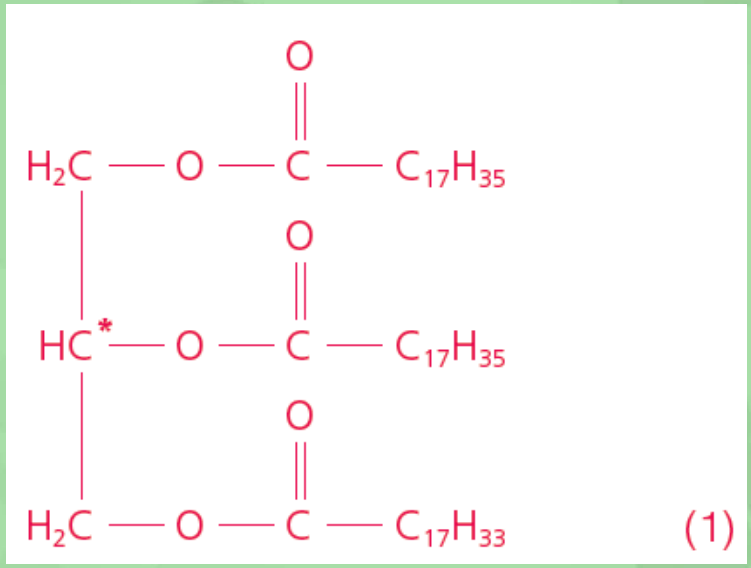
Unit Exercise (p.216)

16 The hydrolysis of 1 mole of a triglyceride gave 1 mole of oleic acid ($C_{17}H_{33}COOH$) and 2 moles of stearic acid ($C_{17}H_{35}COOH$) together with propane-1,2,3-triol. The triglyceride is optically active.

a) Draw the structure of the triglyceride. Label the chiral centre by using '*'.



(1)

b) Explain how this triglyceride can be hydrogenated.

Hydrogen gas
passes over the triglyceride, 180 °C
nickel catalyst (1)

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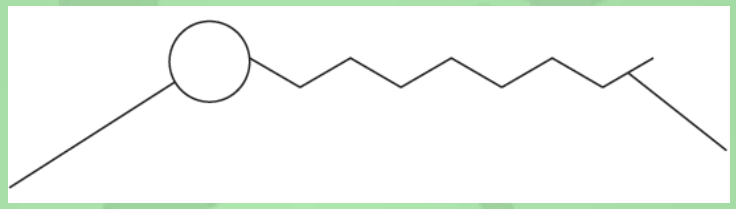
Unit Exercise (p.216)

17 This question is about emulsifiers and cooking.

Mayonnaise is a mixture of an emulsifier, an oil and water.
The emulsifier helps to stop the oil and water from separating.
Look at the structure of an emulsifier molecule.

hydrophilic (1) head  hydrophobic (1) tail

a) Label the two parts of the emulsifier molecule.

b) Explain how an emulsifier helps to stop oil and water from separating.

(OCR GCSE Gateway Science, Chem. B, B741, Jun. 2014, 2(a))

The hydrophobic tail is soluble in oil. (1)
The hydrophilic head is soluble in water. (1)

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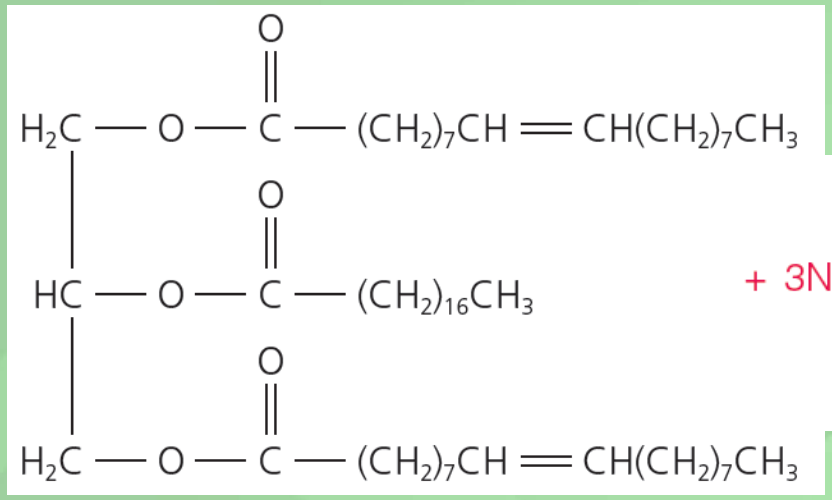
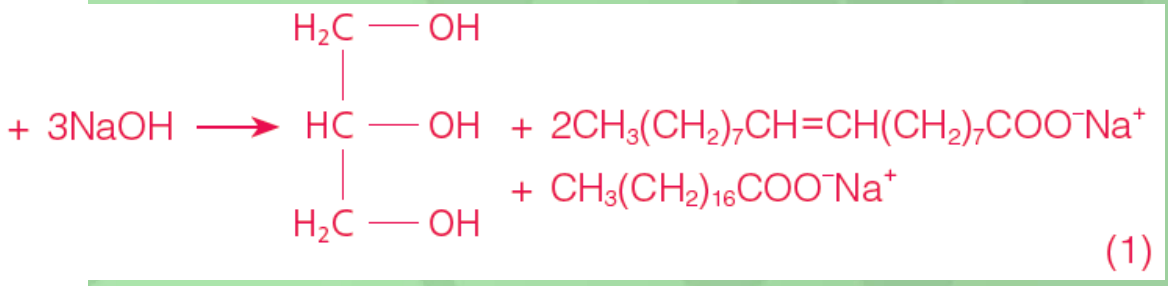
Unit Exercise (p.216)

18 The structure of a triglyceride found in olive oil is shown:





a) Olive oil can be used to make soap by heating with concentrated sodium hydroxide solution.

i) Name the type of reaction involved. Saponification / alkaline hydrolysis (1)

ii) Write the chemical equation involved for the formation of soap from olive oil.

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Unit Exercise (p.216)

*b) Explain the cleansing property of the soap formed from olive oil.

When a soap solution is added to a piece of fabric with grease and dirt, the hydrocarbon 'tails' of the soap molecules dissolve in the grease, leaving the anionic 'heads' sticking out. (1)

The surrounding water molecules attract the anionic 'heads' and lift the grease off the surface. (1)

The grease breaks up into tiny droplets when stirred. These tiny droplets cannot come together again due to the repulsion between the anionic 'heads' of the soap molecules. (1)

Rinsing washes away the tiny droplets and leaves the fabric clean. (1)

Communication mark (1)

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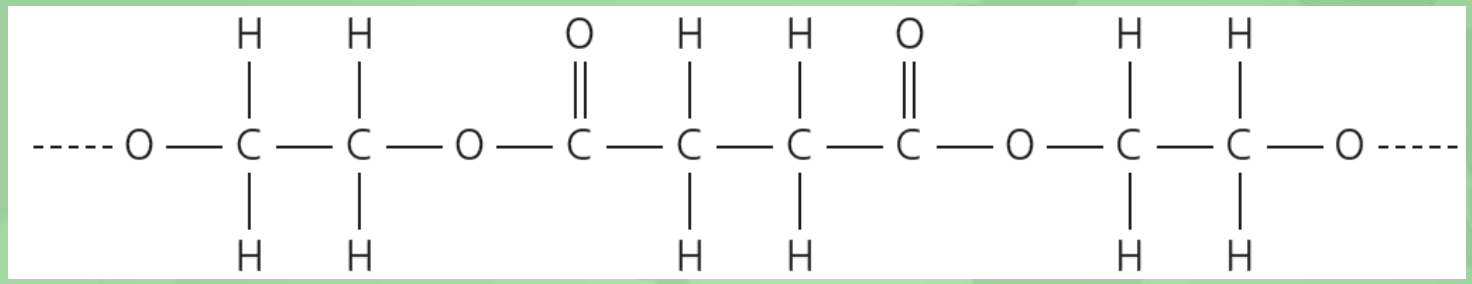
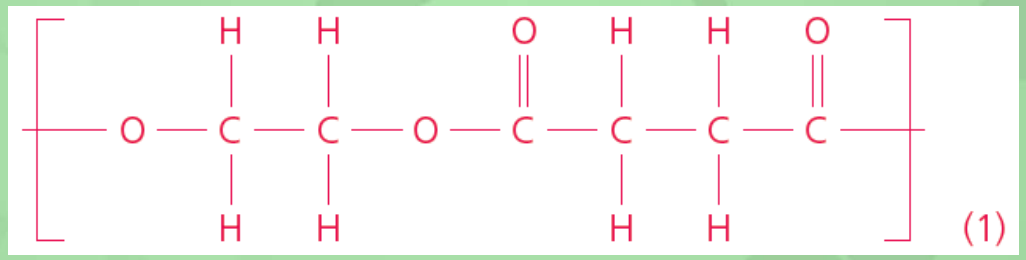
Unit Exercise (p.216)

19 A section of a condensation polymer is shown below:

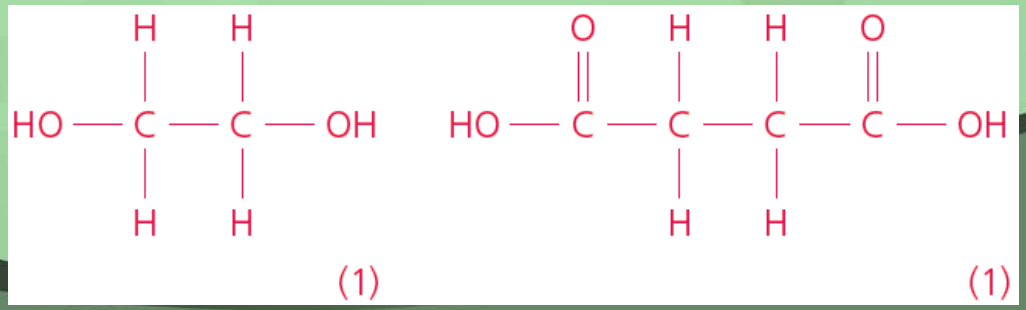


a) Identify the functional group in this polymer. Ester linkage (1)

b) Draw the repeating unit of the polymer.



c) Write the structural formulae of monomers for the polymer.



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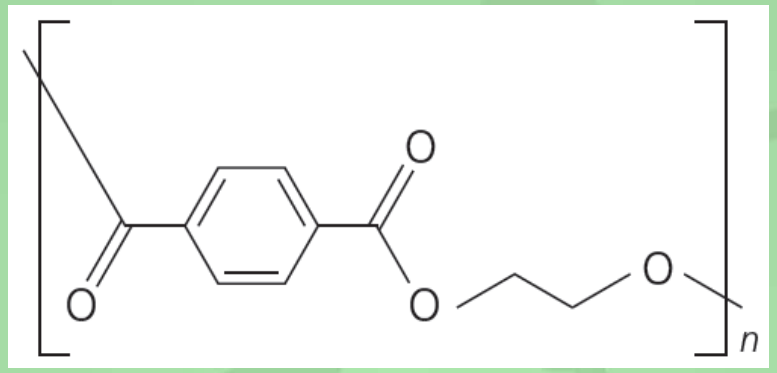
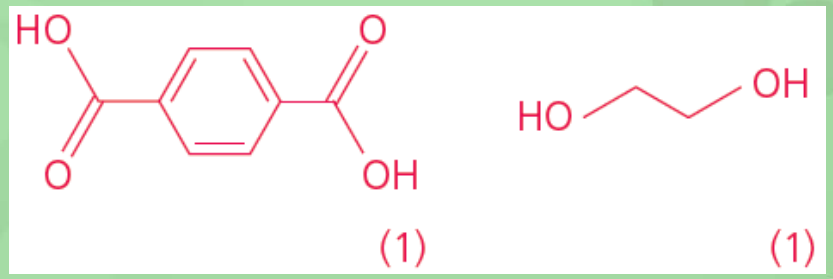
Unit Exercise (p.216)

20 Poly(ethylene terephthalate) (PET) is a synthetic polymer that can be used to make bottles for carbonated drinks. PET has the structure shown below:



a) Identify the functional group in this polymer. Ester linkage (1)

b) Write the structural formulae of two monomers that can be polymerised to PET.



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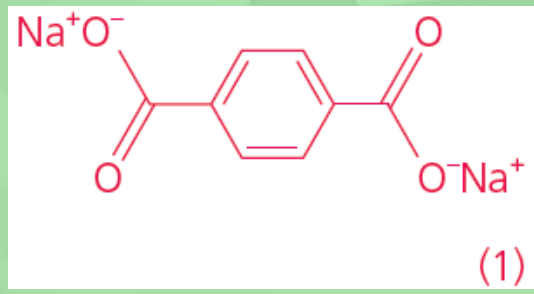
Unit Exercise (p.216)

c) PET bottles CANNOT be used to store drain cleansers containing concentrated sodium hydroxide solution because PET reacts with strong alkalis.

i) What is the reaction involved? Alkaline hydrolysis (1)

ii) Write the structural formula of ONE of the products of the reaction.



(1)

or

(1)

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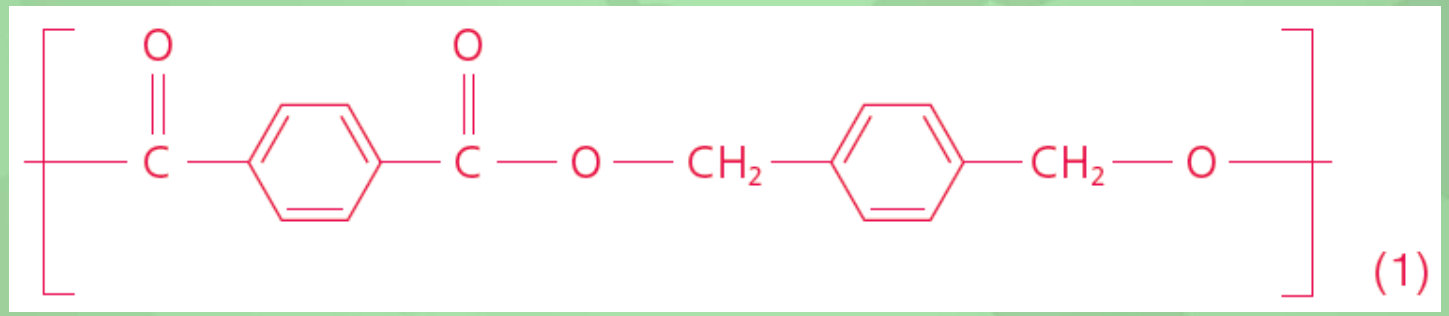
Unit Exercise (p.216)

21 The polymer Kodel is made using the two monomers shown below.

a) Draw the repeating unit of Kodel.



b) What small molecule would be eliminated during the formation of Kodel?

H_2O (1)

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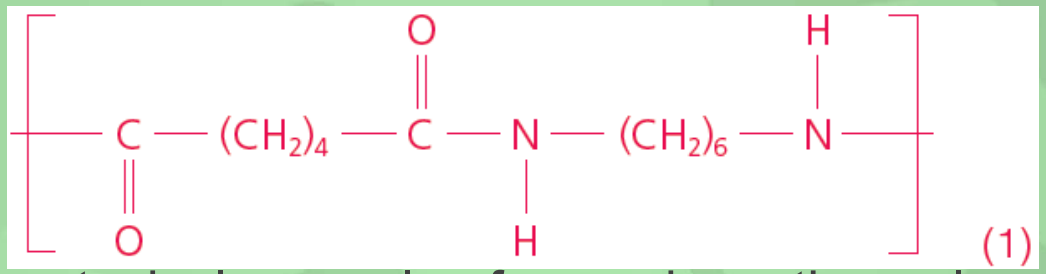
Unit Exercise (p.216)

22 Nylon-6,6 is made from hexanedioic acid and another compound.

a) State the name of a compound that can react with hexanedioic acid to form nylon-6,6. Hexane-1,6-diamine (1)

b) Draw the repeating unit of nylon-6,6.



(1)

c) Nylon-6,6 is a typical example of a condensation polymer. Explain the meaning of the term 'condensation polymer'.

A condensation polymer is formed when many monomer molecules join together via condensation reactions, with the elimination of simple molecules, such as water.

d) State TWO major uses of nylon-6,6.

Any two of the following:

- Making climbing ropes (1)
- Making fishing lines (1)
- Making clothes (1)

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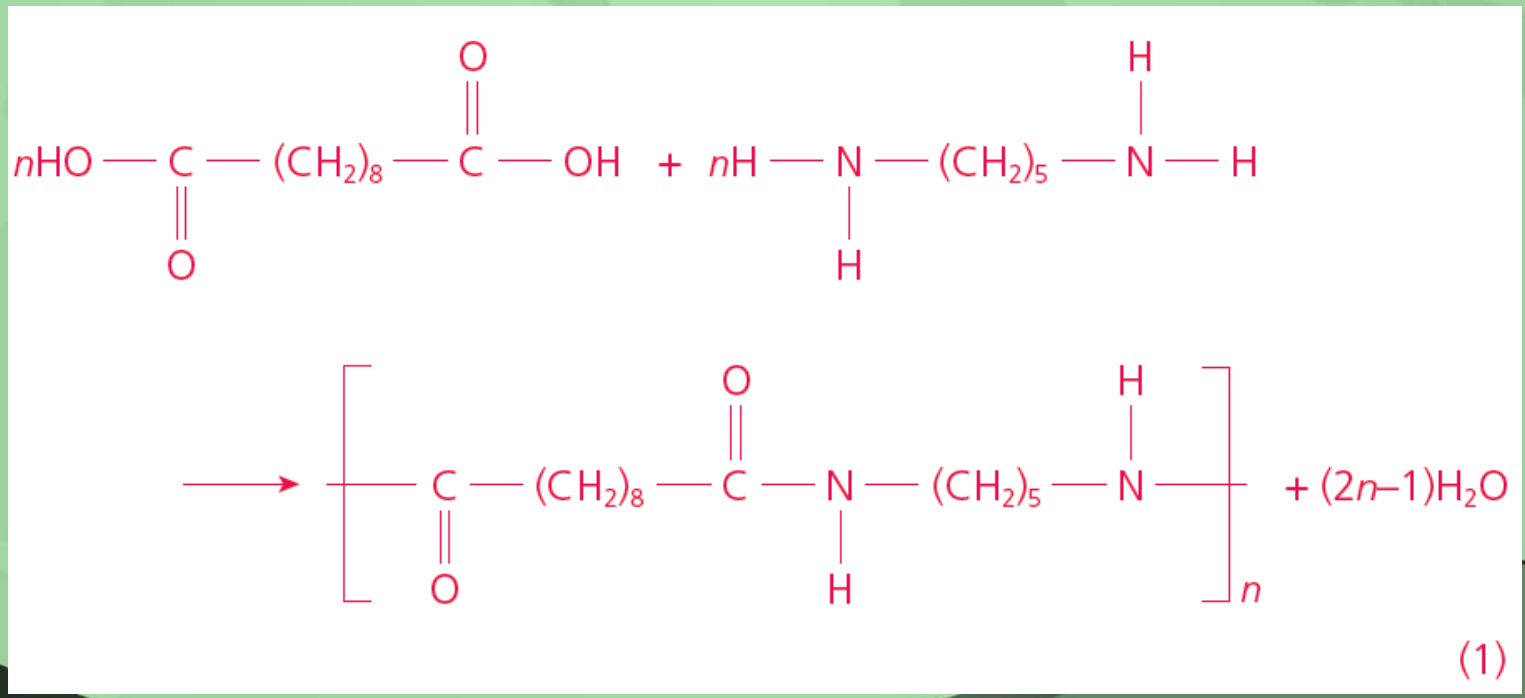
Unit Exercise (p.216)

23 Nylon-5,10 can be formed by the reaction of a diamine ($H_2N(CH_2)_5NH_2$) with a dicarboxylic acid.

a) Write the structural formula of the dicarboxylic acid used to form nylon-5,10. $HOOC(CH_2)_8COOH$ (1)

b) Write the chemical equation for the formation of nylon-5,10.



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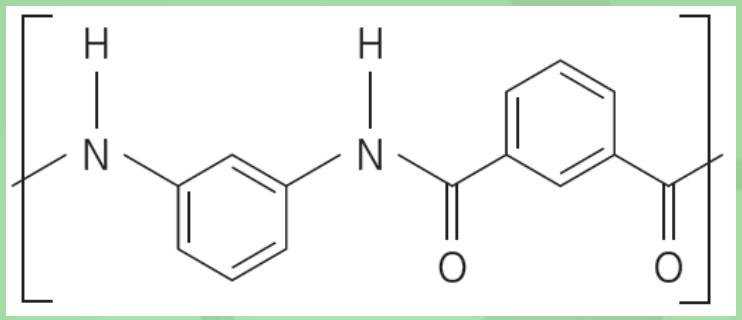
Unit Exercise (p.216)

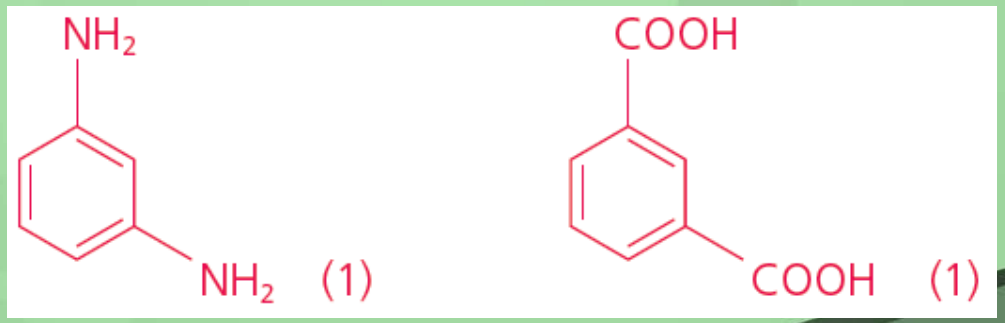
24 The repeating unit of a polymer Nomex is shown below:



a) Name the functional group made during the formation of Nomex.

Amide linkage (1)

b) Draw the structures of the two monomers needed to make Nomex.



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Topic Exercise (p.224)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

 **question targeted at level 3 and above;**
 **question targeted at level 4 and above;**
 **question targeted at level 5.**
‘ * ’ indicates 1 mark is given for effective communication.

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Topic Exercise (p.224)

PART I MULTIPLE CHOICE QUESTIONS

1 Chemists use knowledge of forces between molecules and ions to explain why different substances are soluble in water.
Which of the following statements is correct?

A Pentane is insoluble in water because pentane molecules are non-polar and do NOT form hydrogen bonds with water molecules.
B Propanone is soluble in water even though water molecules do NOT form hydrogen bonds with propanone molecules.
C Sodium chloride is soluble in water because water molecules are polar and form hydrogen bonds with Na^+ ions and Cl^- ions.
D Carbon dioxide is insoluble in water because it is non-polar and does NOT form hydrogen bonds with water.

(OCR Advanced Level, Chem. B (Salters), H433, Sample Question Paper, 25)

Answer: A

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Topic Exercise (p.224)

2 How many stereoisomers of $CH_3CH=CHCH(OH)CH_2CH=CH_2$ are there?

chiral centre

A 2
B 4
C 6
D 8

Answer: B

(OCR Advanced Level, Chem. A, H432, Sample Question Paper, 3)

Explanation:
The compound has two *cis-trans* isomers due to the left C=C bond.
The compound has a chiral centre. It has two enantiomers.

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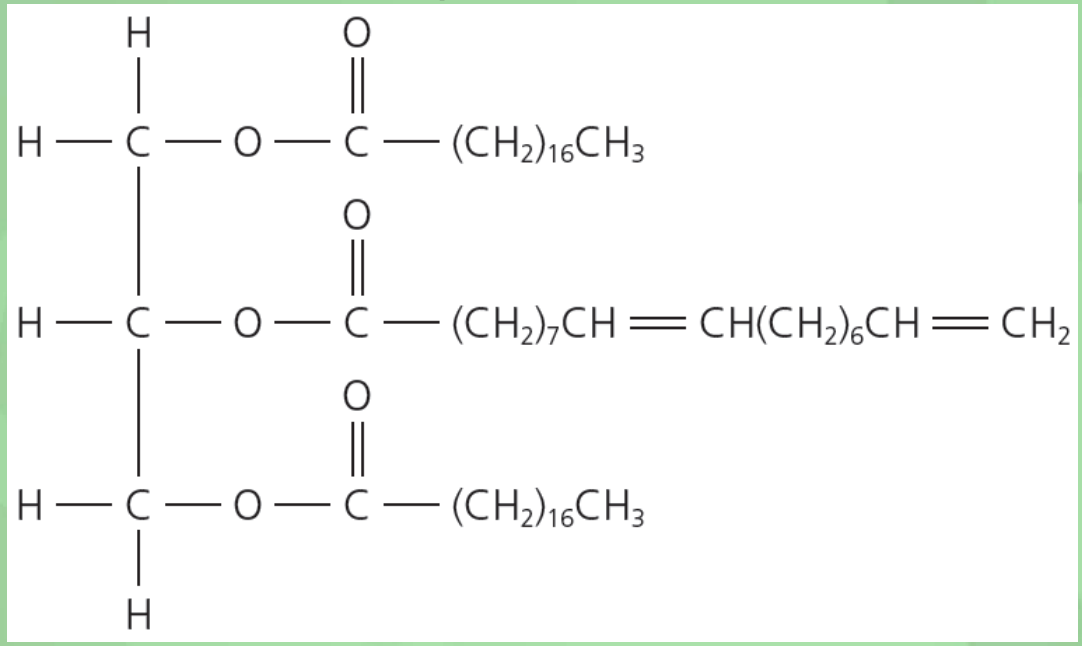
Topic Exercise (p.224)

3 The structure of a compound is shown below:



How many *cis-trans* isomers does this compound have?

A 0
B 2
C 4
D 8

Answer: B

(HKDSE, Paper 1A, 2017, 26)

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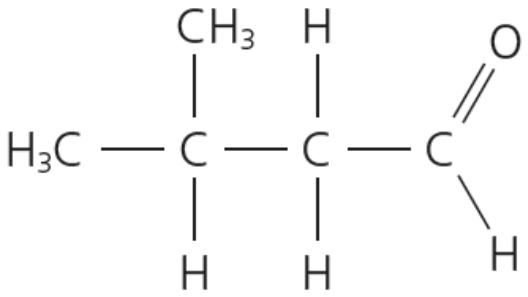
Topic Exercise (p.224)

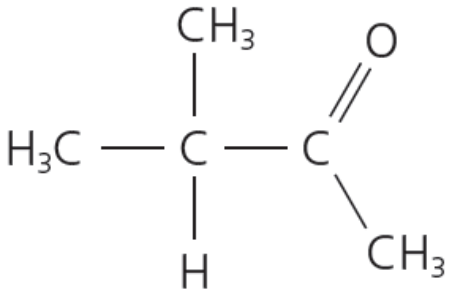
4 Which of the following compounds is chiral?

Answer: D

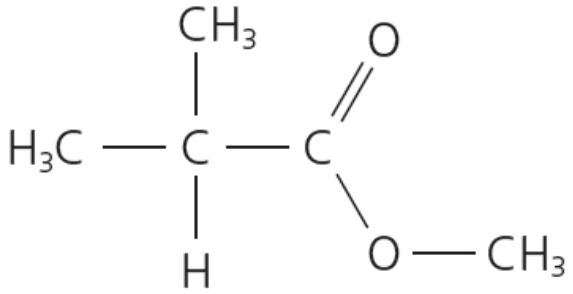
A



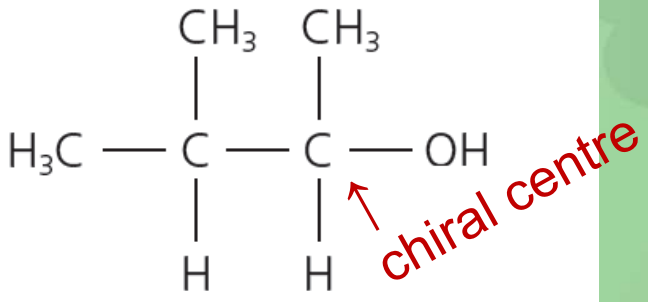
B



C



D



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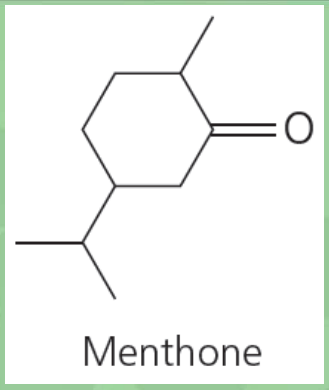
Topic Exercise (p.224)



Menthone

5 Carbonyl compounds have distinctive smells.
Menthone smells of peppermint.

Menthone reacts in a two-step synthesis shown below.
Step 1 A sample of menthone is added to hot acidified aqueous dichromate ions.
Step 2 The resulting mixture from *Step 1* is added to $NaBH_4$ in water.
What happens to the smell of the reaction mixture during the process?

Answer: A

	Step 1	*Step 2*
A	Smell of peppermint remains	Smell of peppermint is lost
B	Smell of peppermint is lost	Smell of peppermint returns
C	Smell of peppermint remains	Smell of peppermint remains
D	Smell of peppermint is lost	Smell of peppermint does NOT return

(OCR Advanced Level, Chem. A, H432, Sample Question Paper, 13)

Explanation:
Step 1 Menthone CANNOT be oxidised by hot acidified aqueous dichromate ions. Hence the smell of peppermint remains.
Step 2 Menthone is reduced by $NaBH_4$ in water. Hence the smell of peppermint is lost.

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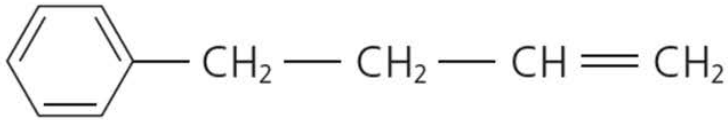
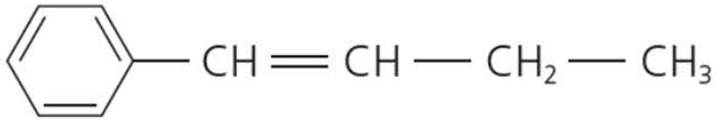
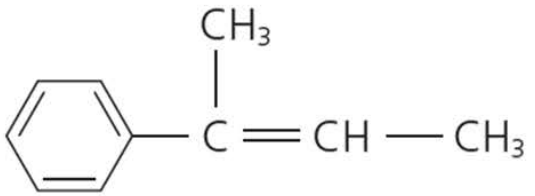
Topic Exercise (p.224)

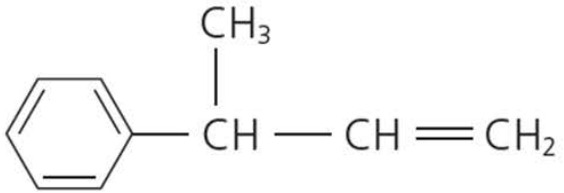
Answer: C

6 Alcohol X (molecular formula $C_{10}H_{14}O$) is resistant to oxidation by acidified potassium dichromate solution.
What is the structure of the compound formed by dehydration of X?

A 

B 

C 

D 

X is a tertiary alcohol.

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Topic Exercise (p.224)

Answer: C

7 The molecular formula of compound X is $C_4H_4O_4$. It has two –COOH groups. How many isomers may X have?

A 5
B 4
C 3
D 2

(HKDSE, Paper 1A, 2016, 29)

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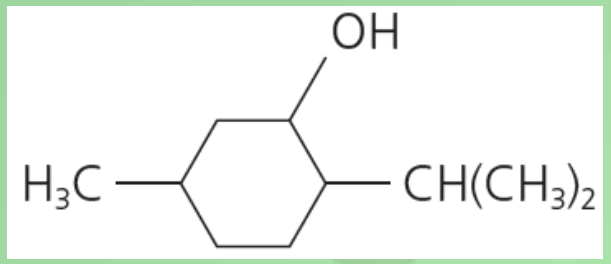
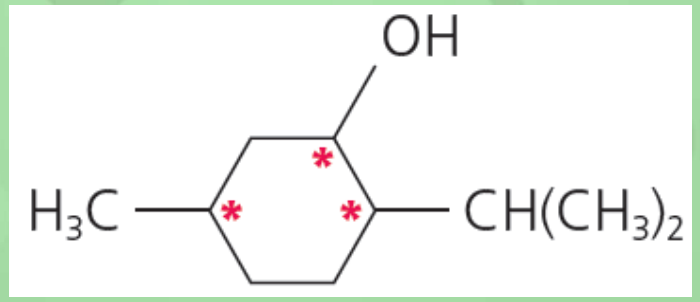
Topic Exercise (p.224)

8 How many chiral centres does menthol have?



A 1
B 2
C 3
D 4

Answer: C



* = chiral centre

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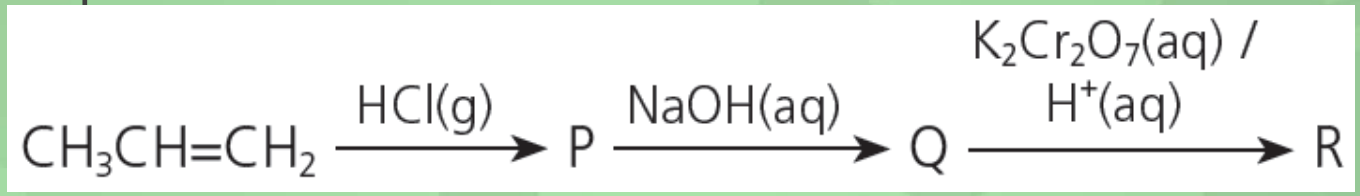
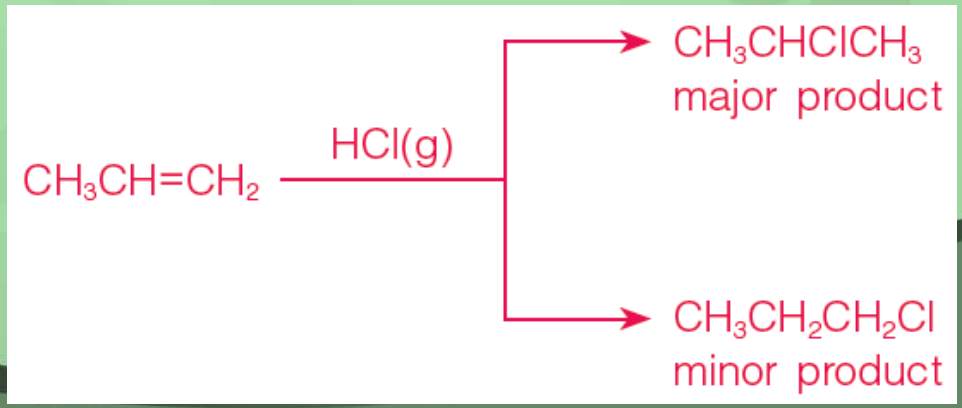
Topic Exercise (p.224)

9 Consider the following organic reactions where P, Q and R are the major organic products formed.



Which of the following combinations is correct?

	P	Q	R
A	$CH_3CHClCH_3$	$CH_3CH(OH)CH_3$	CH_3COCH_3
B	$CH_3CHClCH_3$	$CH_3CH_2CH_2OH$	CH_3CH_2COOH
C	$CH_3CH_2CH_2Cl$	$CH_3CH_2CH_2OH$	CH_3COCH_3
D	$CH_3CH_2CH_2Cl$	$CH_3CH(OH)CH_3$	CH_3CH_2COOH



Answer: A

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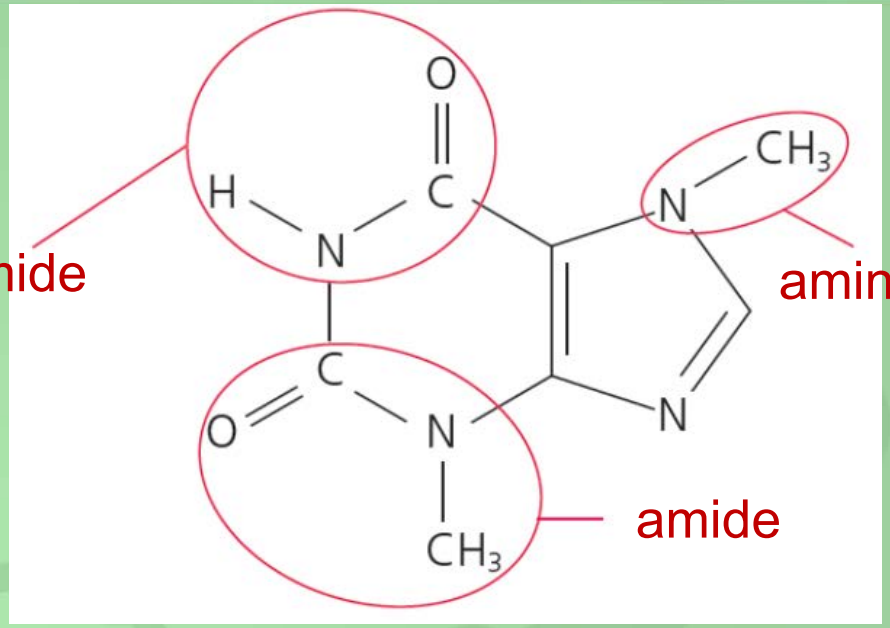
Topic Exercise (p.224)

10 The compound shown below is found in cocoa beans and in chocolate.



Which of the following functional groups are present in the compound?

(1) Amide functional group
(2) Amine functional group
(3) Ester group

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: A

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Topic Exercise (p.224)

11 Which of the following statements concerning aspirin is / are correct?

(1) It undergoes esterification with ethanoic acid in the presence of an acid catalyst.

(2) It reacts with sodium carbonate solution to give a colourless gas.

(3) It can be used to reduce inflammation.

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: D

(HKDSE, Paper 1A, 2014, 32)

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Topic Exercise (p.224)

12 Which of the following statements concerning soap are correct?

(1) Soap is an ester.
(2) Soap can reduce the surface tension of water.
(3) Soap particles consist of both hydrophobic and hydrophilic parts.

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: C

(HKDSE, Paper 1A, 2018, 34)

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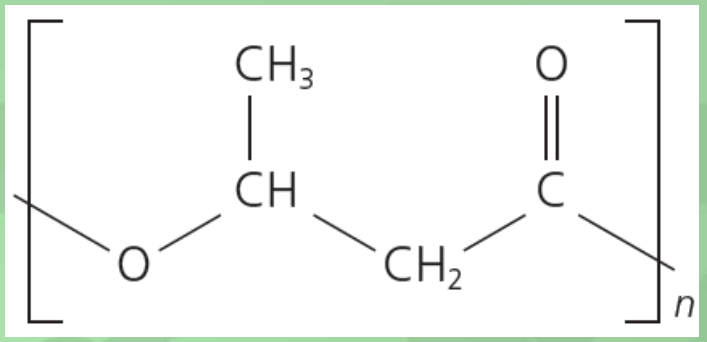
Topic Exercise (p.224)

13 A polymer has the structure shown:



Which of the following statements concerning the polymer is correct?

(1) Its intermolecular attraction is predominantly hydrogen bond.
(2) The polymer chains can be broken in the presence of dilute hydrochloric acid.
(3) The polymer chains can be broken in the presence of dilute sodium hydroxide solution.

A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Answer: C

(HKDSE, Paper 1A, 2015, 34)

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Topic Exercise (p.224)

Directions : Each question (Questions 14–16) consists of two separate statements. Decide whether each of the two statements is true or false; if both are true, then decide whether or not the second statement is a correct explanation of the first statement. Then select one option from A to D according to the following table :

A Both statements are true and the 2nd statement is a correct explanation of the 1st statement.

B Both statements are true but the 2nd statement is NOT a correct explanation of the 1st statement.

C The 1st statement is false but the 2nd statement is true.

D Both statements are false.

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Topic Exercise (p.224)

	1st statement	2nd statement	
14	Ethene exhibits *cis-trans* isomerism.	There is free rotation about the C=C bond.	Answer: D
15	Propan-2-ol is optically active.	Propan-2-ol contains a chiral centre.	Answer: D
	Propan-2-ol does NOT contain a chiral centre.		
16	Both $CH_3(CH_2)_3OH$ and $(CH_3)_3COH$ can react with acidified $K_2Cr_2O_7(aq)$.	Both $CH_3(CH_2)_3OH$ and $(CH_3)_3COH$ have the same functional group. *(HKDSE, Paper 1A, 2017, 36)*	Answer: C

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Topic Exercise (p.224)

PART II STRUCTURED QUESTIONS

17 Explain why ethanedioic acid is more soluble in water than ethanoic acid.

Ethanedioic acid has two carboxyl groups in its structure, so it forms more hydrogen bonds with water than ethanoic acid does. (1)

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Topic Exercise (p.224)

18 The alcohols are an example of a homologous series. The table below shows the boiling points of the first four members of straight-chain alcohols.

Alcohol	Boiling point (°C)
Methanol	65
Ethanol	78
Propan-1-ol	97
Butan-1-ol	118

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Topic Exercise (p.224)

a) Explain the trend in boiling points of alcohols as the number of carbon atoms per molecule increases.

The boiling points of alcohols increase with the number of carbon atoms per molecule.

All the alcohols have molecules bearing one –OH group that can take part in hydrogen bonding. Hydrogen bonds in the alcohols are of comparable strength. (1)

The differences in boiling points are due to the difference in strength of van der Waals' forces among the alcohols.

The larger a molecule, the stronger are the van der Waals' forces between molecules. Thus, the van der Waals' forces increase with the number of carbon atoms per molecule. (1)

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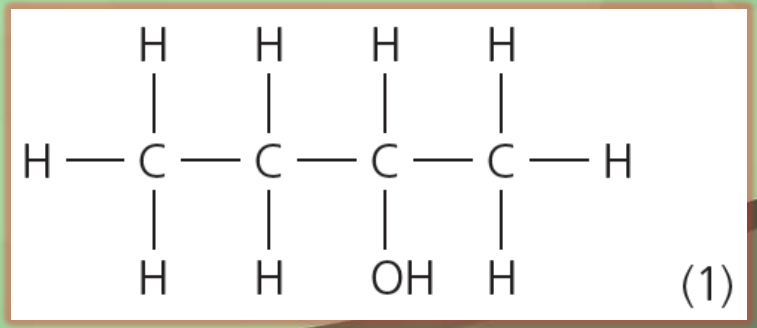
Topic Exercise (p.224)

b) At room temperature, the first four members of the alcohol homologous series are liquids whereas the first four members of the alkane homologous series are gases. Explain this difference.

Alcohols have both hydrogen bonds and van der Waals' forces between their molecules.
Alkanes have only van der Waals' forces between their molecules. (1)

Hydrogen bonds are stronger than van der van der Waals' forces. As a result, the boiling points of alcohols are higher than those corresponding alkanes (i.e. those with the same number of carbon atoms per molecule). (1)

c) Write the structural formula of the position isomer of butan-1-ol.



(1)

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Topic Exercise (p.224)

d) Butan-1-ol can be converted to 1-bromobutane in a one-step reaction.

$CH_3CH_2CH_2CH_2OH \rightarrow CH_3CH_2CH_2CH_2Br$

i) Give the reagent(s) and reaction condition(s) required for this reaction.

Any one of the following:
- NaBr and concentrated H_2SO_4, heat under reflux (1)
- red P and Br_2, heat under reflux (1)

ii) Explain why butan-1-ol is soluble in water while 1-bromobutane is NOT.

1-bromobutane cannot form hydrogen bonds.
Butan-1-ol can form hydrogen bonds due to its –OH group. (1)
Hydrogen bonds between butan-1-ol molecules and water molecules allow butan-1-ol to dissolve.

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Topic Exercise (p.224)

19 The structural formulae of three isomers with the molecular formula $C_5H_{10}O$ are shown: Isomer X $CH_3CH{=}CHCH(OH)CH_3$

Isomer Y $CH_3CH_2CH_2CH_2CHO$

Isomer Z $CH_3CH_2CH_2COCH_3$

a) Give the systematic name of isomer X. Pent-3-en-2-ol (1)

b) State the type of structural isomerism shown by these three isomers.
Functional group isomerism (1)

c) Isomer X exists as *cis-trans* isomers.

i) Give TWO reasons why isomer X exists as *cis-trans* isomers.

- It contains a carbon-carbon double bond.There is restricted rotation of atoms or groups around the carbon-carbon double bond. (1)
- There are two different atoms or groups on each carbon atom of the carbon-carbon double bond. (1)

ii) Draw the structures of the two forms of isomer X.

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Topic Exercise (p.224)

d) Suggest a chemical test to show how isomers Y and Z can be distinguished.

Any one of the following:

- Warm each isomer with acidified $K_2Cr_2O_7(aq)$ separately. (1)
  Y turns the dichromate solution from orange to green.
  There is no observable change for Z. (1)
- Warm each isomer with acidified $KMnO_4(aq)$ separately. (1)
  Y turns the permanganate solution from purple to colourless.
  There is no observable change for Z. (1)

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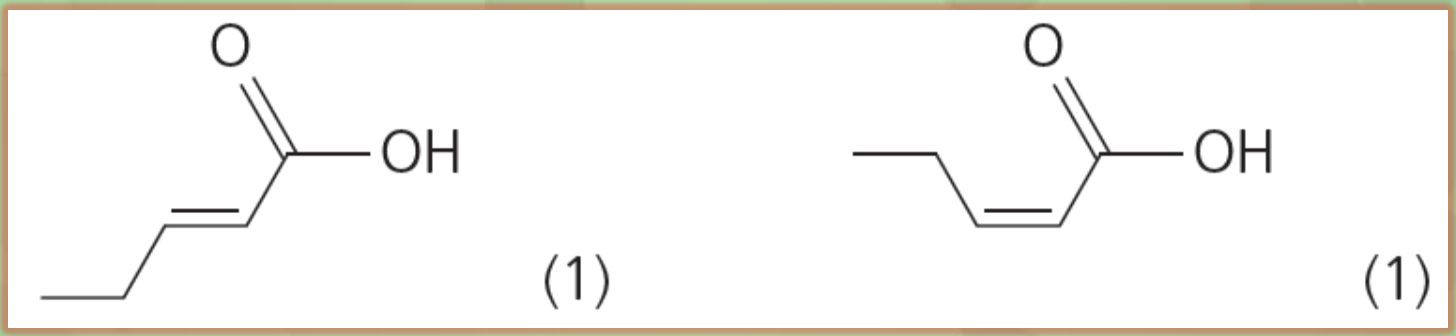
Topic Exercise (p.224)

20 Pentenoic acid (C_4H_7COOH) has some isomers that can show *cis-trans* isomerism and others that cannot.

a) Give the skeletal formulae for the *cis* and *trans* isomers of this compound.



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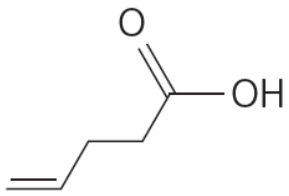
Topic Exercise (p.224)

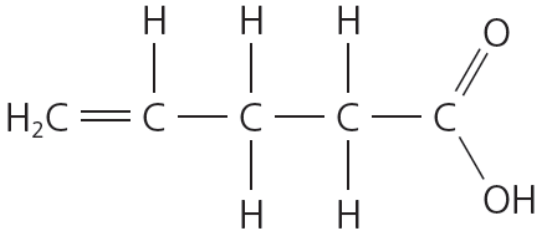
b) Give the structural formula of an isomer of pentenoic acid that CANNOT show *cis-trans* isomerism and explain why it CANNOT.

Any one of the following:

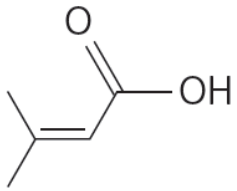


(1)

or

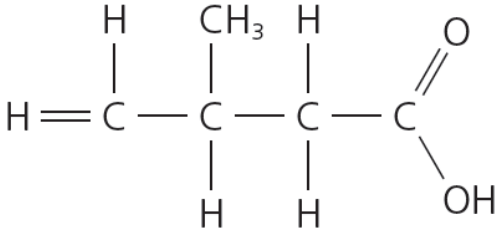


(1)



(1)

or



(1)

This isomer CANNOT show *cis-trans* isomerism as one carbon atom of the carbon-carbon double bond has two hydrogen atoms / methyl groups attached. (1)

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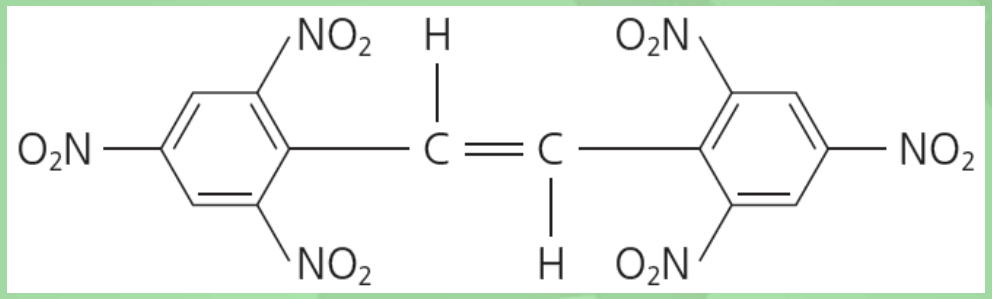
Topic Exercise (p.224)

21 The explosive hexanitrostilbene (HNS) has been used to separate different sections in space rockets.



a) HNS is the *trans* isomer of a pair of *cis-trans* isomers.
Explain why HNS can exhibit *cis-trans* isomerism.

- It contains a carbon-carbon double bond. There is restricted rotation of atoms or groups around the carbon-carbon double bond. (1)
- There are two different atoms or groups on each carbon atom of the carbon-carbon double bond. (1)

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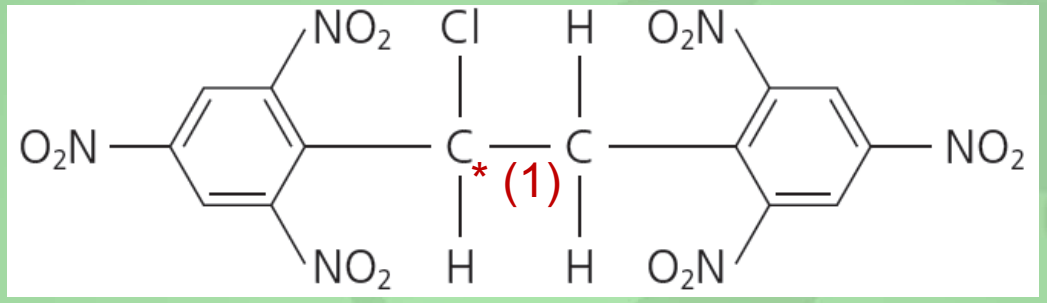
Topic Exercise (p.224)

b) The manufacture of HNS is believed to proceed via compound X shown below.



i) Compound X contains a chiral centre. Identify the chiral centre by using '*'.

ii) Compound X exists as two enantiomers.

(I) Explain what is meant by the term 'enantiomers'.

Two molecules that are non-superposable mirror images of each other are called enantiomers. (1)

(II) How do the enantiomers affect plane-polarised light?

They rotate the plane of polarisation of plane-polarised light by the same amount but in opposite directions, one clockwise and the other anticlockwise. (1)

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Topic Exercise (p.224)

*22 Compounds A, B and C all have the molecular formula C_5H_{10}.

A and B decolourise aqueous bromine but C does not.
B exists as two stereoisomers but A does not show stereoisomerism.
Use this information to deduce a possible structure for each of compounds A, B and C and explain your deductions.
State the meaning of the term stereoisomers and explain how they arise in compound B.

(AQA Advanced Subsidiary, Paper 2, Jun. 2017, 3)

A and B are unsaturated compounds as they decolourise aqueous bromine.
C is a saturated compound as it does not decolourise aqueous bromine. (1)

A may be any one of the following:

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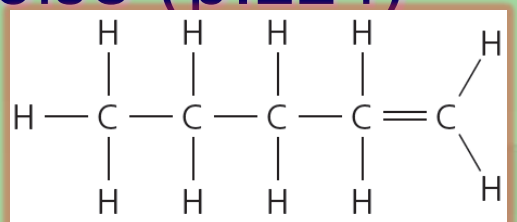
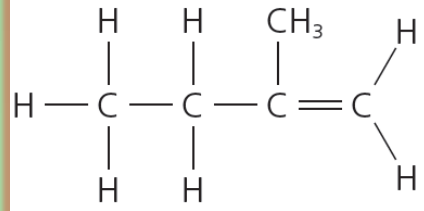
Topic Exercise (p.224)

- pent-1-ene



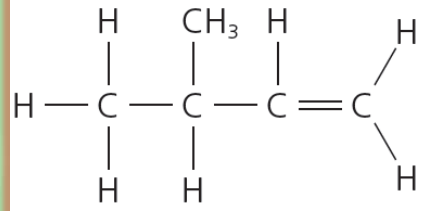
(1)

- 2-methylbut-1-ene



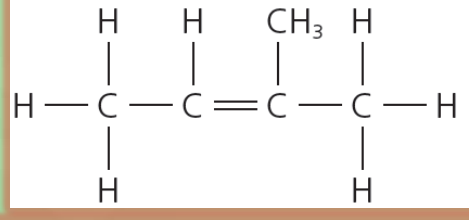
(1)

- 3-methylbut-1-ene



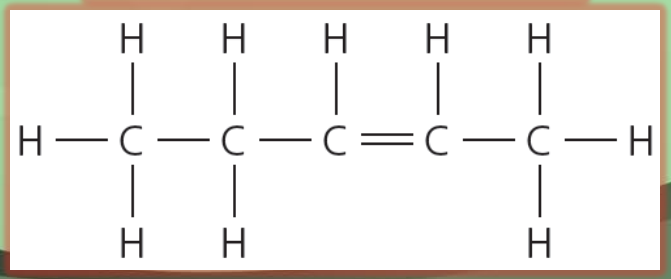
(1)

- 2-methylbut-2-ene



(1)

B is pent-2-ene



(1)

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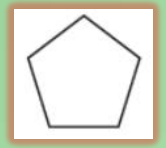
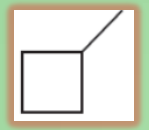
Topic Exercise (p.224)

C may be any one of the following:

- cyclopentane  (1)
- methylcyclobutane  (1)
- any dimethylpropane (1)

Stereoismers have the same structural formula (the atoms are bonded together in the same way — same connectivity), but the atoms are arranged differently in space. (1)

Compound B exists as two stereoisomers because

- it contains a carbon-carbon double bond and there is restricted rotation of atoms or groups around the carbon-carbon double bond. (1)
- there are two different atoms or groups on each carbon atom of the carbon-carbon double bond. (1)

Communication mark (1)

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Topic Exercise (p.224)

23 Four aldehydes (A, B, C and D) are structural isomers with the molecular formula $C_5H_{10}O$. The aldehydes have the following properties:
Aldehyde A has a straight chain while B, C and D are branched.
Aldehyde B is the only aldehyde with a chiral centre.

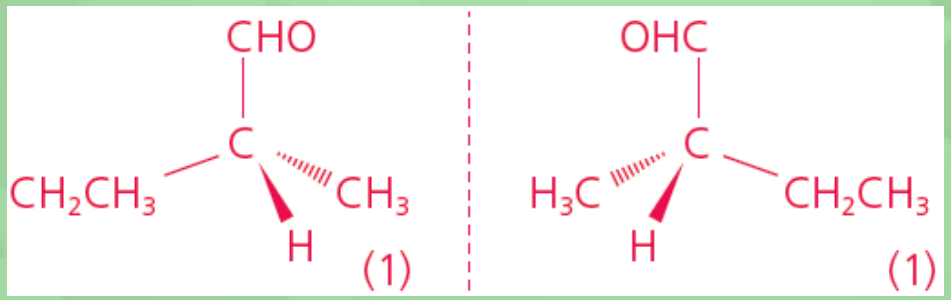
a) Give the meaning of 'structural isomers'.

Structural isomers are two or more compounds that have the same molecular formula but the atoms are bonded together in different orders (i.e. with different structures). (1)

b) Aldehyde B exhibits stereoisomerism.

i) Name the type of stereoisomer that B exhibits. Enantiomerism (1)

ii) Draw the three-dimensional structures of the two stereoisomers of B.



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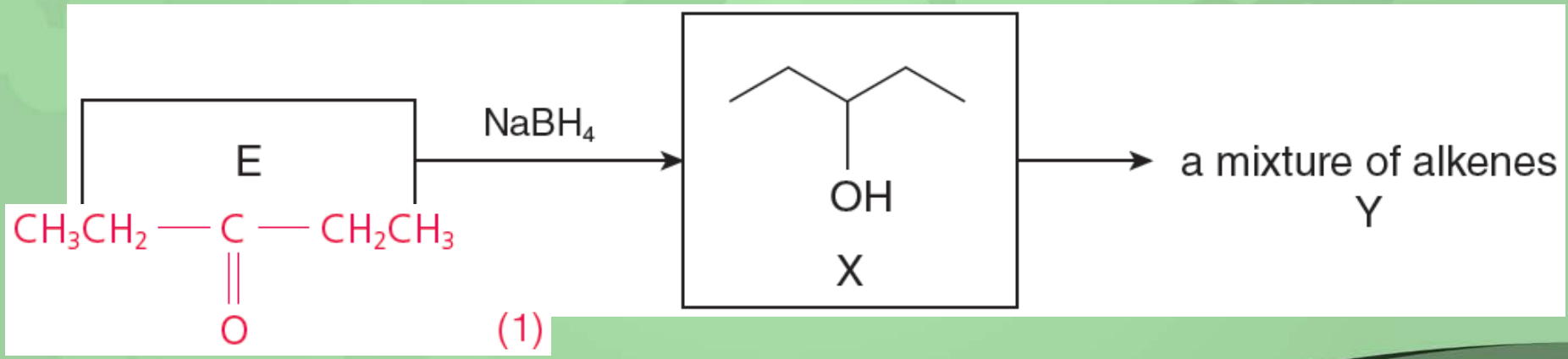
Topic Exercise (p.224)

b) iii) State a physical property which is different for the two stereoisomers.

Both stereoisomers show optical rotation. They rotate the plane of polarisation of plane-polarised light by the same amount but in opposite directions, one clockwise and the other anticlockwise. (1)

c) Compound E is another carbonyl compound with the same molecular formula $C_5H_{10}O$. Consider the following conversions starting from compound E:



(1)

i) Draw the structure of compound E.

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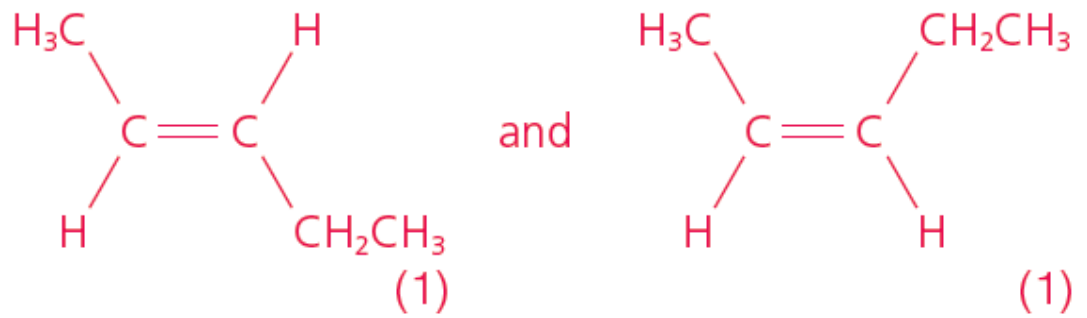
Topic Exercise (p.224)

c) ii) Suggest the reagent and reaction condition for converting X to Y.

Concentrated sulphuric acid, heat or concentrated phosphoric acid, heat (1)

iii) The mixture Y contains two alkenes with the same structural formula. Draw the respective structures of these two alkenes, and state their isomeric relationship.



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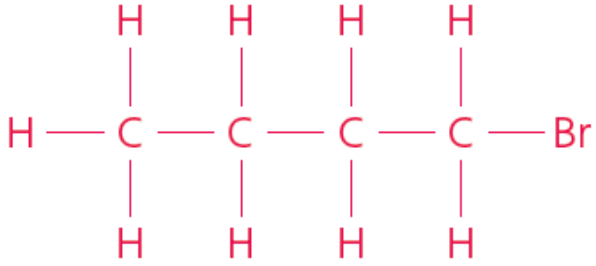
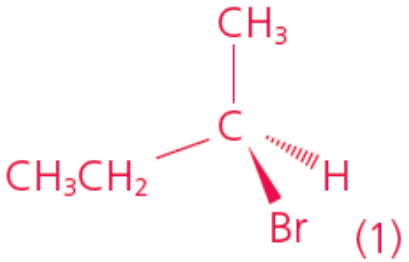
Topic Exercise (p.224)

24 The reaction between but-1-ene and hydrogen bromide produces a mixture of three isomers.

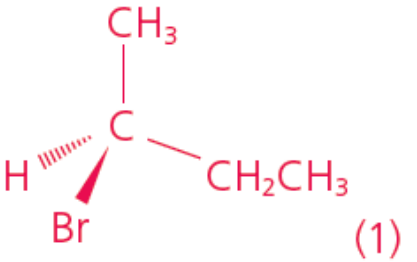
a) Draw the structure of each of the THREE isomers.



(1)



(1)



(1)

b) Outline how each of the isomers can be distinguished from one another.

Use a polarimeter to differentiate the isomers. (1)

The two isomers of 2-bromobutane rotate the plane of polarisation of plane-polarised light by the same amount but in opposite directions, one clockwise and the other anticlockwise.

1-bromobutane has no effect on plane-polarised light. (1)

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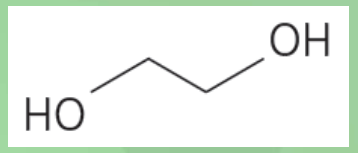
Topic Exercise (p.224)



25 The structure of ethylene glycol is shown below:

a) What is the systematic name of ethylene glycol? Ethane-1,2-diol (1)

b) Ethylene glycol contains primary alcohol groups. It is heated under reflux with acidified potassium dichromate solution.

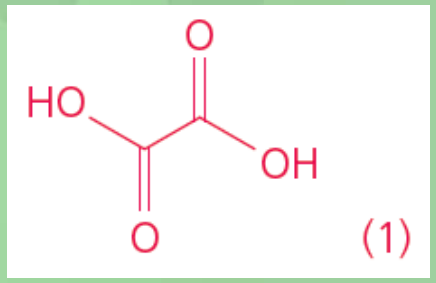
i) Why are the alcohol groups in ethylene glycol classified as primary?

It has one carbon atom attached to the carbon atom bearing the hydroxyl group. (1)

ii) Name the type of reaction that occurs.

Oxidation (1)

iii) Write the skeletal formula of the organic product.



(1)

iv) What colour change would you observe as this reaction takes place?

From orange to green (1)

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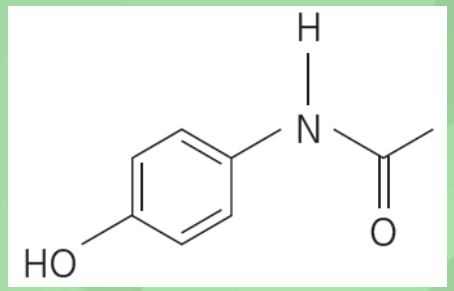
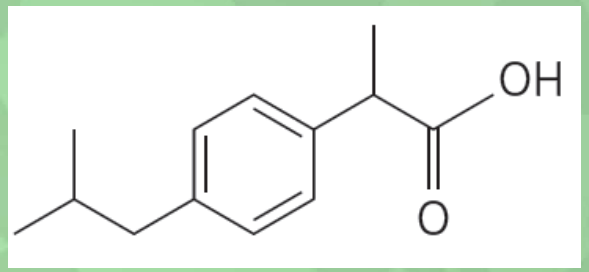
Topic Exercise (p.224)

26 The compounds shown below are used as medicines to relieve pain and reduce inflammation.



paracetamol



ibuprofen

a) Both these molecules contain a benzene ring. List the other functional groups contained in each compound.

Paracetamol: amide functional group (1), hydroxyl group (1)
Ibuprofen: carboxyl group (1)

b) Describe ONE way in which the behaviour of these compounds will differ from one another. Any one of the following:

- Paracetamol can be hydrolysed under alkaline conditions with the release of ammonia, but ibuprofen does not undergo hydrolysis. (1)
- Ibuprofen reacts with sodium hydrogencarbonate solution with the release of carbon dioxide, but paracetamol does not react with sodium hydrogencarbonate solution. (1)

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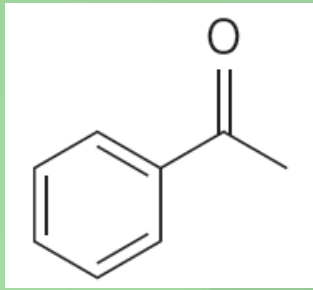
Topic Exercise (p.224)

27 The structure of acetophenone is shown below:



Heating a mixture of acetophenone and $NaBH_4$ in methanol solvent under reflux can give two isomeric compounds P and Q. P and Q have the same melting point and same solubility in methanol.

a) Draw a labelled diagram of the set-up for heating the mixture under reflux.
b) Suggest another reagent that can also react with acetophenone in a suitable solvent to give P and Q.
c) What kind of isomers are P and Q?
d) State ONE different physical property between P and Q.
e) Suggest a chemical test to show how acetophenone and P can be distinguished.

(HKDSE, Paper 1B, 2016, 13)

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

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Topic Exercise (p.224)

28 Compound P of molecular formula $C_4H_{10}O$ was heated with acidified $K_2Cr_2O_7(aq)$ under reflux. The solution changed from orange to green and a carbonyl compound Q of molecular formula C_4H_8O was formed.

a) Name the type of reaction that occurred when compound P was heated with acidified $K_2Cr_2O_7(aq)$.

Oxidation (1)

b) What information about compound P can be made from its reaction with acidified $K_2Cr_2O_7(aq)$? Explain your answer.

Compound P is a secondary alcohol. (1)
It produces a ketone when heated with acidified $K_2Cr_2O_7(aq)$ under reflux. (1)

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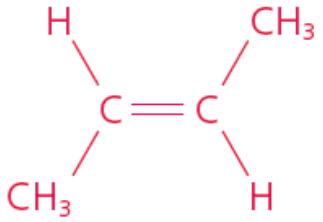
Topic Exercise (p.224)

c) When compound P was heated with concentrated sulphuric acid, a mixture of three isomers formed. All these isomers decolourised aqueous bromine.

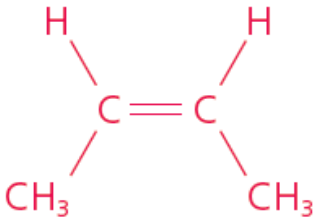
i) Name the type of reaction that occurred when compound P was heated with concentrated sulphuric acid. Dehydration (1)

ii) Write the structural formulae of three isomers formed.

$CH_3CH_2CH=CH_2$ (1)

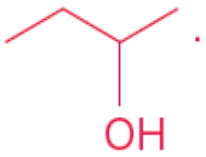


(1)

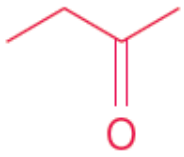


(1)

iii) Write the skeletal formulae of compounds P and Q.

P is  .

(1)

Q is  .

(1)

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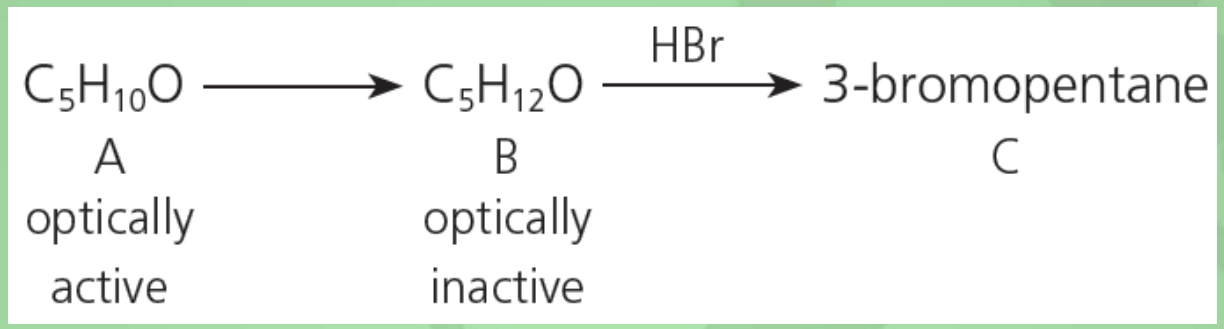
Topic Exercise (p.224)

29 Consider the following conversions:



a) Write the structural formula of C.

b) i) Deduce the structural formula of B.

ii) Name the type of reaction for the conversion of B to C.

c) i) Deduce the structural formula of A. Label on this structural formula all chiral centre(s), if any, by using '*'.

ii) State the reagent(s) required for the conversion of A to B.

(HKDSE, Paper 1B, 2017, 12)

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

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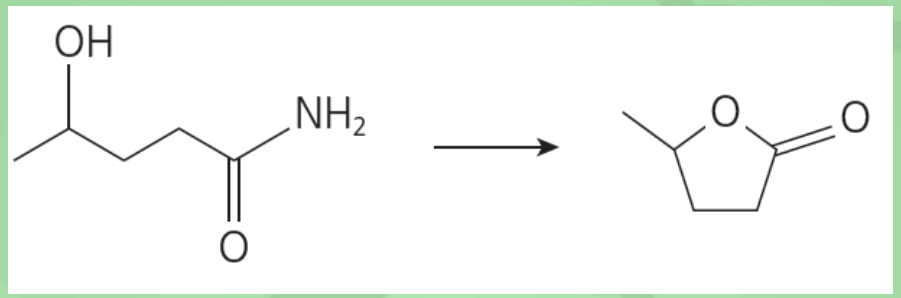
Topic Exercise (p.224)

30) Outline a synthetic route, with *no more than three steps*, to accomplish the following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of organic product.



(HKDSE, Paper 1B, 2016, 12)

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

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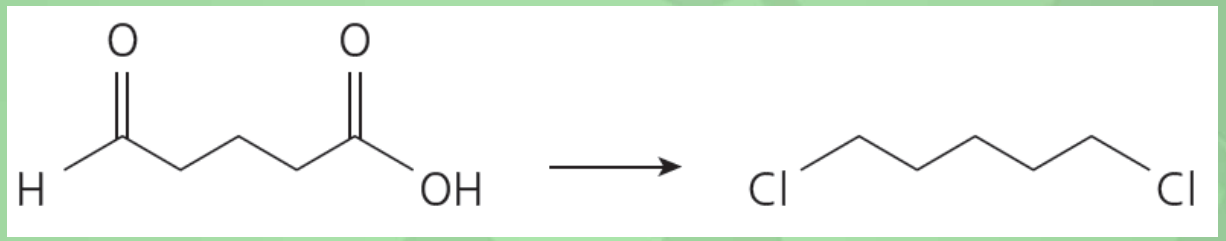
Topic Exercise (p.224)

31 Outline a synthetic route, with *no more than three steps*, to accomplish following conversion. For each step, give the reagent(s), reaction conditions (as appropriate) and structure of organic product.



(HKDSE, Paper 1B, 2018, 10)

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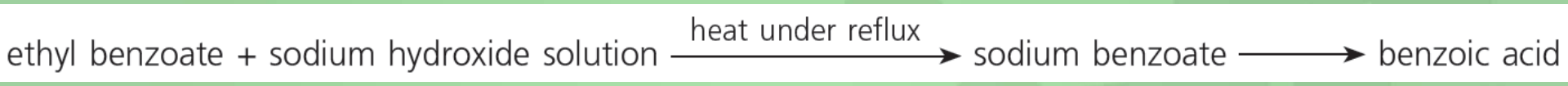
Topic Exercise (p.224)

32 A student designed the following reaction scheme starting from ethyl benzoate.



a) Name the type of reaction that occurs between ethyl benzoate and sodium hydroxide solution. Alkaline hydrolysis (1)

b) Ethyl benzoate and sodium hydroxide solution are heated under reflux in a round-bottomed flask.

i) What should be added to the flask along with ethyl benzoate and sodium hydroxide solution? Anti-bumping granules (1)

ii) What change in appearance of the contents of the flask indicates that the reaction is complete?

Any one of the following:
- The oily layer disappears. (1)
- Two layers are no longer observed. (1)
- The contents go clear. (1)
- The contents go from cloudy to colourless. (1)

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Topic Exercise (p.224)

c) What is added to sodium benzoate solution to precipitate out benzoic acid? Hydrochloric acid (1)

d) A yield of 76.6% benzoic acid is obtained from 5.88 g of ethyl benzoate. Calculate the mass of benzoic acid produced.
(Relative molecular masses: ethyl benzoate = 150.0, benzoic acid = 122.0)

Number of moles of ethyl benzoate used

$= \frac{5.88\ g}{150.0\ g\ mol^{-1}} = 0.0392\ mol$

= number of moles of benzoic acid obtained theoretically

Theoretical yield of benzoic acid

= 0.0392 mol x 122.0 g mol^{-1}

= 4.78 g (1)

Actual yield of benzoic acid

= 4.78 g x 76.6%

= 3.66 g (1)

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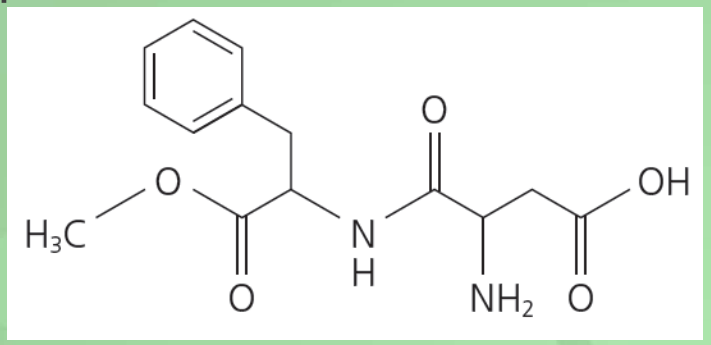
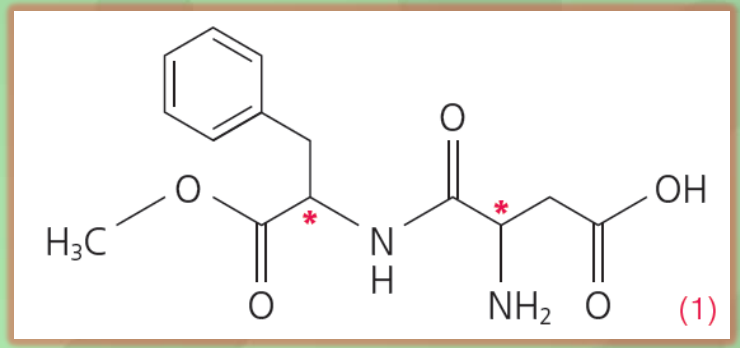
Topic Exercise (p.224)

33 Aspartame is an artificial sweetener that has the structure shown below.

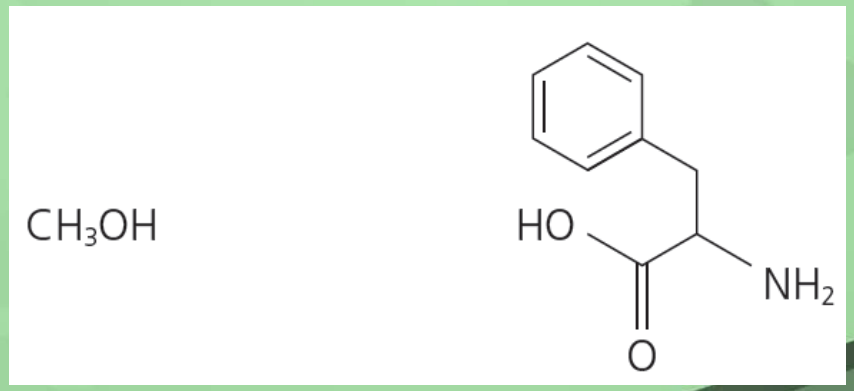


aspartame



a) Label the chiral centre(s) by using '*' in the above diagram.

b) In the stomach, aspartame is hydrolysed by acid to produce three products. Two of the products of hydrolysis are shown below.



methanol

phenylalanine

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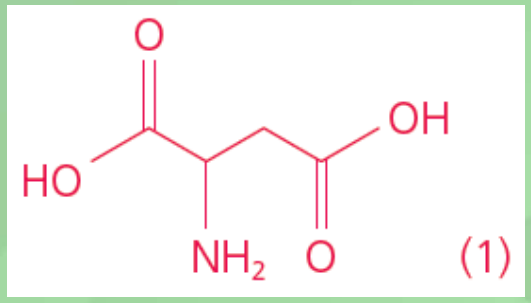
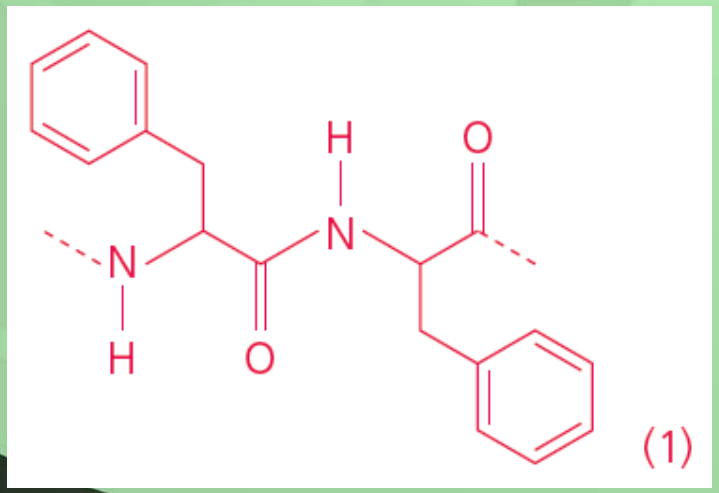
Topic Exercise (p.224)

b) i) Draw the structure of the third product of hydrolysis.



(1)

ii) One of the products of hydrolysis, phenylalanine can undergo polymerisation. Draw a part of the structure of the polymer, showing TWO repeating units.



(1)

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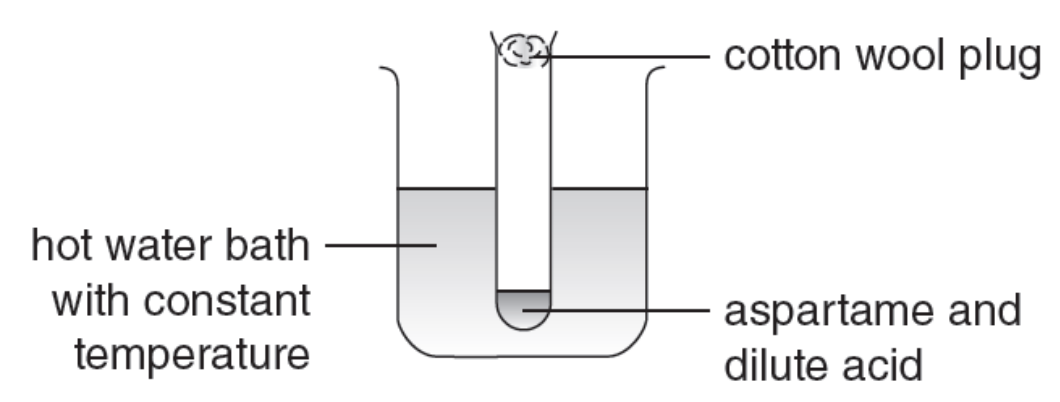
Topic Exercise (p.224)

iii) To investigate this hydrolysis reaction in the laboratory, the apparatus shown below is set up. The extent of hydrolysis at a given temperature can be determined by measuring the quantity of methanol produced.



What improvement could be made to the apparatus to reduce the loss of methanol by evaporation?

Any one of the following:

- Use a condenser. (1)
- Raise the test-tube so that a greater length of the test tube is above the hot water, but with the reaction mixture still immersed or below the level of the water. (1)

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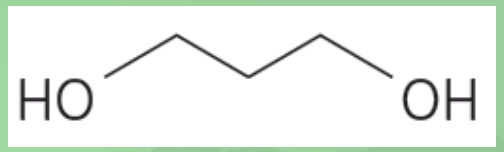
Topic Exercise (p.224)

34 Propane-1,3-diol is a starting material for the manufacture of some important materials.

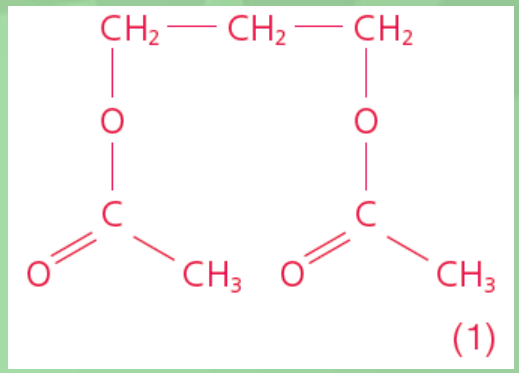


a) Compound X is formed when propane-1,3-diol is heated with ethanoic acid in the presence of concentrated sulphuric acid. The molecular formula of compound X is $C_7H_{12}O_4$.

i) Suggest TWO functions of the concentrated sulphuric acid in the process.

- As a catalyst (1)
- To remove the water formed in the reaction (1)

ii) Write the structural formula of compound X.



(1)

b) The polymer PTT is made from propane-1,3-diol and benzene-1,4-dicarboxylic acid.

i) Name the functional group made during the formation of PTT.

Ester linkage (1)

ii) Write the chemical equation for the formation of PTT.

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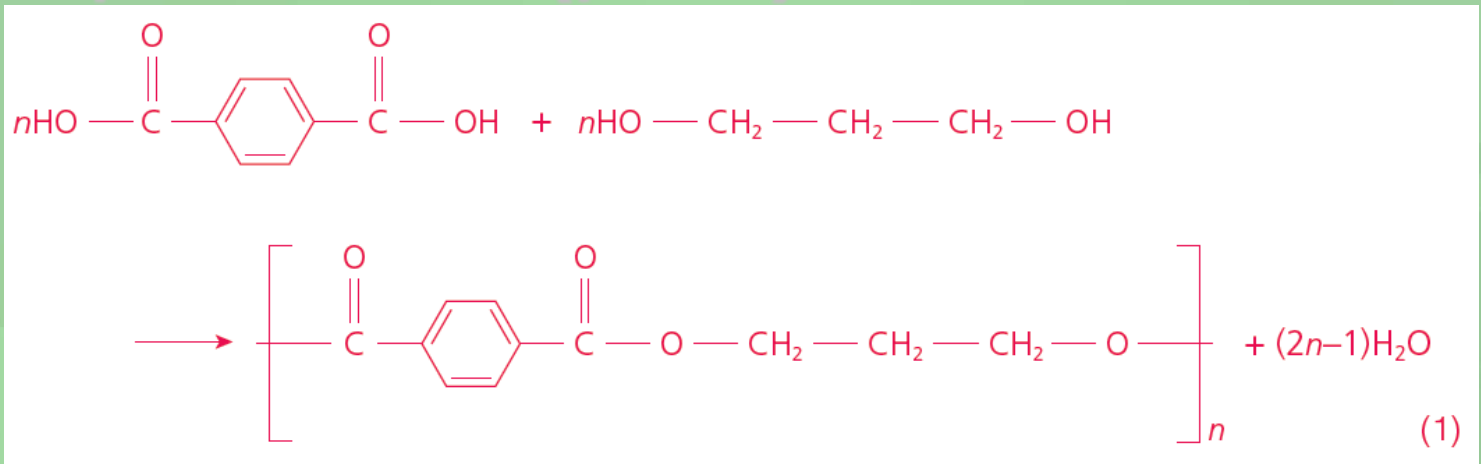
Topic Exercise (p.224)



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Topic Exercise (p.224)

35 To prepare bromoethane, a mixture of ethanol, bromine and red phosphorus is heated under reflux.
Bromine and red phosphorus react to produce phosphorus tribromide.
Ethanol reacts with phosphorus tribromide according to the equation below.

$$3CH_3CH_2OH(l) + PBr_3(l) \rightarrow 3CH_3CH_2Br(l) + H_3PO_3(l)$$

The table below lists some information of ethanol and bromoethane.

Property	Ethanol	Bromoethane
Molar mass ($g\ mol^{-1}$)	46.0	108.9
Density ($g\ cm^{-3}$)	0.789	1.47
Boiling point (°C)	78	38
Water solubility	miscible	slightly soluble

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Topic Exercise (p.224)

a) Describe the set-up for heating the mixture under reflux in the laboratory. You need to mention the apparatus involved.

Boil the liquid mixture in a container attached to a vertical condenser. (1)

*b) The crude product of bromoethane is washed with 10% $NaHCO_3$(aq). Outline the experimental procedure involved, including the necessary safety precautions.

Add dropwise 10% $NaHCO_3$(aq), until no effervescence occurs. (1)
Pour the content to a separating funnel. Stopper and shake the separating funnel vigorously. During shaking, open the tap of the separating funnel regularly (e.g. every 10 seconds) to release the pressure built inside the funnel. (1)
Remove the aqueous layer. Repeat the washing procedure until no effervescence occurs upon the addition of 10% $NaHCO_3$(aq). (1)
Communication mark (1)

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Topic Exercise (p.224)

c) The washed product from (b) contained moisture. Suggest a suitable reagent for drying.

Anhydrous calcium chloride / sodium sulphate (1)

d) Name a method for further purifying after obtaining the dried product from (c).

Simple distillation / fractional distillation (1)

e) Suggest ONE reason, other than the volatility of the reactants or products, why the preparation does NOT produce a 100% yield.

Any one of the following:

- Some of the product may be lost due to mechanical transfer. (1)
- Some of the product may be lost during the separation process. (1)
- There may be side reactions in which the reactants form different products. (1)
- The reaction may not go to completion. (1)

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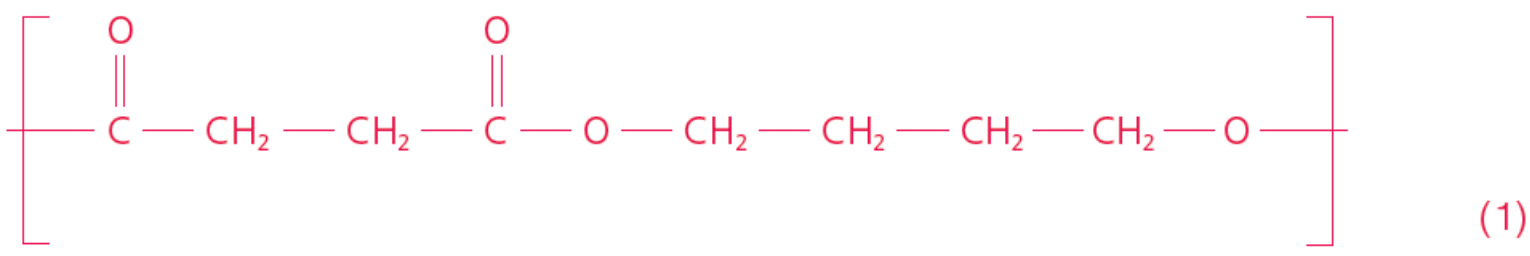
Topic Exercise (p.224)

36 The reaction of butane-1,4-diol with butanedioic acid produces the polymer PBS used in biodegradable packaging and disposable cutlery.

a) Name the functional group made during the formation of PBS.

Ester linkage (1)

b) Draw the repeating unit of PBS.



(1)

c) Butanedioic acid can be prepared from 1,4-dibromobutane. Outline a synthetic route, with *no more than three steps*, to accomplish the conversion: 1,4-dibromobutane → butanedioic acid

For each step, give the reagent(s), reaction conditions and structure of the organic product.

1,4-dibromobutane $\xrightarrow[\text{heat under reflux}]{\text{NaOH(aq)}}$ butane-1,4-diol $\xrightarrow[\text{heat under reflux}]{\text{acidified } K_2Cr_2O_7\text{(aq)}}$ butanedioic acid

(1) (1) (1)

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