35. POLYMERIZATION

Learning outcomes
Candidates should be able to:

35.1 Condensation polymerisation
Learning outcomes Candidates should be able to: 1 describe the formation of polyesters: (a) the reaction between a diol and a dicarboxylic acid or dioyl chloride (b) the reaction of a hydroxycarboxylic acid 2 describe the formation of polyamides: (a) the reaction between a diamine and a dicarboxylic acid or dioyl chloride (b) the reaction of an aminocarboxylic acid (c) the reaction between amino acids 3 deduce the repeat unit of a condensation polymer obtained from a given monomer or pair of monomers 4 identify the monomer(s) present in a given section of a condensation polymer molecule
35.2 Predicting the type of polymerisation
Learning outcomes Candidates should be able to: 1 predict the type of polymerisation reaction for a given monomer or pair of monomers 2 deduce the type of polymerisation reaction which produces a given section of a polymer molecule
35.3 Degradable polymers
Learning outcomes Candidates should be able to: 1 recognise that poly(alkenes) are chemically inert and can therefore be difficult to biodegrade 2 recognise that some polymers can be degraded by the action of light 3 recognise that polyesters and polyamides are biodegradable by acidic and alkaline hydrolysis

Condensation polymerisation

We can think of condensation polymerization as an addition reaction (in which reactant molecules bond to each other), followed by an elimination reaction (in which a small molecule is released).

Formation of polyesters

Polyester: polymer whose monomers are bonded to each other via the ester link, -COO-.

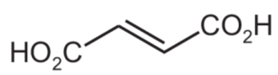
the reaction between a diol and a dicarboxylic acid or dioyl chloride

the reaction of a hydroxycarboxylic acid

1. A polyester can be synthesised from the reaction of $(COCl)_2$ with ethane-1,2-diol, $HOCH_2CH_2OH$.
Draw **two** repeat units of the polymer formed. Any functional groups should be displayed. [2]

2. Fumaric acid can form addition and condensation polymers.

fumaric acid



Draw the repeat unit of the polyester formed when fumaric acid reacts with ethane-1,2-diol, $(CH_2OH)_2$.
The ester bond should be shown fully displayed. [2]

3. (i) Draw the structure of exactly one repeat unit of the polymer formed when benzene-1,4-dicarboxylic acid reacts with ethane-1,2-diol, $HOCH_2CH_2OH$. The linkage formed between the monomers should be shown fully displayed. [2]

(ii) State the type of polymerisation that occurs when benzene-1,4-dicarboxylic acid reacts with ethane-1,2-diol and name the linkage formed between the monomers.

type of polymerisation ....

linkage .... [1]

4. A section of a polyester is shown.

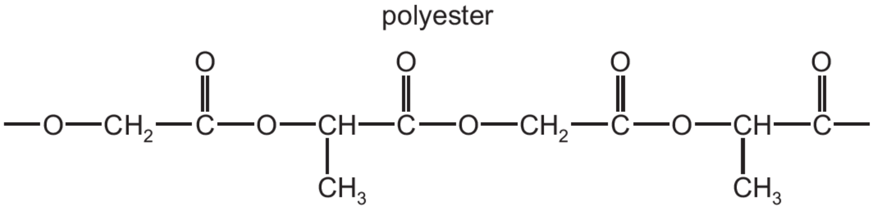


Fig. 8.1

Draw the structures of the two monomers that form this polyester.

[2]

5. Under certain conditions, ethane-1,2-diol, $HOCH_2CH_2OH$, reacts with propane-1,3-dioic acid, $HOOCCH_2COOH$, to form different organic products, as shown in Fig. 7.1.

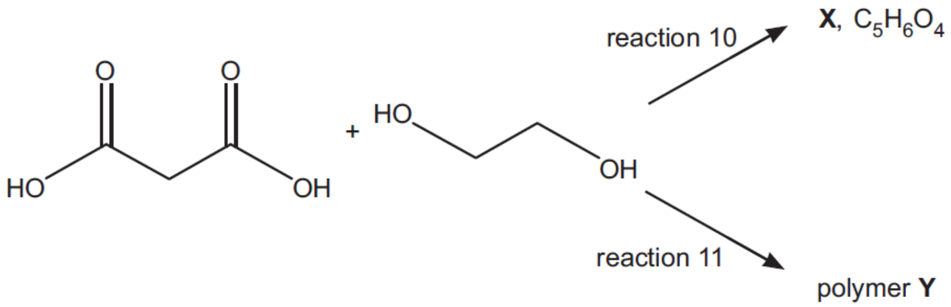


Fig. 7.1

(i) X does not react with Na metal.
Draw the structure of the organic product X, $C_5H_6O_4$, shown in Fig. 7.1. [1]

(ii) Reactions 10 and 11 in Fig. 7.1 are different types of reaction.
Name the type of reaction for reaction 10 and for reaction 11.

reaction 10 ....

reaction 11 .... [1]

(iii) Draw a section of polymer Y showing only one repeat unit.
The new functional group formed should be displayed. [2]

6. Lactic acid, $CH_3CH(OH)COOH$, is the only monomer needed to form the polymer polylactic acid, PLA.
Draw a short length of the PLA polymer chain, including a minimum of two monomer residues. The methyl groups may be written as $–CH_3$, but all other bonds should be shown fully displayed.
Label one repeat unit of polylactic acid on your diagram. [2]

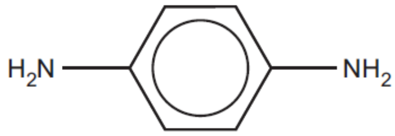
Formation of polyamides

Polyamides: polymers made in the condensation polymerization reaction between a diamine and a dicarbolylic acid (or a dioyl chloride) or between amino acids.

7. Ethanedioic acid, HOOCCOOH, can react with propane-1,3-diamine, $H_2NCH_2CH_2CH_2NH_2$, to form polymer W.
Draw a section of polymer W showing only one repeat unit.
The new functional group formed should be displayed. [2]

8. Polyamide X can be synthesised from ethanedioic acid and benzene-1,4-diamine.

benzene-1,4-diamine



(i) Draw the repeat unit of polyamide X in the box.
The new functional group formed should be shown displayed.

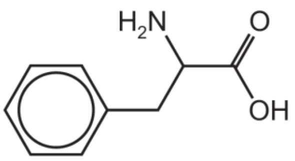
polyamide **X**

9. Polyamide **L** can be synthesised from dicarboxylic acid **J**, $HO_2C(CH_2)_2CO_2H$, and diamine **K**, $H_2N(CH_2)_6NH_2$.
Draw the repeat unit of the polymer formed in the box. Any functional groups should be shown displayed. [2]

polyamide **L**

10. **P** can be used to produce compound **T**.

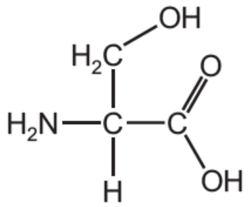
T



T can polymerise under suitable conditions. No other monomer is involved in this reaction.
Draw a section of the polymer chain formed that includes three **T** monomers. Identify the repeat unit on your diagram. [2]

11. Serine can polymerise to form two different types of condensation polymer; a polyester and a polypeptide.

serine



Draw the structure of the polypeptide showing two repeat units. The peptide linkage should be shown displayed. [2]

e) 1,3-diaminopropane, $H_2NCH_2CH_2CH_2NH_2$, can be used to make polyamides.

(i) Identify one compound that would react with 1,3-diaminopropane to form a polyamide.

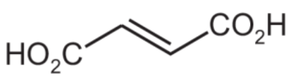
.... [1]

(ii) Draw a section of the polymer chain formed from 1,3-diaminopropane and the compound you chose in (e)(i).
Your answer should:

- include four monomer residues (two of each type of monomer)
- show the amide link fully displayed
- clearly identify one repeat unit of this polymer. [2]

12. Fumaric acid can form addition and condensation polymers.

fumaric acid



(i) Draw the repeat unit of the addition polymer poly(fumaric acid). [1]

13. A polymer can form from asparagine, $HOOCCH(NH_2)CH_2CONH_2$, as the only monomer.
Draw a length of the polymer chain containing three monomer residues.
Clearly label the repeat unit of the polymer on your diagram. [3]

14. Asparagine can polymerise to form poly(asparagine).
Draw the structure of poly(asparagine), showing two repeat units. The peptide linkage should be shown displayed. [2]

15. Proteins are polymers of amino acids.
Complete the table to show how the secondary and tertiary structures of proteins are stabilised.

	one intermolecular force responsible	groups involved
secondary structure		
tertiary structure		

Degradation of polymers

Poly(alkene)s, such as poly(ethene) and poly(propene), are chemically inert because their polymer chains are non-polar, saturated hydrocarbons, like giant alkane molecules. This makes them nonbiodegradable.

Polyamides and polyesters are biodegradable because they undergo hydrolysis, unlike polyalkenes.

16. Explain why polyesters normally biodegrade more readily than polyalkenes.

....

....

.... [1]

17. Explain why condensation polymers normally biodegrade more readily than addition polymers.

....

.... [1]

18. Poly(alkenes) biodegrade very slowly. Explain why.

....

.... [1]

19. Explain why condensation polymers can normally biodegrade more readily than addition polymers.

....

.... [1]

20. Many polymers are degradable.
State **two** different processes by which some polymers can be degraded.

....

.... [1]

21. (i) Give the name of the type of polymerisation involved in the formation of PLA and the name of the functional group that forms between the monomers.

type of polymerisation ....

functional group .... [1]

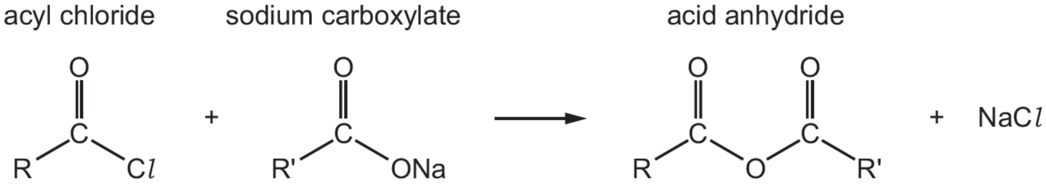
(ii) Predict whether PLA is readily biodegradable. Explain your answer.

....

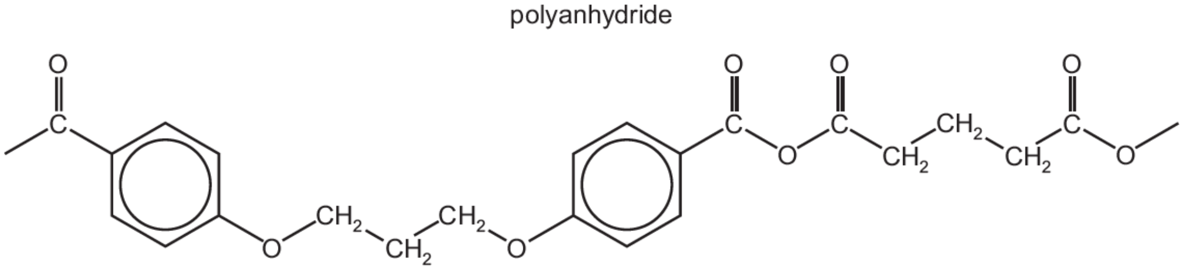
.... [1]

Identifying types polymerization

22. Acyl chlorides react with sodium carboxylates to form acid anhydrides as shown in Fig. 5.1.



The condensation polymers, polyanhydride and polyester, are formed by similar methods.
The repeat unit for a polyanhydride is shown in Fig. 5.2.



(i) Use Fig. 5.1 and Fig. 5.2 to suggest the structures of the two monomers used to make this polyanhydride.

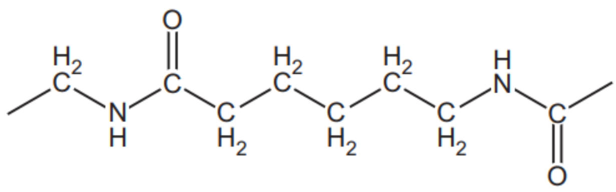
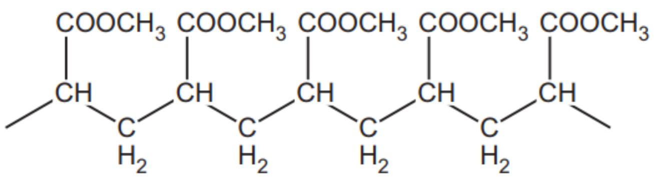
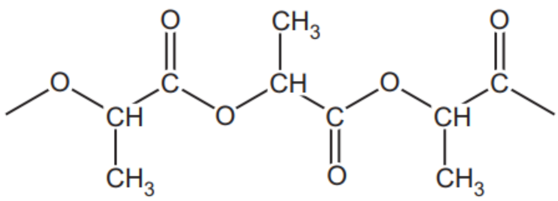
(ii) Polyanhydrides are biodegradable polymers.
Suggest how this polyanhydride can be degraded.

....

.... [1]

23. Table 4.1 shows the structures of sections of three polymers, X, Y and Z.
Each polymer is made from only one type of monomer.

Table 4.1

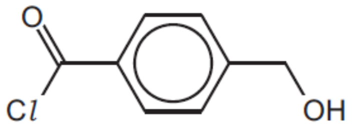
polymer	structure of section of polymer
X	
Y	
Z	

(a) Complete Table 4.2 to state the type of polymerisation and draw the structure of the monomer for each polymer, X, Y and Z. [4]

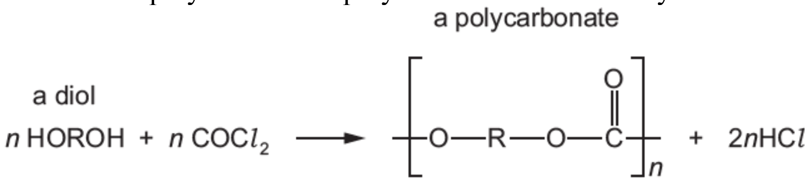
Table 4.2

polymer	type of polymerisation	structure of monomer
X		
Y		
Z		

24. Table 7.1 shows monomers that can undergo polymerisation.
Complete Table 7.1.

monomer	type of polymerisation
$CH_2C(CH_3)COOH$	
	
$CH_3CH(NH_2)COOH$	

25. The class of polymers called polycarbonates are made by the reaction of carbonyl dichloride, $COCl_2$, with a diol.

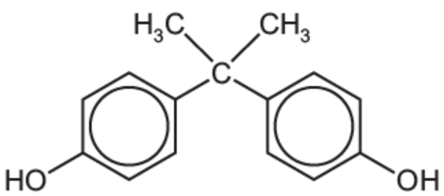


Deduce the *type of polymerisation* shown here.

.... [1]

26. Nalgene® is a polycarbonate formed from the diol **P** and $COCl_2$.

P



(ii) Draw **one** repeat unit of Nalgene®. [1]

(iii) Nalgene® is a strong and tough polymer.
Identify **two** types of intermolecular force that are responsible for these properties of Nalgene®.

1 ....

2 .... [1]

(c) Explain the significance of hydrogen bonding in DNA in relation to the accurate replication of genetic information.

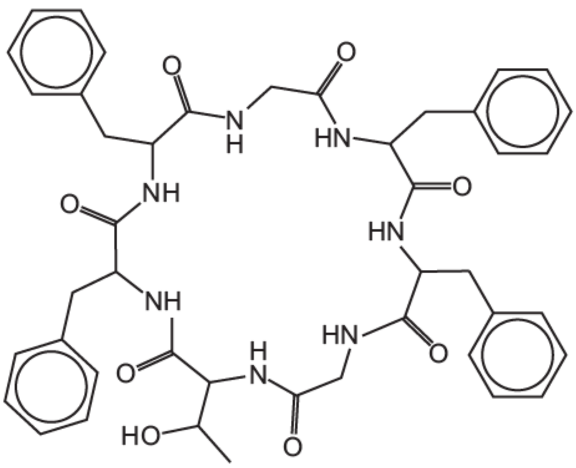
....

....

.... [2]

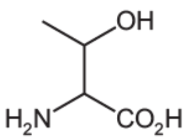
(e) The cyclic peptide **B** is shown.

B



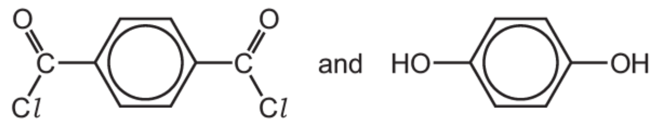
Cyclic peptide **B** is broken into its monomers by heating under reflux with dilute hydrochloric acid.
The amino acid threonine, Thr, and two other organic products are formed.

threonine



(i) Draw the structures of the two other organic products formed. [2]

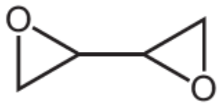
27. **(a)** The table shows three pairs of monomers that are capable of polymerisation.
Complete the table by identifying each type of polymerisation.

pair of monomers	type of polymerisation
$HOCH_2CH_2OH$ and $HO_2CCH_2CO_2H$	
	
CH_3CHCF_2 and CH_3CHCH_2	

[1]

(b) 2-aminopropanoic acid, CH3CH(NH_2)CO_2H, can polymerise under suitable conditions. No other monomer is involved in this reaction.
(i) Draw a section of the polymer chain formed, including **three** monomer residues. Clearly identify **one** repeat unit on your diagram. [3]

28. The skeletal formula of compound **W** is shown.



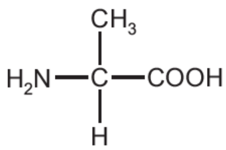
When **W** is mixed with a second compound, called a hardener, a polymerisation reaction occurs, producing a non-solvent-based adhesive.
(i) Give the name of this type of non-solvent-based adhesive.

.... [1]

(ii) The hardener is a diamine. A diamine has an alkyl chain with two amine groups which are not bonded to the same carbon atom.
Draw the structural formula of a compound that would make a suitable hardener. [1]

29. When CH_3CHCl COOH reacts with aqueous NH_3, alanine forms.

alanine



Alanine is an amino acid. Its isoelectric point is 6.1.
(i) Polymer **C** forms from the reaction between alanine and 4-aminobutanoic acid, $H_2N(CH_2)_3COOH$.
Draw a repeat unit of **C**. The functional group formed should be displayed. [2]

(ii) State the type of polymerisation shown in **(i)**.

.... [1]

(iii) Scientists are investigating **C** as a replacement for poly(propene) in packaging.
Suggest an advantage of using **C** instead of poly(propene).

....

.... [1]

30. Polymers consist of monomers joined together by undergoing either addition or condensation polymerisation. Compound **H** can react to form an addition polymer, **K**, or a condensation polymer, **L**, depending on the conditions.
(i) Draw **one** repeat unit of addition polymer **K**. [1]

(ii) Draw **two** repeat units of condensation polymer **L**.
The new functional group formed should be displayed. [2]

31. Coordination polymers are made when a bidentate ligand acts as a bridge between different metal ions.

Under certain conditions, $Ru^{3+}(aq)$ and the bidentate ligand *dps* can form a coordination polymer containing $([Ru(dps)Cl_4]^-)n$ chains.

dps

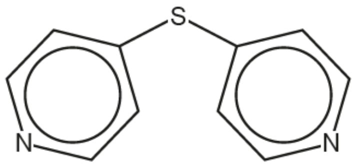
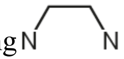


Fig. 2.2

The bidentate ligand *dps* uses each of the nitrogen atoms to bond to a different Ru^{3+}.
Complete Fig. 2.3 by drawing the structure for the coordination polymer $([Ru(dps)Cl_4]^-)n$.
Show **two** repeat units.

The *dps* ligand can be represented using 

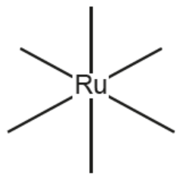


Fig. 2.3

[2]

*****This is not a complete note. It is to guide you. It is recommended to study the prescribed textbooks along with this material. *****