

9701 Chemistry Paper 4 - Polymerisation

Topical questions | 19 questions

1. Question part 1/2 | 9701 Feb-March 2016 P4 V2 Q9

- 9 (a) (i)** Name an example of a synthetic polyester and a synthetic polyamide.

polyester

polyamide

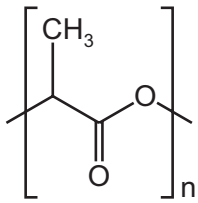
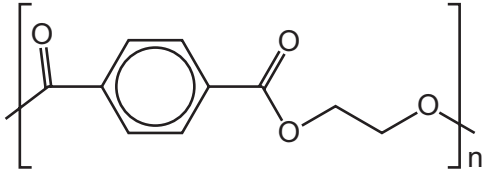
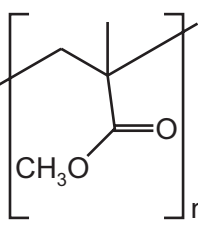
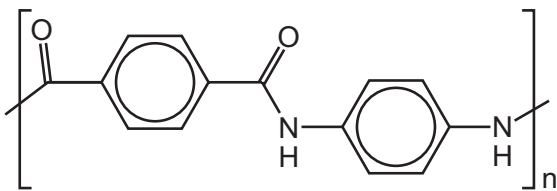
[1]

- (ii)** Polyesters and polyamides are formed by condensation reactions.

Name a molecule which is commonly eliminated in such reactions.

..... [1]

- (b) (i)** The table shows the repeat units of a number of polymers. Place a tick (✓) against the ones which are biodegradable.

polymer	repeat unit	biodegradable
A		
B		
C		
D		

[2]

- (ii)** Draw the structures of two monomers used to form polymer **B**.

[2]

(c) A section of polypeptide was hydrolysed and the following amino acids identified.

amino acid	formula
T	$\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$
U	$\text{C}_6\text{H}_5\text{CH}_2\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$
V	$\text{H}_2\text{N}(\text{CH}_2)_4\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$

(i) Which of the amino acids **T**, **U** or **V** has the highest pH in aqueous solution? Explain why.

amino acid

.....

.....

[1]

(ii) State how many different dipeptides could be formed from a reaction mixture consisting of amino acids **T** and **U**.

..... [1]

(iii) Polypeptides contain a high proportion of carbon and hydrogen in their structures, yet many are soluble in water.

By referring to the structure of a polypeptide, explain why.

.....

.....

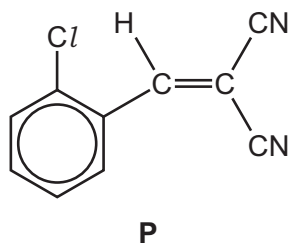
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..... [2]

[Total: 10]

2. Question part 1/2 | 9701 Oct-Nov 2017 P4 V1 Q5

5 Compound **P** contains several functional groups.



(a) Name the functional groups present in **P**.

.....
..... [2]

(b) Compound **P** can be polymerised.

Draw a section of the polymer of **P** showing **two** repeat units.
Name the type of polymerisation.

type of polymerisation [2]

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2. Question part 2/2 | 9701 Oct-Nov 2017 P4 V1 Q5

- (c) Complete the following table to show the structures of the products formed and the *type of organic reaction* when **P** reacts with the four reagents.

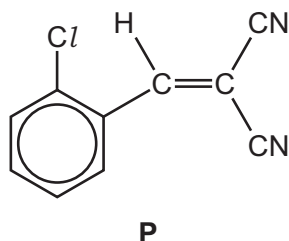
reagent	structure(s) of product(s)		<i>type of organic reaction</i>
excess Br ₂ (aq)			
excess hot, concentrated, acidified MnO ₄ ⁻ (aq)			
excess hot HCl(aq)			
excess H ₂ /Pt catalyst			

[8]

[Total: 12]

3. Question part 1/2 | 9701 Oct-Nov 2017 P4 V3 Q5

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(a) Name the functional groups present in **P**.

.....
..... [2]

(b) Compound **P** can be polymerised.

Draw a section of the polymer of **P** showing **two** repeat units.
Name the type of polymerisation.

type of polymerisation [2]

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3. Question part 2/2 | 9701 Oct-Nov 2017 P4 V3 Q5

- (c) Complete the following table to show the structures of the products formed and the *type of organic reaction* when **P** reacts with the four reagents.

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[8]

[Total: 12]

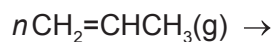
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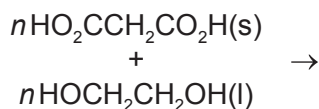
4. Question part 1/4 | 9701 Feb-March 2018 P4 V2 Q7

- 7 (a) (i) Complete the equations to show the **two** types of polymerisation. Draw **one** repeat unit for each polymer. Include any other products.

- addition polymerisation



- condensation polymerisation



[3]

- (ii) Suggest the sign of the entropy changes, ΔS° , for each of the **two** types of polymerisation. Explain your answers.

- ΔS° for addition polymerisation

.....

.....

.....

- ΔS° for condensation polymerisation

.....

.....

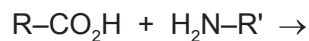
.....

[2]

4. Question part 2/4 | 9701 Feb-March 2018 P4 V2 Q7

(b) An amide bond forms when a carboxylic acid reacts with an amine.

(i) Complete the equation by writing the products in the box.



+

[1]

(ii) Use your answer to (i) to work out the bonds that are broken and the bonds that are formed during the reaction between a carboxylic acid and an amine.

- bonds that are broken

.....

- bonds that are formed

.....

[2]

(iii) Use bond energy values from the *Data Booklet* to calculate the enthalpy change, ΔH° , when **one** mole of amide bonds is formed in the reaction in (i).

$$\Delta H^\circ = \dots\dots\dots \text{kJ} \quad [2]$$

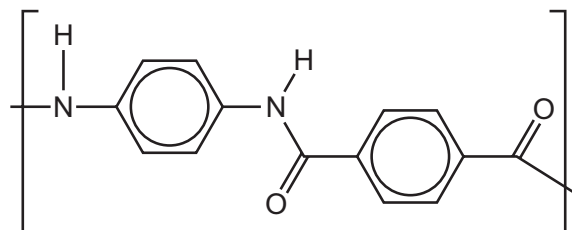
(c) Amide bonds can also be formed by reacting acyl chlorides with amines.

The enthalpy change for this process, ΔH° , is $-6.00 \text{ kJ mol}^{-1}$.

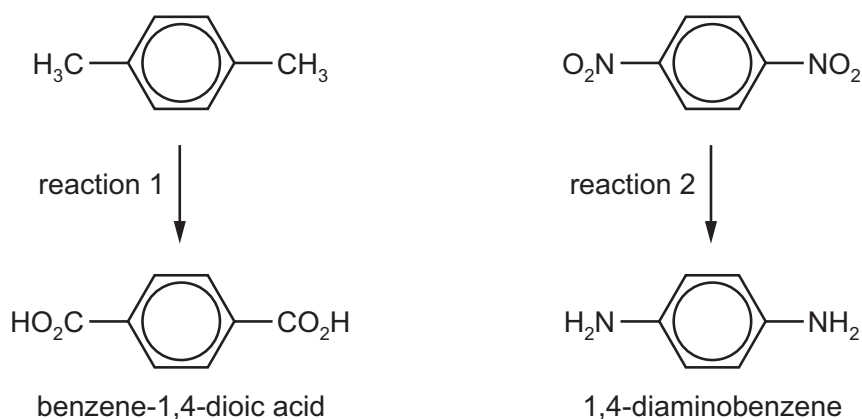
Calculate the minimum entropy change, ΔS° , for this reaction to be spontaneous (feasible) at 298 K.

$$\Delta S^\circ = \dots\dots\dots \text{JK}^{-1} \text{mol}^{-1} \quad [2]$$

The repeat unit of the polyamide *Kevlar* is shown.



- (d) The monomers of *Kevlar*, benzene-1,4-dioic acid and 1,4-diaminobenzene, can be synthesised as follows.



State the reagents and conditions needed for:

- (i) reaction 1

..... [1]

- (ii) reaction 2

.....
 [2]

- (e) *Kevlar* is both strong and rigid.

Complete the table to identify **two** intermolecular forces and the groups involved which are responsible for these properties of *Kevlar*.

intermolecular force	group(s) involved

[2]

[Total: 17]

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4. Question part 4/4 | 9701 Feb-March 2018 P4 V2 Q7

Question 8 starts on the next page.

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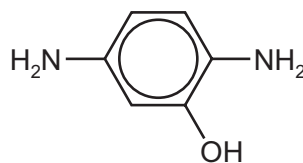
Topical questions | 19 questions

5. Question part 1/2 | 9701 Oct-Nov 2018 P4 V1 Q5

- 5 (a)** Polyhydroxyamide is a fire-resistant polyamide which is formed from the two monomers, **F** and **G**.



F



G

- (i) Predict the number of peaks that will be seen in the carbon-13 NMR spectra of **F** and **G**.

	number of peaks
F	
G	

[2]

- (ii) Draw the repeat unit of polyhydroxyamide. The amide bond should be shown displayed.

[2]

- (b) When poly(ethene) is formed from ethene, many bonds are broken and formed.

Place **one tick (✓)** in **each row** of the table to indicate the types of bonds broken and formed in this process.

	σ -bonds only	π -bonds only	both σ - and π -bonds
bonds broken			
bonds formed			

[2]

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5. Question part 2/2 | 9701 Oct-Nov 2018 P4 V1 Q5

(c) Addition polymers can be classified into two types.

- homopolymer - a polymer made up of the same monomer unit
- copolymer - a polymer made up of two or more different monomer units

The reaction of propene, $\text{CH}_3\text{CH}=\text{CH}_2$, with phenylethene, $\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$, gives a copolymer.

Draw a length of the chain of this copolymer that contains one molecule of **each** monomer.

[2]

(d) (i) Polyalkenes biodegrade very slowly.

Explain why by referring to the structures of the polymers.

.....
.....
..... [1]

(ii) Some polymers will degrade in the environment.

Describe **two** processes by which this occurs.

1
2
[2]

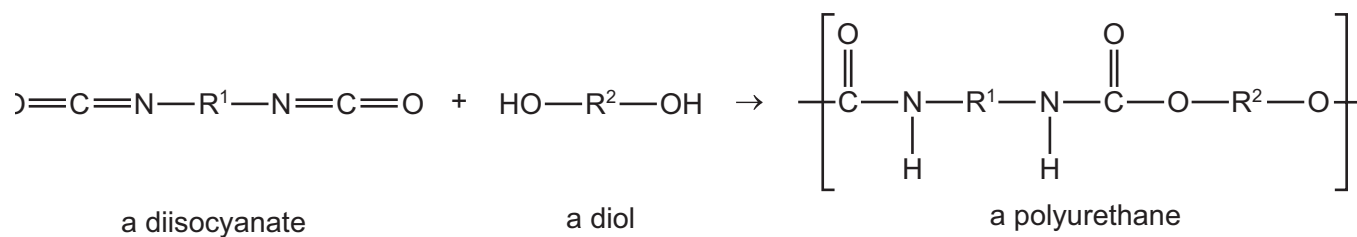
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9701 Chemistry Paper 4 - Polymerisation

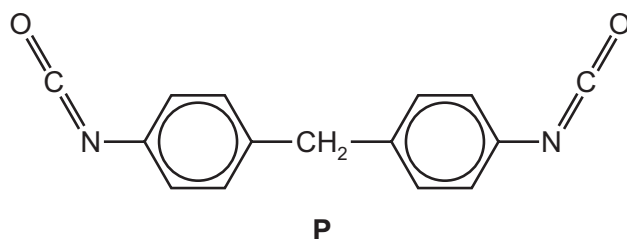
Topical questions | 19 questions

6. Question part 1/2 | 9701 Oct-Nov 2018 P4 V2 Q7

- 7 (a) Polyurethanes are polymers made by the reaction of a diisocyanate with a diol as shown.
R¹ and R² are hydrocarbon groups.



Lycra[®] is a polyurethane formed from the diisocyanate **P** and HOCH₂CH₂OH.



- (i) Give the molecular formula for **P**.

..... [1]

- (ii) Draw the repeat unit of Lycra[®].

[2]

(iii) Fibres of Lycra® are strong due to the intermolecular forces between the polymer chains.

Complete the table to identify two intermolecular forces responsible for this property and the group(s) involved.

intermolecular force	group(s) involved

[2]

(b) Name **one** example of each of the following types of polymer.

type of polymer	example
synthetic polyamide	
synthetic polyester	
conducting polymer	
non-solvent based adhesive	

[3]

[Total: 8]

9701 Chemistry Paper 4 - Polymerisation

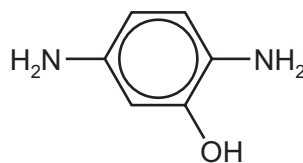
Topical questions | 19 questions

7. Question part 1/2 | 9701 Oct-Nov 2018 P4 V3 Q5

- 5 (a)** Polyhydroxyamide is a fire-resistant polyamide which is formed from the two monomers, **F** and **G**.



F



G

- (i) Predict the number of peaks that will be seen in the carbon-13 NMR spectra of **F** and **G**.

	number of peaks
F	
G	

[2]

- (ii) Draw the repeat unit of polyhydroxyamide. The amide bond should be shown displayed.

[2]

- (b) When poly(ethene) is formed from ethene, many bonds are broken and formed.

Place **one tick (✓)** in **each row** of the table to indicate the types of bonds broken and formed in this process.

	σ -bonds only	π -bonds only	both σ - and π -bonds
bonds broken			
bonds formed			

[2]

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Topical questions | 19 questions

7. Question part 2/2 | 9701 Oct-Nov 2018 P4 V3 Q5

(c) Addition polymers can be classified into two types.

- homopolymer - a polymer made up of the same monomer unit
- copolymer - a polymer made up of two or more different monomer units

The reaction of propene, $\text{CH}_3\text{CH}=\text{CH}_2$, with phenylethene, $\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$, gives a copolymer.

Draw a length of the chain of this copolymer that contains one molecule of **each** monomer.

[2]

(d) (i) Polyalkenes biodegrade very slowly.

Explain why by referring to the structures of the polymers.

.....
.....
..... [1]

(ii) Some polymers will degrade in the environment.

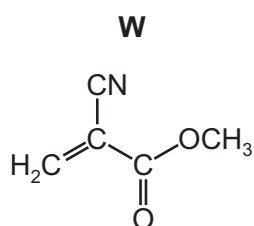
Describe **two** processes by which this occurs.

1
2
[2]

[Total: 11]

8. Question part 1/2 | 9701 Feb-March 2019 P4 V2 Q5

- 5 (a) Methyl 2-cyanoprop-2-enoate, **W**, is the major component of *Super Glue*, a rapid-setting adhesive.
As the adhesive sets, the monomer **W** polymerises.



- (i) Draw a section of the polymer showing **two** repeat units.



[2]

- (ii) Name the type of polymerisation occurring.

..... [1]

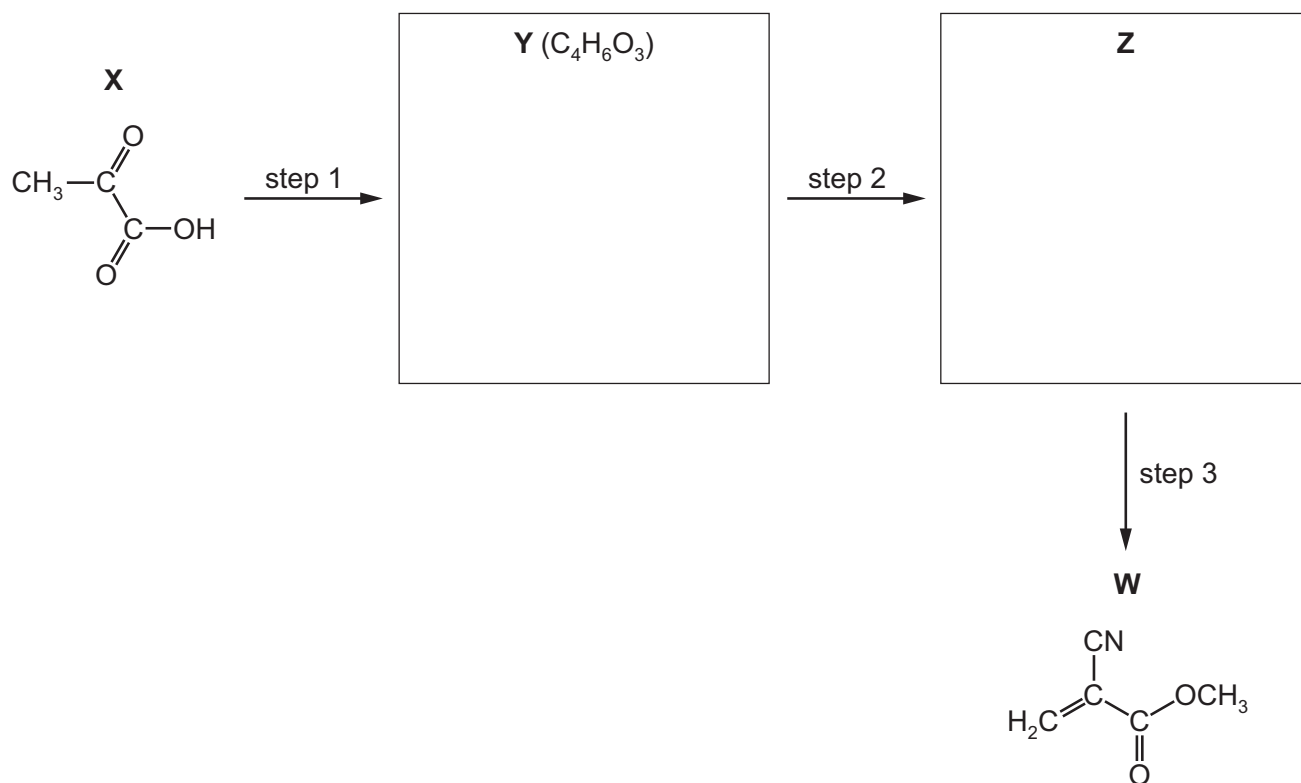
- (iii) Suggest **two** types of intermolecular force that could occur between the *Super Glue* polymer and the objects glued together. For each type of intermolecular force, refer to the atoms/groups in the *Super Glue* polymer involved in the attraction.

type of intermolecular force	atoms/groups in the <i>Super Glue</i> polymer

[2]

8. Question part 2/2 | 9701 Feb-March 2019 P4 V2 Q5

(b) **W** can be synthesised in three steps, starting from 2-oxopropanoic acid, **X**.



(i) Suggest the identities of compounds **Y** and **Z** by drawing their structures in the boxes.

[2]

(ii) Suggest suitable reagents and conditions for each of the steps 1–3.

step 1

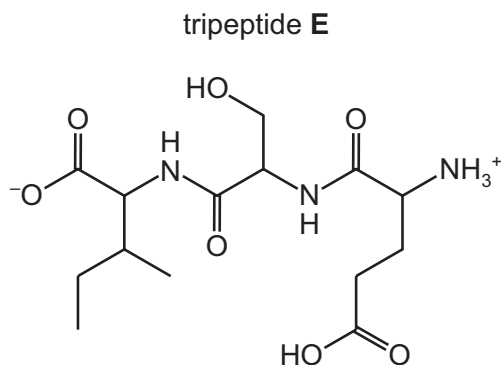
step 2

step 3

[4]

[Total: 11]

- 8 Proteins are natural polymers. When one particular protein is partially hydrolysed the product mixture includes tripeptide **E**.



- (a) (i) Describe the conditions that could be used to hydrolyse **E** to produce a mixture of three amino acids.

..... [1]

- (ii) Draw the structures of the three amino acids produced by this hydrolysis reaction.

The three amino acids should be shown in the correct form for the conditions you have chosen in (a)(i).

--	--	--

[2]

- (b) If a pure sample of **E** is obtained in aqueous solution, several different types of intermolecular forces are possible between pairs of **E** molecules.

Name three different types of intermolecular force that exist between pairs of **E** molecules, stating the groups on the molecules where the forces are acting.

type of force/bond	pair of groups responsible

[3]

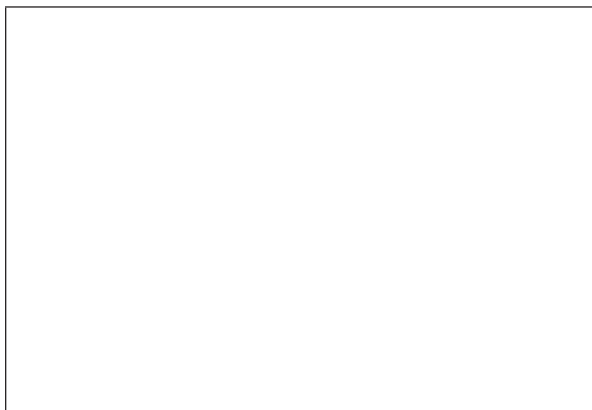
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9. Question part 2/2 | 9701 Oct-Nov 2019 P4 V1 Q8

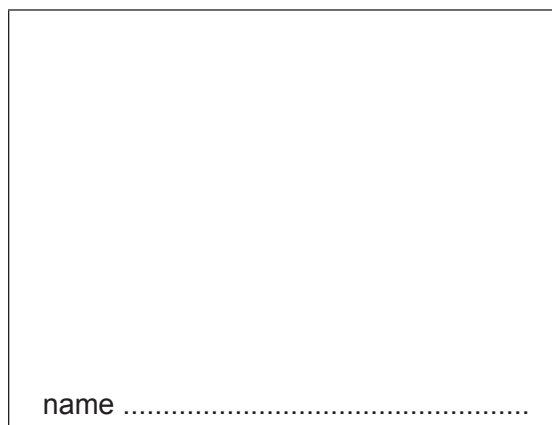
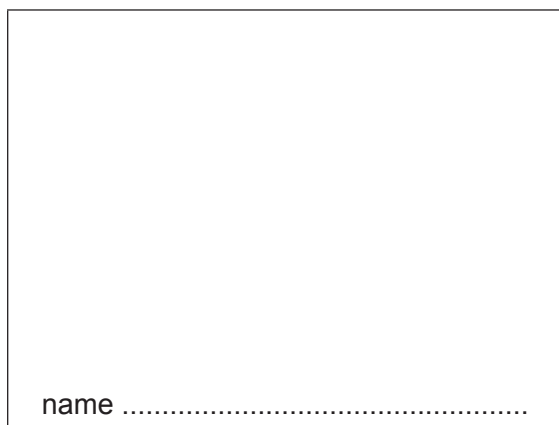
(c) Polyesters and polyamides are two important types of condensation polymer.

- (i) Draw the structure of a compound that can polymerise to produce a polyamide, without the need for a second monomer.



[1]

- (ii) Draw the structures of two different compounds that can polymerise together to produce a polyester with **four** carbon atoms per repeat unit. Name the two compounds.



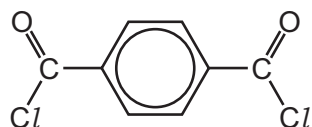
[4]

[Total: 11]

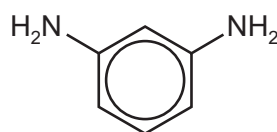
10. Question part 1/2 | 9701 Oct-Nov 2019 P4 V2 Q7

- 7 (a) A polymer, **P**, can be made from the monomers benzene-1,4-dioyl chloride and benzene-1,3-diamine.

benzene-1,4-dioyl chloride



benzene-1,3-diamine



- (i) Draw a section of the polymer chain of **P**. Your structure should include two repeat units.

P

[2]

- (ii) Place **one** tick in the table to describe polymer **P** and its method of polymerisation.

type of polymer	type of polymerisation	
	addition	condensation
polyalkene		
polyamide		
polyester		

[1]

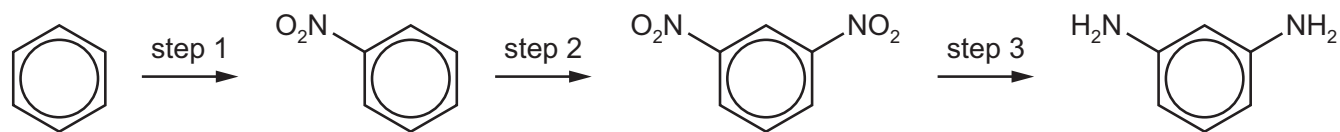
- (iii) State whether or not polymer **P** is biodegradable. Give a reason for your answer.

.....
 [1]

- (iv) State a suitable reagent to produce benzene-1,4-dioyl chloride from benzene-1,4-dicarboxylic acid.

..... [1]

(v) Benzene-1,3-diamine can be made from benzene using the reaction sequence shown.



State the reagents used for steps 1 and 3.

step 1

step 3

[2]

(b) Proteins are natural polymers. A protein is said to have a primary, secondary and tertiary structure.

(i) Describe what is meant by each of these terms.

primary structure

.....

secondary structure

.....

tertiary structure

.....

[3]

(ii) Name the forces or bonds responsible for holding together the primary structure of a protein molecule.

..... [1]

(iii) Name the forces or bonds responsible for the stabilisation of the secondary structure of a protein molecule, and identify the groups of atoms within the protein molecule that are held together by these forces or bonds.

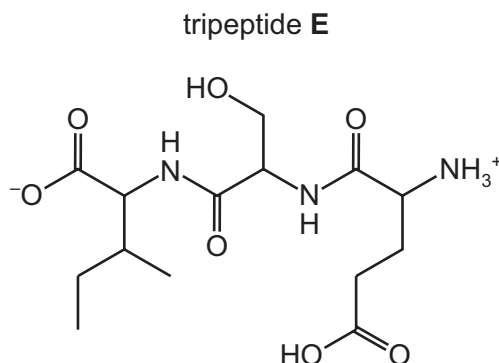
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..... [2]

[Total: 13]

11. Question part 1/2 | 9701 Oct-Nov 2019 P4 V3 Q8

- 8 Proteins are natural polymers. When one particular protein is partially hydrolysed the product mixture includes tripeptide **E**.



- (a) (i) Describe the conditions that could be used to hydrolyse **E** to produce a mixture of three amino acids.

..... [1]

- (ii) Draw the structures of the three amino acids produced by this hydrolysis reaction.

The three amino acids should be shown in the correct form for the conditions you have chosen in (a)(i).

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[2]

- (b) If a pure sample of **E** is obtained in aqueous solution, several different types of intermolecular forces are possible between pairs of **E** molecules.

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type of force/bond	pair of groups responsible

[3]

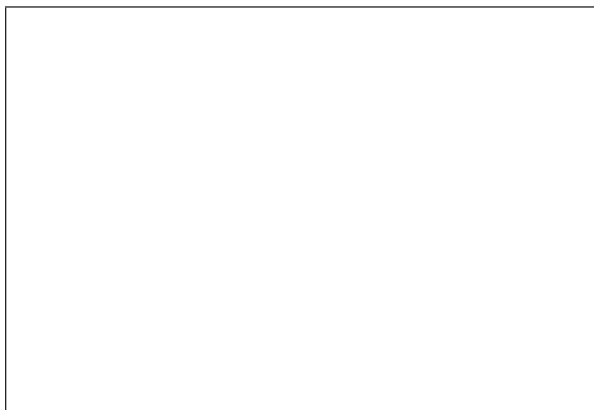
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11. Question part 2/2 | 9701 Oct-Nov 2019 P4 V3 Q8

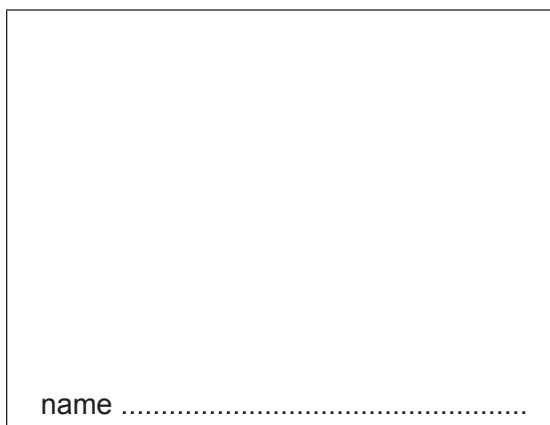
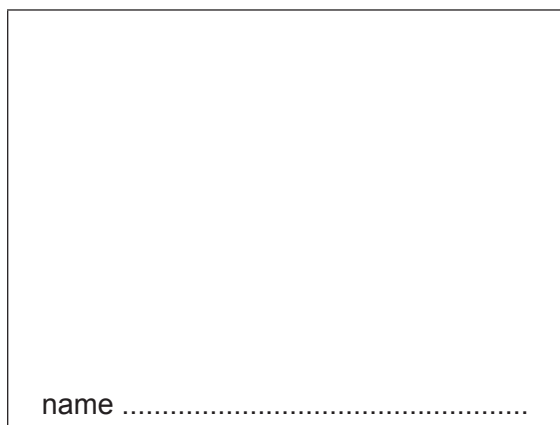
(c) Polyesters and polyamides are two important types of condensation polymer.

- (i) Draw the structure of a compound that can polymerise to produce a polyamide, without the need for a second monomer.



[1]

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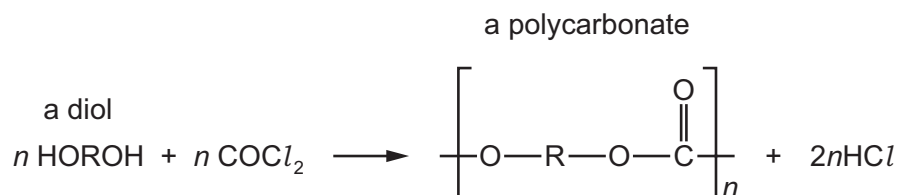


[4]

[Total: 11]

12. Question part 1/3 | 9701 May-June 2020 P4 V2 Q6

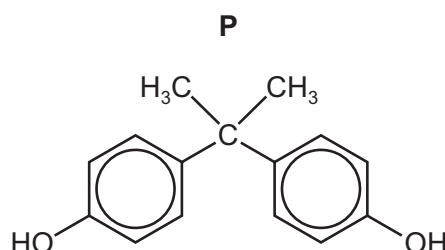
- 6 The class of polymers called polycarbonates are made by the reaction of carbonyl dichloride, COCl_2 , with a diol.



- (a) (i) Deduce the *type of polymerisation* shown here.

..... [1]

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



- (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]

- (b) 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		

[2]

12. Question part 2/3 | 9701 May-June 2020 P4 V2 Q6

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

.....

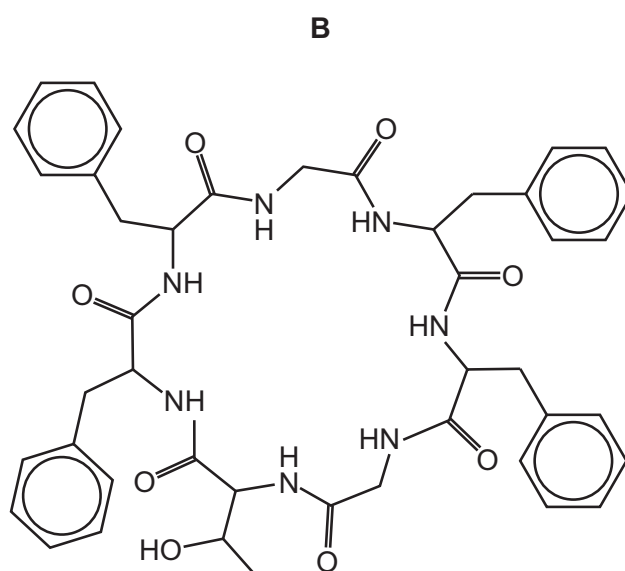
 [2]

- (d) Many polymers are degradable.

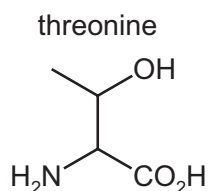
State **two** different processes by which some polymers can be degraded.

.....
 [1]

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



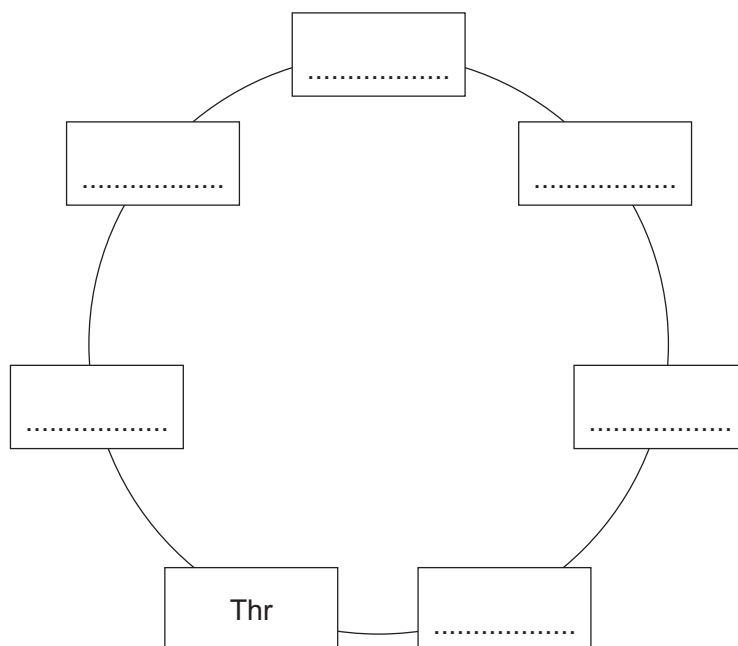
Cyclic peptide **B** is broken into its monomers by heating under reflux with dilute hydrochloric acid. The amino acid threonine, Thr, and two other organic products are formed.



- (i) Draw the structures of the two other organic products formed.

[2]

- (ii) Using the 3-letter abbreviations for the amino acids as given in the *Data Booklet*, complete the sequence for the cyclic peptide, **B**.



[1]

- (iii) Name **two** analytical techniques that could be used to separate these amino acids.

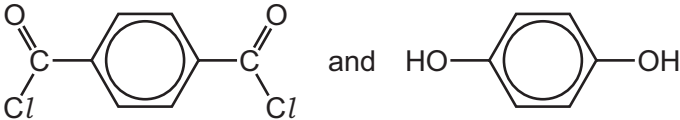
..... and [1]

[Total: 12]

13. Question part 1/2 | 9701 Oct-Nov 2020 P4 V1 Q10

- 10 (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
$\text{HOCH}_2\text{CH}_2\text{OH}$ and $\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$	
	
CH_3CHCF_2 and CH_3CHCH_2	

[1]

- (b)** 2-aminopropanoic acid, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$, 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]

- (ii)** 2-aminopropanoic acid, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$, exists as two stereoisomers.

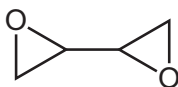
Draw three-dimensional diagrams to show the two stereoisomers of 2-aminopropanoic acid. State the type of stereoisomerism shown.

type of stereoisomerism

[2]

13. Question part 2/2 | 9701 Oct-Nov 2020 P4 V1 Q10

(c) 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.

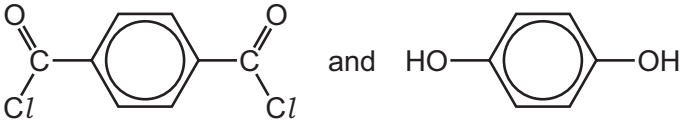
[1]

[Total: 8]

14. Question part 1/2 | 9701 Oct-Nov 2020 P4 V3 Q10

- 10 (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
$\text{HOCH}_2\text{CH}_2\text{OH}$ and $\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$	
	
CH_3CHCF_2 and CH_3CHCH_2	

[1]

- (b)** 2-aminopropanoic acid, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$, 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]

- (ii)** 2-aminopropanoic acid, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$, exists as two stereoisomers.

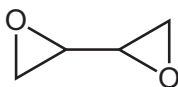
Draw three-dimensional diagrams to show the two stereoisomers of 2-aminopropanoic acid. State the type of stereoisomerism shown.

type of stereoisomerism

[2]

14. Question part 2/2 | 9701 Oct-Nov 2020 P4 V3 Q10

(c) 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.

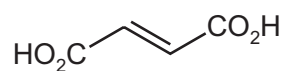
[1]

[Total: 8]

15. Question part 1/3 | 9701 Feb-March 2021 P4 V2 Q6

- 6** Fumaric acid is a naturally occurring dicarboxylic acid.

fumaric acid



- (a)** Identify the products of the reaction between fumaric acid and an excess of hot, concentrated, acidified manganate(VII).

..... [1]

- (b)** Fumaric acid can form addition and condensation polymers.

- (i)** Draw the repeat unit of the addition polymer poly(fumaric acid).

[1]

- (ii)** Draw the repeat unit of the polyester formed when fumaric acid reacts with ethane-1,2-diol, (CH₂OH)₂.

The ester bond should be shown fully displayed.

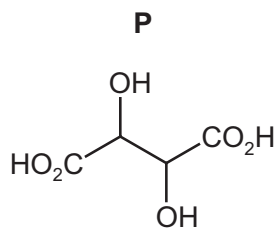
[2]

- (iii)** Explain why polyesters normally biodegrade more readily than polyalkenes.

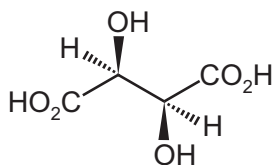
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..... [1]

15. Question part 2/3 | 9701 Feb-March 2021 P4 V2 Q6

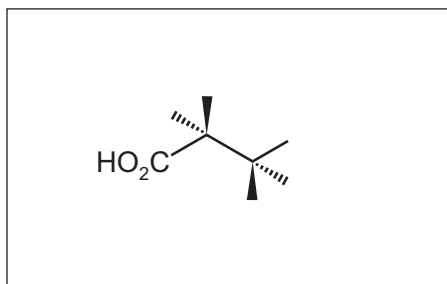
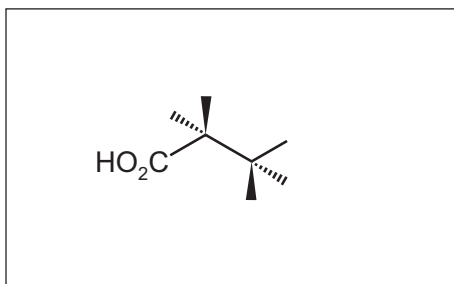
(c) Fumaric acid reacts with cold, dilute, acidified manganate(VII) to form compound **P**.



Only three stereoisomers of **P** exist. One of the stereoisomers is shown.



Complete the three-dimensional diagrams in the boxes to show the **other** two stereoisomers of **P**.



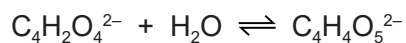
[2]

9701 Chemistry Paper 4 - Polymerisation

Topical questions | 19 questions

15. Question part 3/3 | 9701 Feb-March 2021 P4 V2 Q6

- (d) The enzyme fumarase catalyses the reaction of fumarate ions, $\text{C}_4\text{H}_2\text{O}_4^{2-}$, with water to form malate ions, $\text{C}_4\text{H}_4\text{O}_5^{2-}$.



Describe, with the aid of a suitably labelled diagram, how an enzyme such as fumarase can catalyse a reaction.

.....

.....

.....

.....

[3]

[Total: 10]

16. Question part 1/2 | 9701 May-June 2023 P4 V1 Q6

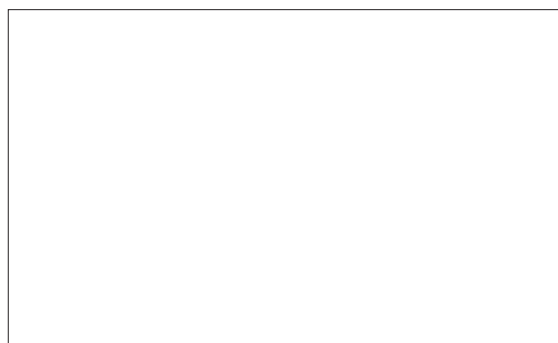
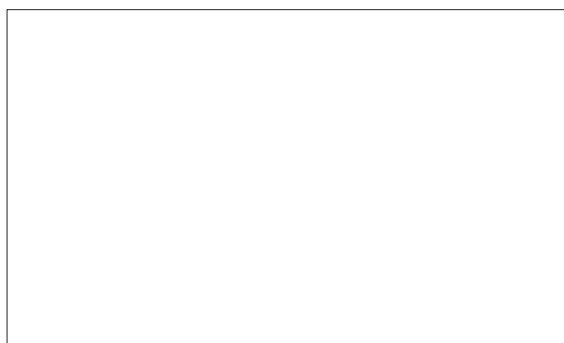
6 (a) Compound **H** has the structural formula $\text{CH}_2=\text{CHCH}(\text{NH}_2)\text{COOH}$.

(i) Name all the functional groups in **H**.

.....
 [2]

(ii) Compound **H** exhibits stereoisomerism.

Draw three-dimensional structures for the two stereoisomers of **H**.
 Name this type of stereoisomerism.



type of stereoisomerism [2]

(b) Compound **H** can be prepared from the reaction of **J** with an excess of hot aqueous acid.

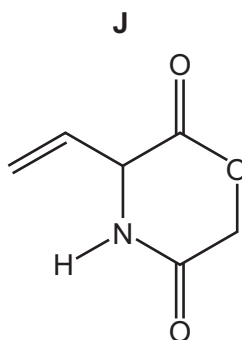


Fig. 6.1

(i) Complete Fig. 6.2 to show the equation for this reaction.

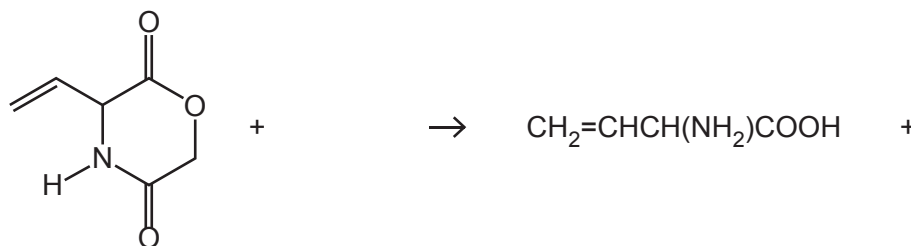


Fig. 6.2

[1]

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16. Question part 2/2 | 9701 May-June 2023 P4 V1 Q6

(ii) Name the type of reaction in (b)(i).

..... [1]

(c) 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]

(iii) Explain why condensation polymers can normally biodegrade more readily than addition polymers.

.....
..... [1]

[Total: 10]

17. Question part 1/3 | 9701 Oct-Nov 2023 P4 V2 Q8

- 8** Lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$, is the only monomer needed to form the polymer polylactic acid, PLA.

- (a) (i)** Draw a short length of the PLA polymer chain, including a minimum of two monomer residues. The methyl groups may be written as $-\text{CH}_3$ but all other bonds should be shown fully displayed.

Label one repeat unit of polylactic acid on your diagram.

[2]

- (ii)** 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]

- (iii)** Predict whether PLA is readily biodegradable. Explain your answer.

.....

..... [1]

- (b)** The proton (^1H) NMR spectrum of $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ in CDCl_3 is shown in Fig. 8.1. The proton NMR chemical shift ranges are shown in Table 8.1.

Lactic acid

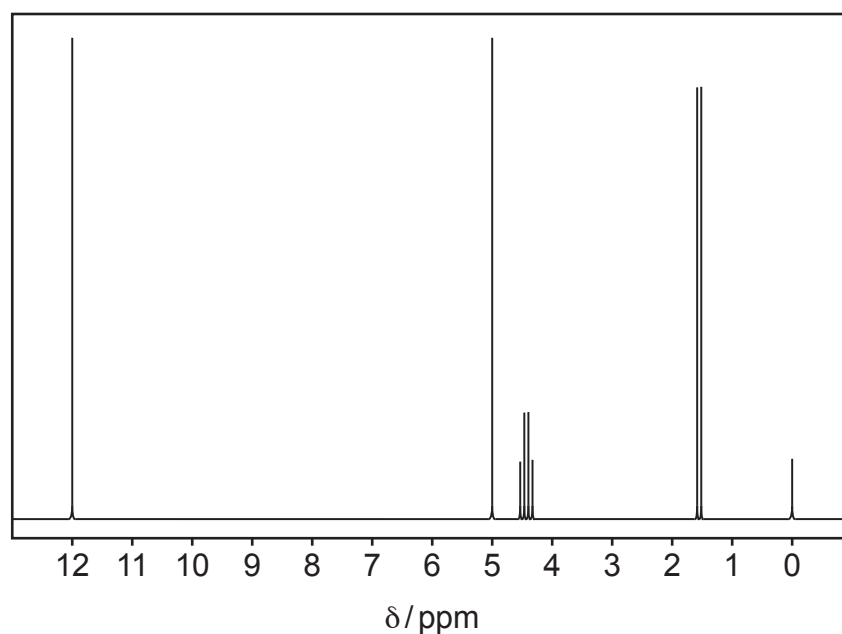


Fig. 8.1

Table 8.1

environment of proton	example	chemical shift range δ /ppm
alkane	$-\text{CH}_3$, $-\text{CH}_2-$, $>\text{CH}-$	0.9–1.7
alkyl next to $\text{C}=\text{O}$	$\text{CH}_3-\text{C}=\text{O}$, $-\text{CH}_2-\text{C}=\text{O}$, $>\text{CH}-\text{C}=\text{O}$	2.2–3.0
alkyl next to aromatic ring	CH_3-Ar , $-\text{CH}_2-\text{Ar}$, $>\text{CH}-\text{Ar}$	2.3–3.0
alkyl next to electronegative atom	CH_3-O , $-\text{CH}_2-\text{O}$, $-\text{CH}_2-\text{Cl}$	3.2–4.0
attached to alkene	$=\text{CHR}$	4.5–6.0
attached to aromatic ring	$\text{H}-\text{Ar}$	6.0–9.0
aldehyde	$\text{H}-\text{COR}$	9.3–10.5
alcohol	ROH	0.5–6.0
phenol	$\text{Ar}-\text{OH}$	4.5–7.0
carboxylic acid	RCOOH	9.0–13.0

(i) Use Fig. 8.1 and Table 8.1 to complete Table 8.2.

Table 8.2

proton environment	chemical shift (δ)	name of splitting pattern
$-\text{COOH}$		
>CH		
$-\text{OH}$		
$-\text{CH}_3$		

[3]

(ii) Name the substance responsible for the peak at $\delta = 0.0$.

..... [1]

(iii) Explain why CDCl_3 is a better solvent than CHCl_3 for use in proton NMR.

.....

..... [1]

- (c) An impure sample of $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ contains pentan-3-one as the only contaminant. The mixture is analysed using gas/liquid chromatography. The pentan-3-one is found to have a longer retention time than the lactic acid.

- (i) Explain what is meant by retention time.

.....
..... [1]

- (ii) Suggest suitable substances, or types of substances, that could be used as the mobile and stationary phases.

mobile phase
stationary phase [1]

- (iii) Describe how the percentage composition of the mixture can be determined from the gas/liquid chromatogram.

.....
..... [1]

[Total: 12]

18. Question part 1/2 | 9701 May-June 2025 P4 V4 Q4

- 4 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**.

Table 4.2

polymer	type of polymerisation	structure of monomer
X		
Y		
Z		

18. Question part 2/2 | 9701 May-June 2025 P4 V4 Q4



(b) Amino acids can act as monomers.

State what is meant by the isoelectric point of an amino acid.

.....

..... [1]

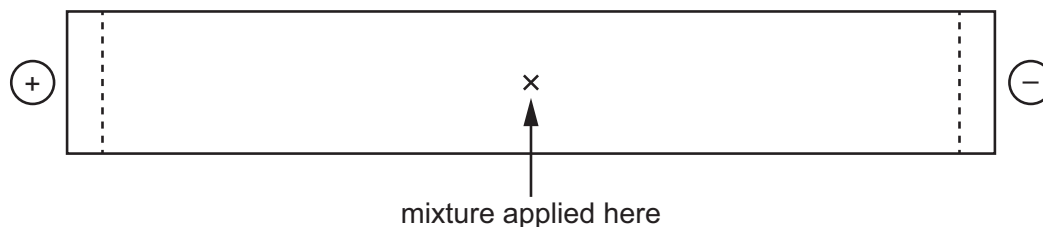
(c) Electrophoresis can be used to separate and identify amino acids.

Table 4.3 shows information about the three amino acids glycine, lysine and glutamic acid.

Table 4.3

amino acid	structural formula of amino acid	isoelectric point
glycine (gly)	$\text{H}_2\text{NCH}_2\text{COOH}$	6.0
lysine (lys)	$\text{H}_2\text{NCH}(\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{COOH}$	9.7
glutamic acid (glu)	$\text{H}_2\text{NCH}(\text{CH}_2\text{CH}_2\text{COOH})\text{COOH}$	3.2

(i) A mixture containing these three amino acids is analysed in a buffer solution of pH 6.0.

Draw and label **three** spots on Fig. 4.1 to indicate the predicted position of each of these amino acids, gly, lys and glu, after electrophoresis.**Fig. 4.1**

[2]

(ii) Electrophoresis is repeated using a buffer solution of pH 11.

Predict how the position of glycine will change, if at all, after electrophoresis.

.....

..... [1]

[Total: 8]

19. Question part 1/4 | 9701 Oct-Nov 2025 P4 V1 Q7

- 7 (a) State the relative acidities of bromoethanoic acid, BrCH_2COOH , chloroethanoic acid, ClCH_2COOH , ethanoic acid, CH_3COOH and ethanol, $\text{CH}_3\text{CH}_2\text{OH}$.

Explain your answer.

.....

most acidic least acidic

.....

.....

.....

.....

.....

.....

.....

[4]

- (b) Fig. 7.1 shows the reaction of methylbenzene and ethanedioic acid with KMnO_4 .

Predict the major carbon-containing product for each of these reactions.

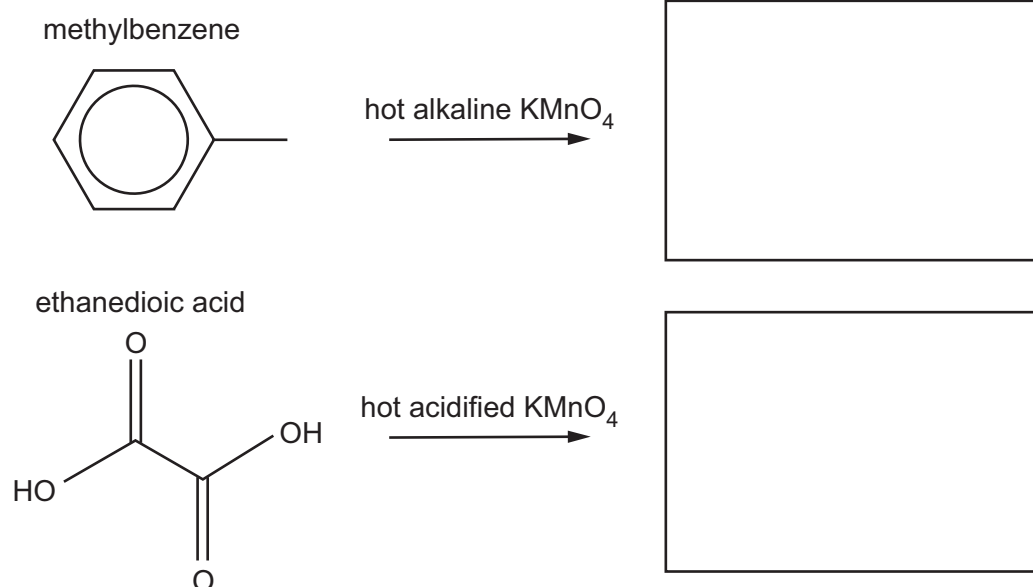


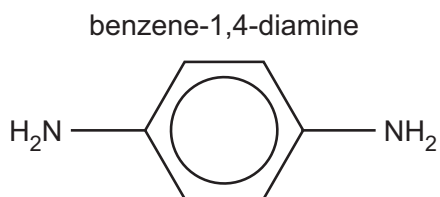
Fig. 7.1

[2]

19. Question part 2/4 | 9701 Oct-Nov 2025 P4 V1 Q7

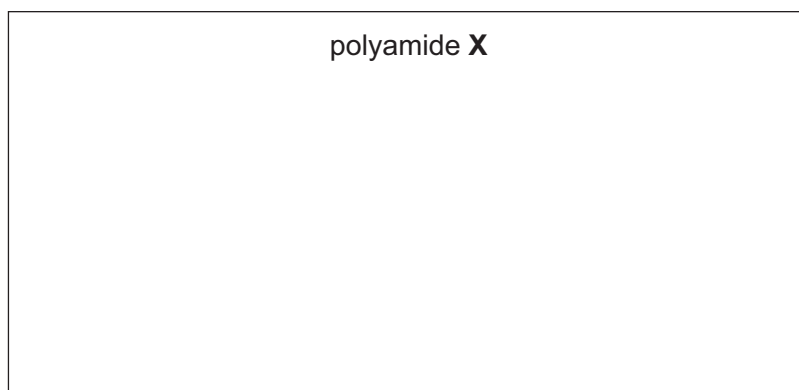


(c) Polyamide **X** can be synthesised from ethanedioic acid and benzene-1,4-diamine.



(i) Draw the repeat unit of polyamide **X** in the box.

The new functional group formed should be shown displayed.

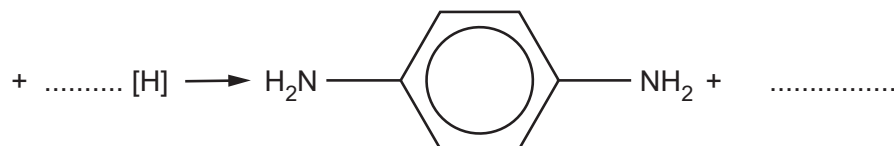


[2]

(ii) Benzene-1,4-diamine can be formed by reduction of 1,4-dinitrobenzene.

Complete the equation for this reduction.

[H] represents one atom of hydrogen from a reducing agent.



[1]

19. Question part 3/4 | 9701 Oct-Nov 2025 P4 V1 Q7

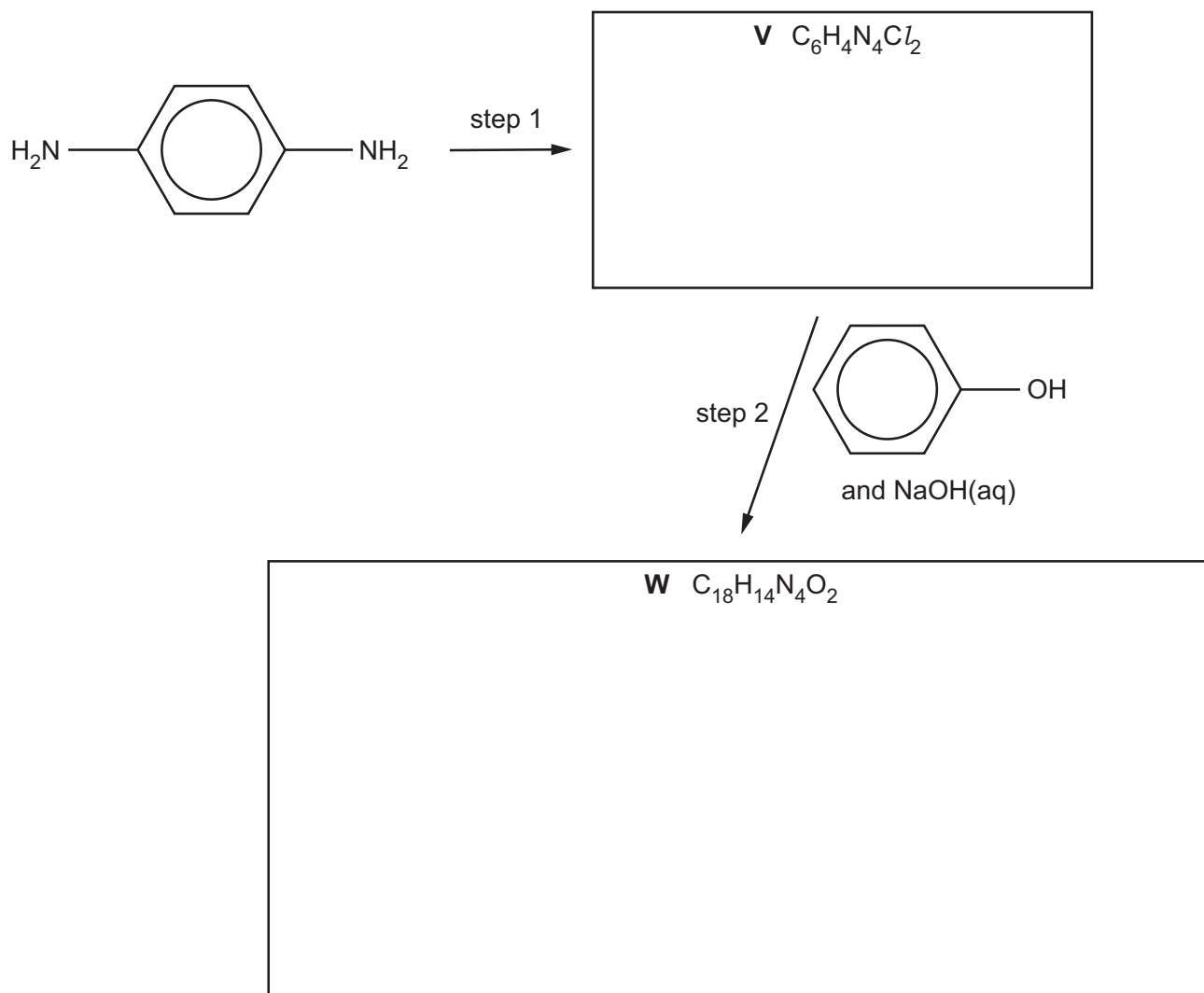
(d) Fig. 7.2 shows the two-step synthesis of the azo compound **W**.

Fig. 7.2

(i) Suggest structures for compounds **V** and **W** and draw them in the boxes in Fig. 7.2. [2]

(ii) Give the reagents and conditions for step 1.

..... [1]

[Total: 12]

9701 Chemistry Paper 4 - Polymerisation

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19. Question part 4/4 | 9701 Oct-Nov 2025 P4 V1 Q7



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