

# **Y13 Chemistry Homework Book 2**

## **Organic Chemistry**

Name:

Teacher:



## Y12-13 Transition

Grade achieved in end of year exam:

My personal target grade:

What am I applying to do at Uni:

What topics I found difficult (and why you think that was the case)



# Optical isomerism and carbonyl chemistry

|  |
|--|
| <b>Optical isomerism</b>   |
| T 1. Draw the structural formulas and displayed formulas of enantiomers  |
| T 2. Understand how racemic mixtures (racemates) are formed and why they are optically inactive                                    |
| <b>Aldehydes and ketones</b>   |
| T 1. Write overall equations for reduction reactions using $[H]$ as the reductant  |
| T 2. Outline the nucleophilic addition mechanism for reduction reactions with $NaBH_4$ (the nucleophile should be shown as $H^-$ ) |
| T 3. Write overall equations for the formation of hydroxynitriles using $HCN$  |
| T 4. Outline the nucleophilic addition mechanism for the reaction with $KCN$ followed by dilute acid                               |
| T 5. Explain why nucleophilic addition reactions of $KCN$ , followed by dilute acid, can produce a mixture of enantiomers          |

Exam booklet reflection:

WWW

EBI

Checked by teacher

Doddle quiz homework:

Aldehydes and ketones

Score:



# A LEVEL CHEMISTRY

## TOPIC 16 – ALDEHYDES, KETONES AND OPTICAL ISOMERISM

### TEST

Answer all questions

Max 50 marks

|  |
|--|
| Name .....                             |
| Mark ...../50    .....%    Grade ..... |

## SECTION A

1. (a) (i) Give a suitable reagent and state the necessary conditions for the conversion of propan-2-ol into propanone. Name the type of reaction.

*Reagent* .....

*Conditions* .....

*Type of reaction* .....

- (ii) Propanone can be converted back into propan-2-ol. Give a suitable reagent and write an equation for this reaction.  
(Use [H] to represent the reagent in your equation.)

*Reagent* .....

*Equation*

.....

(5)

- (b) Propanal is an isomer of propanone.

- (i) Draw the structure of propanal.

- (ii) A chemical test can be used to distinguish between separate samples of propanone and propanal. Give a suitable reagent for the test and describe what you would observe with propanone and with propanal.

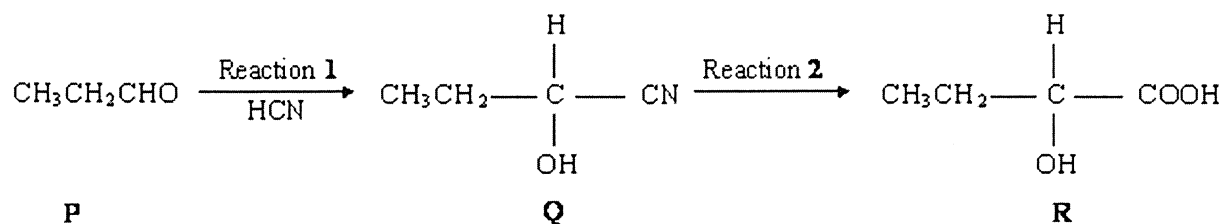
*Test reagent* .....

*Observation with propanone* .....

*Observation with propanone* .....

(4)  
(Total 9 marks)

2. Consider the sequence of reactions below.



- (a) Name and outline a mechanism for Reaction 1.

Name of mechanism .....

Mechanism

(5)

- (b) Name compound Q

.....

(1)

- (c) Draw the structure of the main organic product formed in each case when R reacts separately with the following substances:

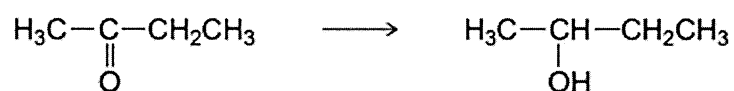
(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

(2)

(Total 8 marks)

3. The reducing agent in the following conversion is  $\text{NaBH}_4$



- (i) Name and outline a mechanism for the reaction.

Name of mechanism .....

Mechanism

(5)

- (ii) By considering the mechanism of this reaction, explain why the product formed is optically inactive.

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(3)

(Total 8 marks)

4. (a) **P**, **Q** and **R** have the molecular formula  $C_6H_{12}$

All three are branched-chain molecules and none is cyclic.

**P** can represent a pair of optical isomers.

**Q** can represent a pair of geometrical isomers.

**R** can represent another pair of geometrical isomers different from **Q**.

Draw one possible structure for one of the isomers of each of **P**, **Q** and **R**.

Structure of **P**

Structure of **Q**

Structure of **R**

(3)

- (b) Butanone reacts with reagent **S** to form compound **T** which exists as a racemic mixture. Dehydration of **T** forms **U**,  $C_5H_7N$ , which can represent a pair of geometrical isomers.

- (i) State the meaning of the term *racemic mixture* and suggest why such a mixture is formed in this reaction.

*Racemic mixture* .....

.....

*Explanation*.....

.....

.....

- (ii) Identify reagent **S**, and draw a structural formula for each of **T** and **U**.

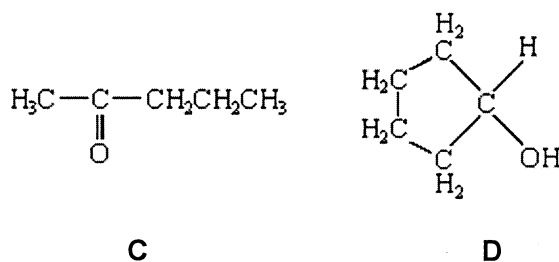
*Reagent S* .....

*Compound T*

*Compound U*

(6)  
(Total 9 marks)

5. Compounds **C** and **D**, shown below, are isomers of  $C_5H_{10}O$



- (a) Name compound **C**.

.....

(1)

- (b) Use **Table 2** on the Data Sheet to help you to answer this question.

- (i) Suggest the wavenumber of an absorption which is present in the infra-red spectrum of **C** but not in that of **D**.

.....

- (ii) Suggest the wavenumber of an absorption which is present in the infra-red spectrum of **D** but not in that of **C**.

.....

(2)

- (c) Identify a reagent that you could use to distinguish between **C** and **D**. For each of **C** and **D**, state what you would observe when the compound is treated with this reagent.

Reagent .....

Observation with **C** .....

Observation with **D** .....

(3)

- (d) Compound **E**,  $CH_3CH_2CH_2CH_2CHO$ , is also an isomer of  $C_5H_{10}O$

Identify a reagent which will react with **E** but not with **C** or **D**. State what you would observe when **E** is treated with this reagent.

Reagent .....

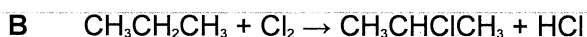
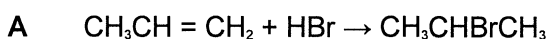
Observation with **E** .....

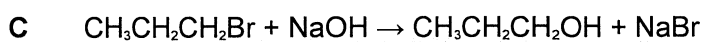
(2)

(Total 8 marks)

## SECTION B

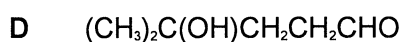
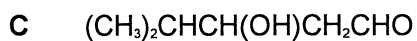
6. Which one of the following reactions involves nucleophilic addition?





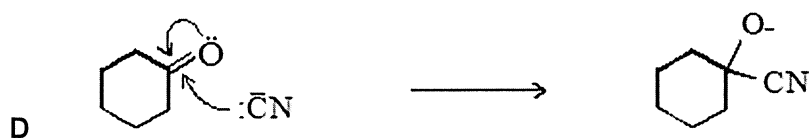
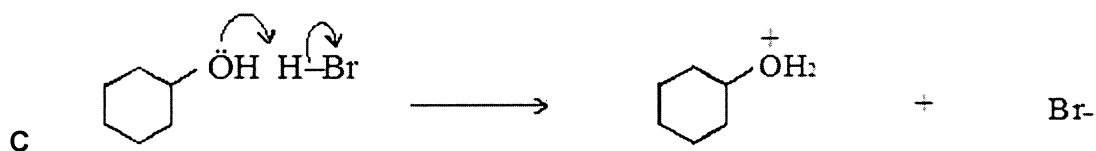
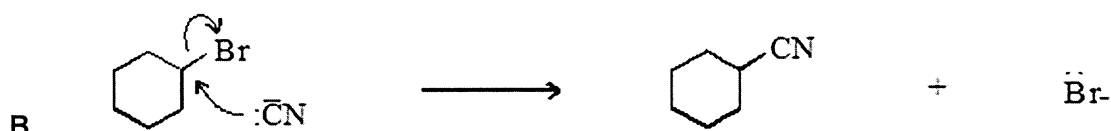
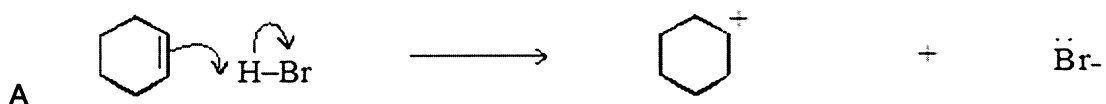
(Total 1 mark)

7. Which one of the following isomers is not oxidised under mild reaction conditions?



(Total 1 mark)

8. In which one of the following are the curly arrows **not** used correctly?



(Total 1 mark)

9. Which one of the following is **not** a suitable method for the preparation of ethanol?

- A oxidation of ethane
- B hydration of ethene
- C reduction of ethanal
- D hydrolysis of bromoethane

(Total 1 mark)

10. Which one of the following will undergo nucleophilic addition?

- A hex-3-ene
- B hexan-3-one
- C 3-bromohexane
- D hexan-3-ol

(Total 1 mark)

11. How many structural isomers, which are aldehydes, have the molecular formula  $C_5H_{10}O$ ?

- A 2
- B 3
- C 4
- D 5

(Total 1 mark)

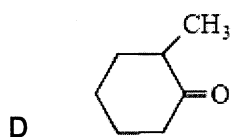
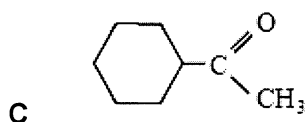
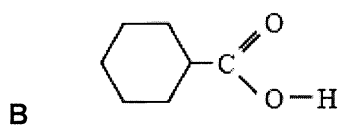
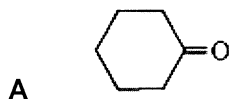
12. On reduction, a racemate can be formed by

- A  $CH_3CH_2CH_2CH_2CHO$
- B  $CH_3CH_2CH_2COCH_3$
- C  $CH_3CH_2COCH_2CH_3$
- D  $CH_3CH=CHCH_2CHO$

(Total 1 mark)

13. The compound lithium tetrahydridoaluminate(III),  $\text{LiAlH}_4$ , is a useful reducing agent. It behaves in a similar fashion to  $\text{NaBH}_4$ . Carbonyl compounds and carboxylic acids are reduced to alcohols. However,  $\text{LiAlH}_4$  also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following can be reduced by  $\text{LiAlH}_4$  to a primary alcohol?



(Total 1 mark)



# Carboxylic acids, esters, and amines

|   |
|---|
| <b>Carboxylic acids and derivatives</b>   |
| <b>T</b> 1. Carboxylic acids are weak acids but will liberate CO <sub>2</sub> from carbonates.  |
| <b>T</b> 2. Carboxylic acids and alcohols react, in the presence of an acid catalyst, to give esters.   |
| <b>T</b> 3. Common uses of esters (eg in solvents, plasticisers, perfumes and food flavourings).  |
| <b>T</b> 4. Vegetable oils and animal fats are esters of propane-1,2,3-triol (glycerol).  |
| <b>T</b> 5. Esters can be hydrolysed in acid or alkaline conditions to form alcohols and carboxylic acids or salts of carboxylic acids.   |
| <b>T</b> 6. Vegetable oils and animal fats can be hydrolysed in alkaline conditions to give soap (salts of long-chain carboxylic acids) and glycerol.   |
| <b>T</b> 7. Biodiesel is a mixture of methyl esters of long-chain carboxylic acids.   |
| <b>T</b> 8. Biodiesel is produced by reacting vegetable oils with methanol in the presence of a catalyst.   |
| <b>Acylation</b>  |
| <b>T</b> 1. Outline the mechanism of nucleophilic addition–elimination reactions of acyl chlorides with water, alcohols, ammonia and primary amines.  |
| <b>Amines</b>   |
| <b>T</b> 1. Primary aliphatic amines can be prepared by the reaction of ammonia with halogenoalkanes and by the reduction of nitriles.  |
| <b>T</b> 2. Aromatic amines, prepared by the reduction of nitro compounds, are used in the manufacture of dyes.   |
| <b>T</b> 3. Explain the difference in base strength between ammonia, primary aliphatic amines and primary aromatic amines in terms of the availability of the lone pair of electrons on the N atom. |
| <b>T</b> 4. Outline the mechanisms of ammonia and amines with halogenoalkanes to form primary, secondary, tertiary amines and quaternary ammonium salts.  |
| <b>T</b> 5. The use of quaternary ammonium salts as cationic surfactants.   |
| <b>T</b> 6. Outline the mechanisms of the nucleophilic addition–elimination reactions of ammonia and primary amines with acyl chlorides.  |

Exam booklet reflection:

WWW

EBI

Checked by teacher

Doddle quiz homework:

Amines

Score:

Carboxylic acids,

Score:

esters and acylation



# A LEVEL CHEMISTRY

## TOPIC 17 – CARBOXYLIC ACIDS, AMINES, ESTERS AND ACYLATION

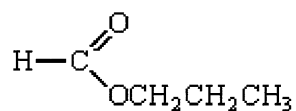
### TEST

Answer all questions

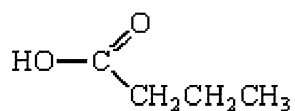
Max 50 marks

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|------|----------|--------|-------------|
| Name | .....    |        |             |
| Mark | ...../50 | .....% | Grade ..... |

1. (a) Consider the following pair of isomers.



**C**



**D**

- (i) Name compound **C**.

.....

- (ii) Identify a reagent which could be used in a test-tube reaction to distinguish between **C** and **D**. In each case, state what you would observe.

*Reagent* .....

*Observation with C* .....

*Observation with D*.....

**(4)**  
**(Total 4 marks)**

2. (a) Write an equation for the formation of methyl propanoate,  $\text{CH}_3\text{CH}_2\text{COOCH}_3$ , from methanol and propanoic acid.

.....

(1)

- (b) Name and outline a mechanism for the reaction between methanol and propanoyl chloride to form methyl propanoate.

*Name of mechanism* .....

*Mechanism*

(5)

- (c) Propanoic anhydride could be used instead of propanoyl chloride in the preparation of methyl propanoate from methanol. Draw the structure of propanoic anhydride.

(1)

- (d) (i) Give **one** advantage of the use of propanoyl chloride instead of propanoic acid in the laboratory preparation of methyl propanoate from methanol.

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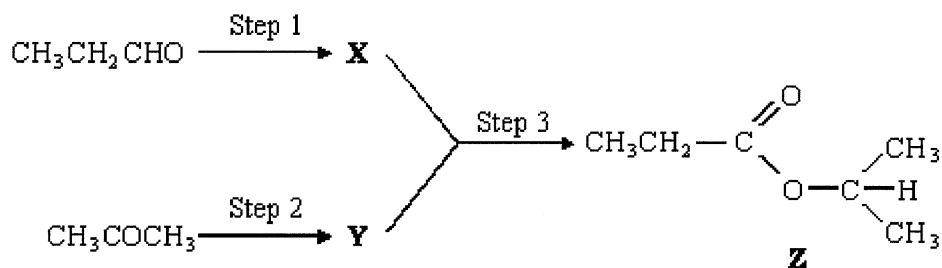
- (ii) Give **one** advantage of the use of propanoic anhydride instead of propanoyl chloride in the industrial manufacture of methyl propanoate from methanol.

.....

.....

(2)

(Total 9 marks)



For each of the three steps in the synthesis, name the type of reaction involved and give reagents and conditions. Equations are **not** required.

[illegible]

p

4. This question is about the primary amine  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$

(a) The amine  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$  reacts with  $\text{CH}_3\text{COCl}$

Name and outline a mechanism for this reaction.

Give the IUPAC name of the organic product.

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 .....

(6)

(b) Isomers of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$  include another primary amine, a secondary amine and a tertiary amine.

(i) Draw the structures of these **three** isomers.  
 Label each structure as primary, secondary or tertiary.

(3)

(ii) Use **Table 1** on the Data Sheet to explain how you could use infrared spectra in the range outside the fingerprint region to distinguish between the secondary amine and the tertiary amine.

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 .....  
 .....  
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(2)

Route **B** is a one-stage process and starts from  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ .

- (i) Identify the intermediate compound in Route A.

Give the reagents and conditions for both stages in Route **A** and the single stage in Route **B**.

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(7)

- (ii) Give **one** disadvantage of Route **A** and **one** disadvantage of Route **B**.

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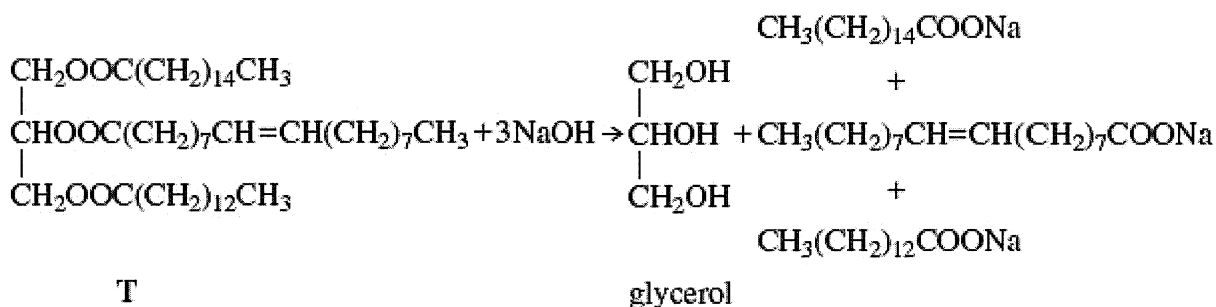
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**(2)**

(Total 20 marks)

5. The triester, **T**, shown below is found in palm oil. When **T** is heated with an excess of sodium hydroxide solution, the alcohol glycerol is formed together with a mixture of three other products as shown in the following equation.



- (a) (i) Give the IUPAC name for glycerol.

.....

(1)

- (ii) Give a use for the mixture of sodium salts formed in this reaction.

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(1)

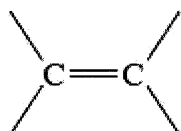
- (b) When **T** is heated with an excess of methanol, glycerol is formed together with a mixture of methyl esters.

- (i) Give a use for this mixture of methyl esters.

.....

(1)

- (ii) One of the methyl esters in the mixture has the IUPAC name methyl (Z)-octadec-9-enoate. Draw **two** hydrogen atoms on the diagram below to illustrate the meaning of the letter Z in the name of this ester.



(1)

- (iii) One of the other methyl esters in the mixture has the formula  $\text{CH}_3(\text{CH}_2)_{12}\text{COOCH}_3$ . Write an equation for the complete combustion of one molecule of this ester.

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(1)

(Total 5 marks)

6. Describe briefly how you could measure the melting point of aspirin.

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**(Total 2 marks)**

# Aromatic Chemistry

|   |
|---|
| Aromatic chemistry  |
| T 1. Use thermochemical evidence from enthalpies of hydrogenation to account for this extra stability             |
| T 2. Explain why substitution reactions occur in preference to addition reactions.                                |
| T 3. Outline the electrophilic substitution mechanism of nitration, including the generation of the nitronium ion |
| T 4. Outline the electrophilic substitution mechanism of acylation using $\text{AlCl}_3$ as a catalyst            |

Exam booklet reflection:

WWW

EBI

Checked by teacher

Doddle quiz homework:

**Aromatic Chemistry**

**Score:**

**Arenes**

**Score:**

**Phenols**

**Score:**



# A LEVEL CHEMISTRY

## TOPIC 18 – AROMATIC CHEMISTRY

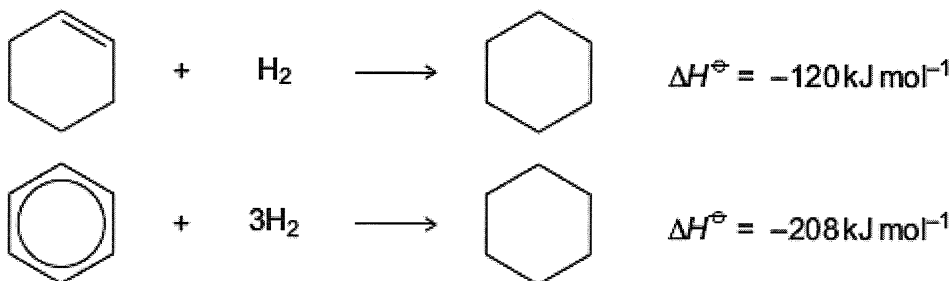
### TEST

Answer all questions

Max 50 marks

|      |          |        |             |
|------|----------|--------|-------------|
| Name | .....    |        |             |
| Mark | ...../50 | .....% | Grade ..... |

1. The hydrocarbons benzene and cyclohexene are both unsaturated compounds. Benzene normally undergoes substitution reactions, but cyclohexene normally undergoes addition reactions.
- (a) The molecule cyclohexatriene does not exist and is described as hypothetical. Use the following data to state and explain the stability of benzene compared with the hypothetical cyclohexatriene.



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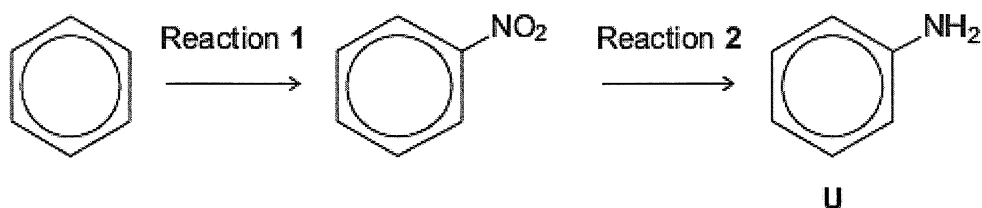
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(4)

(b) Benzene can be converted into amine **U** by the two-step synthesis shown below.



The mechanism of Reaction 1 involves attack by an electrophile.

Give the reagents used to produce the electrophile needed in Reaction 1.

Write an equation showing the formation of this electrophile.

Outline a mechanism for the reaction of this electrophile with benzene.

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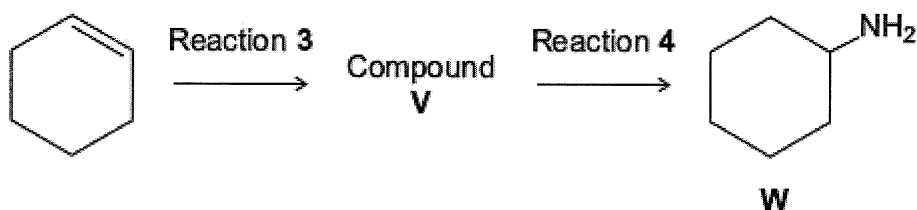
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(6)

- (c) Cyclohexene can be converted into amine **W** by the two-step synthesis shown below.



Suggest an identity for compound **V**.

For Reaction **3**, give the reagent used and name the mechanism.

For Reaction **4**, give the reagent and condition used and name the mechanism.

Equations and mechanisms with curly arrows are **not** required.

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(6)

- (d) Explain why amine **U** is a weaker base than amine **W**.

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(3)

(Total 19 marks)

2. Give a reagent that could be used in a test-tube reaction to distinguish between benzene and cyclohexene.  
Describe what you would see when the reagent is added to each compound and the test tube is shaken.

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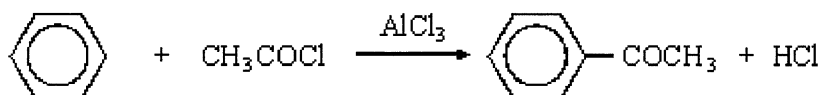
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(3)  
(Total 3 marks)

3. An equation for the formation of phenylethanone is shown below. In this reaction a reactive intermediate is formed from ethanoyl chloride. This intermediate then reacts with benzene.



- (i) Give the formula of the reactive intermediate.
- .....
- (ii) Outline a mechanism for the reaction of this intermediate with benzene to form phenylethanone.

(4)  
(Total 4 marks)

4. (a) Outline a mechanism for the formation of ethylamine from bromoethane. State why the ethylamine formed is contaminated with other amines. Suggest how the reaction conditions could be modified to minimise this contamination.

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(6)

- (b) Suggest one reason why phenylamine cannot be prepared from bromobenzene in a similar way. Outline a synthesis of phenylamine from benzene. In your answer you should give reagents and conditions for each step, but equations and mechanisms are not required.

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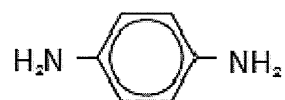
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(5)

(Total 11 marks)

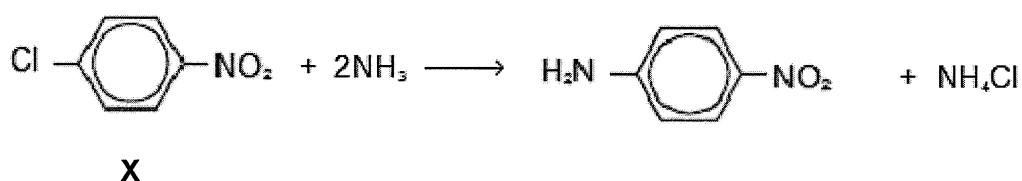
5. Kevlar is a polymer used in protective clothing.

One of the monomers used in the synthesis of Kevlar is



An industrial synthesis of this monomer uses the following two-stage process starting from compound **X**.

Stage 1



Stage 2



- (a) Suggest why the reaction of ammonia with **X** in Stage 1 might be considered unexpected.

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.....

(2)

- (b) Suggest a combination of reagents for the reaction in Stage 2.

.....

(1)

- (c) Compound **X** can be produced by nitration of chlorobenzene.

Give the combination of reagents for this nitration of chlorobenzene.  
Write an equation or equations to show the formation of a reactive intermediate from these reagents.

Reagents .....

.....

Equation(s) .....

.....

**(3)**

- (d) Name and outline a mechanism for the formation of **X** from chlorobenzene and the reactive intermediate in part (iii).

Name of mechanism .....

Mechanism

**(4)**

**(Total 10 marks)**

6. Which one of the following does **not** contain any delocalised electrons?

- A poly(propene)
- B benzene
- C graphite
- D sodium

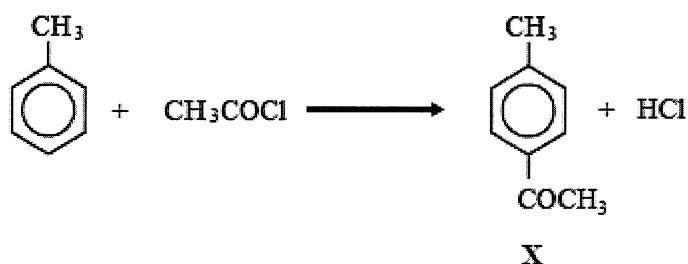
(Total 1 mark)

7. The relative molecular mass ( $M_r$ ) of benzene-1,4-dicarboxylic acid is

- A 164
- B 166
- C 168
- C 170

(Total 1 mark)

8. Ethanoyl chloride reacts with methylbenzene forming compound X according to the equation below.



If the experimental yield is 40.0%, the mass in grams of X ( $M_r = 134.0$ ) formed from 18.4 g of methylbenzene ( $M_r = 92.0$ ) is

- A 26.8
- B 16.1
- C 10.7
- D 7.4

(Total 1 mark)



# Polymers and Biochemistry

|  |
|--|
| <b>Polymers</b>  |
| <b>T</b> 1. Draw the repeating unit of a condensation polymer from monomer structure(s)  |
| <b>T</b> 2. Draw the repeating unit from a section of the condensation polymer chain   |
| <b>T</b> 3. Draw the structure(s) of the monomer(s) from a section of the polymer  |
| <b>T</b> 4. Explain the nature of the intermolecular forces between molecules of condensation polymers.  |
| <b>T</b> 5. Explain why polyesters and polyamides can be hydrolysed but polyalkenes cannot.  |
| <b>T</b> 6. The advantages and disadvantages of different methods of disposal of polymers, including recycling.  |
| <b>Amino acids, proteins and DNA</b>   |
| <b>T</b> 1. Draw the structures of amino acids as zwitterions and the ions formed from amino acids in acid solution  |
| <b>T</b> 2. Draw the structures of amino acids as zwitterions and the ions formed from amino acids in alkaline solution  |
| <b>T</b> 3. Draw the structure of a peptide formed from up to three amino acids  |
| <b>T</b> 4. Draw the structure of the amino acids formed by hydrolysis of a peptide  |
| <b>T</b> 5. Identify primary, secondary and tertiary structures in diagrams  |
| <b>T</b> 6. Explain how these structures are maintained by hydrogen bonding and S–S bonds  |
| <b>T</b> 7. Calculate $R_f$ values for amino acids from a chromatogram.  |
| <b>T</b> 8. The action of enzymes as catalysts, including the concept of a stereospecific active site that binds to a substrate molecule.                                  |
| <b>T</b> 9. Explain why a stereospecific active site can only bond to one enantiomeric form of a substrate or drug.  |
| <b>T</b> 10. A nucleotide is made up from a phosphate ion bonded to 2-deoxyribose which is in turn bonded to one of the four bases adenine, cytosine, guanine and thymine. |
| <b>T</b> 11. Explain how hydrogen bonding between base pairs leads to the two complementary strands of DNA.  |
| <b>T</b> 12. Explain why cisplatin prevents DNA replication  |
| <b>T</b> 13. Explain why such drugs can have adverse effects.  |

Exam booklet reflection:

WWW

EBI

Checked by teacher

Doddle quiz homework:

**Polyesters and amides**

**Score:**

**Polymers**

**Score:**



# A LEVEL CHEMISTRY

## TOPIC 19 – AMINO ACIDS, POLYMERS, ORGANIC SYNTHESIS AND BIOCHEMISTRY

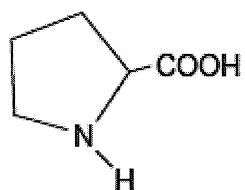
### TEST

Answer all questions

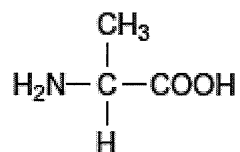
Max 50 marks

|      |          |        |             |
|------|----------|--------|-------------|
| Name | .....    |        |             |
| Mark | ...../50 | .....% | Grade ..... |

1. (a) The structures and common names of two amino acids are shown.



proline



alanine

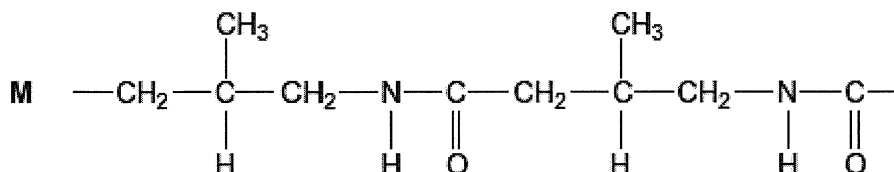
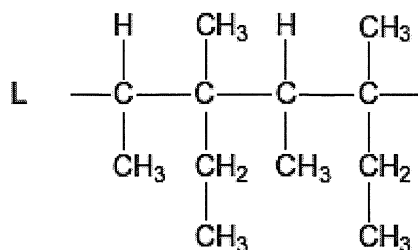
- (i) Draw the structure of the zwitterion of proline.

(1)

- (ii) Draw the structure of the tripeptide formed when a proline molecule bonds to two alanine molecules, one on each side.

(2)

- (b) Sections of two polymers, **L** and **M**, are shown.



- (i) Give the IUPAC name of a monomer that forms polymer **L**.

.....

(1)

- (ii) Give the IUPAC name of the monomer that forms polymer **M**.

.....

(1)

- (iii) Draw the section of a polymer made from a dicarboxylic acid and a diamine that is isomeric with the section of polymer **M** shown.

(1)

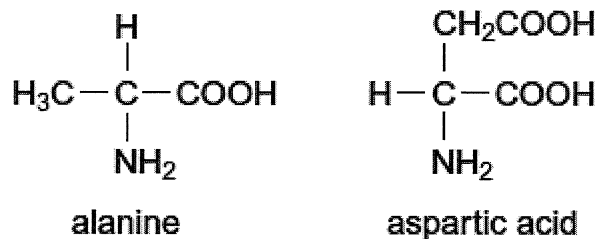
- (vi) Explain why polymer **L** is non-biodegradable.

.....  
 .....  
 .....

(1)

(Total 7 marks)

2. Alanine and aspartic acid are naturally occurring amino acids.



- (a) Draw the structure of the zwitterion formed by alanine.

(1)

- (b) Draw the structure of the compound formed when alanine reacts with methanol in the presence of a small amount of concentrated sulfuric acid.

(1)

- (c) Draw the structure of the species formed by aspartic acid at high pH.

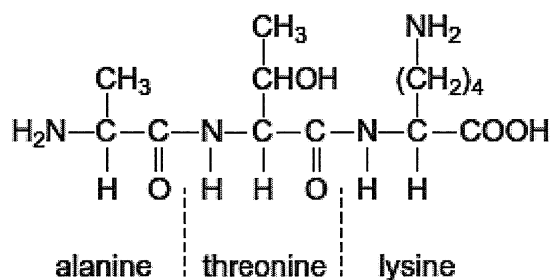
(1)

- (d) Draw the structure of a dipeptide formed by two aspartic acid molecules.

(1)

(Total 4 marks)

3. (a) The tripeptide shown is formed from the amino acids alanine, threonine and lysine.



- (i) Draw a separate circle around **each** of the asymmetric carbon atoms in the tripeptide.

(1)

- (ii) Draw the zwitterion of alanine.

(1)

- (iii) Give the IUPAC name of threonine.

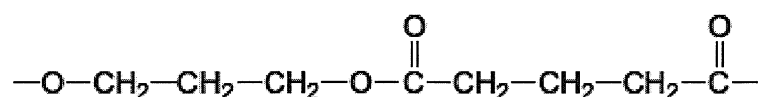
.....

(1)

- (iv) Draw the species formed by lysine at low pH.

(1)

- (b) The repeating unit shown represents a polyester.



- (i) Name this type of polymer.

.....

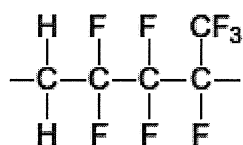
(1)

- (ii) Give the IUPAC name for the alcohol used to prepare this polyester.

.....

(1)

- (c) The repeating unit shown represents a polyalkene co-polymer. This co-polymer is made from two different alkene monomers.



- (i) Name the type of polymerisation occurring in the formation of this co-polymer.

.....

(1)

- (ii) Draw the structure of each alkene monomer.

Alkene monomer 1

Alkene monomer 2

(2)

- (d) One of the three compounds shown in parts (a), (b) and (c) cannot be broken down by hydrolysis.

Write the letter **(a)**, **(b)** or **(c)** to identify this compound and explain why hydrolysis of this compound does **not** occur.

Compound .....

Explanation .....

.....

.....

(2)

(Total 11 marks)

4. (a) The compound  $\text{H}_2\text{C}=\text{CHCN}$  is used in the formation of acrylic polymers.

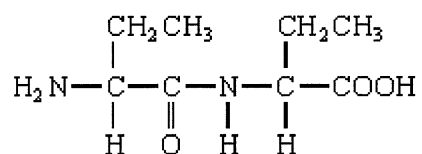
(i) Draw the repeating unit of the polymer formed from this compound.

(ii) Name the type of polymerisation involved in the formation of this polymer.

.....

(2)

- (b) When the dipeptide shown below is heated under acidic conditions, a single amino acid is produced.



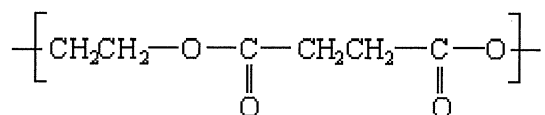
(i) Name this amino acid.

.....

(ii) Draw the structure of the amino acid species present in the acidic solution.

(2)

(c) The repeating unit of a polyester is shown below.



(i) Deduce the empirical formula of the repeating unit of this polyester.

.....

(ii) Draw the structure of the acid which could be used in the preparation of this polyester and give the name of this acid.

*Structure* .....

*Name* .....

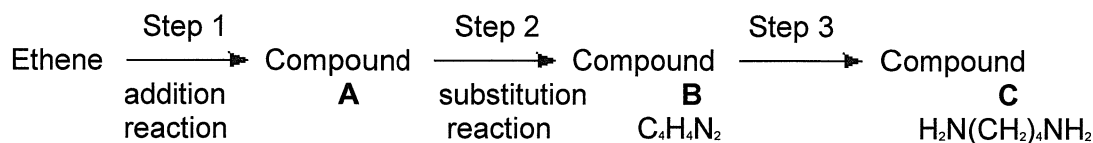
(iii) Give **one** reason why the polyester is biodegradable.

.....

.....

(4)  
(Total 8 marks)

5. (a) Compound **C**,  $\text{H}_2\text{N}(\text{CH}_2)_4\text{NH}_2$ , can be synthesised from ethene in three steps as shown below.



Name compound **C** and draw a structure for each of compounds **A** and **B**.  
 State the reagent(s) required for each step and name the type of reaction involved in the conversion of **B** into **C**.

.....

.....

.....

.....

.....

.....

.....

.....

(7)

- (b) Draw the repeating unit of the polyamide formed when **C** reacts with hexanedioic acid. Discuss the interactions between the chains of the polyamide.

.....

.....

.....

.....

(4)

- (c) Explain why polyamides are degraded by sodium hydroxide whereas polymers such as poly(ethene) are not.

.....

.....

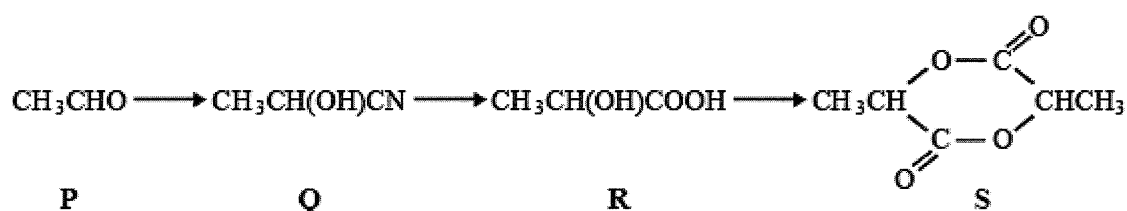
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(3)

(Total 14 marks)

- 6.** This question refers to the reaction sequence below.

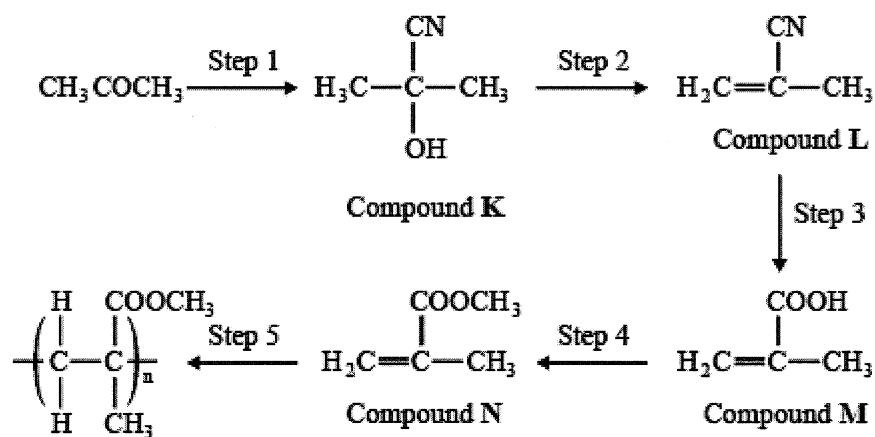


Which one of the following is **not** involved in the reaction sequence?

- A** esterification  
**B** hydrolysis  
**C** nucleophilic addition  
**D** reduction

**(Total 1 mark)**

7. This question concerns the preparation of the plastic poly(methyl 2-methylpropenoate) (*Perspex*), starting from propanone.

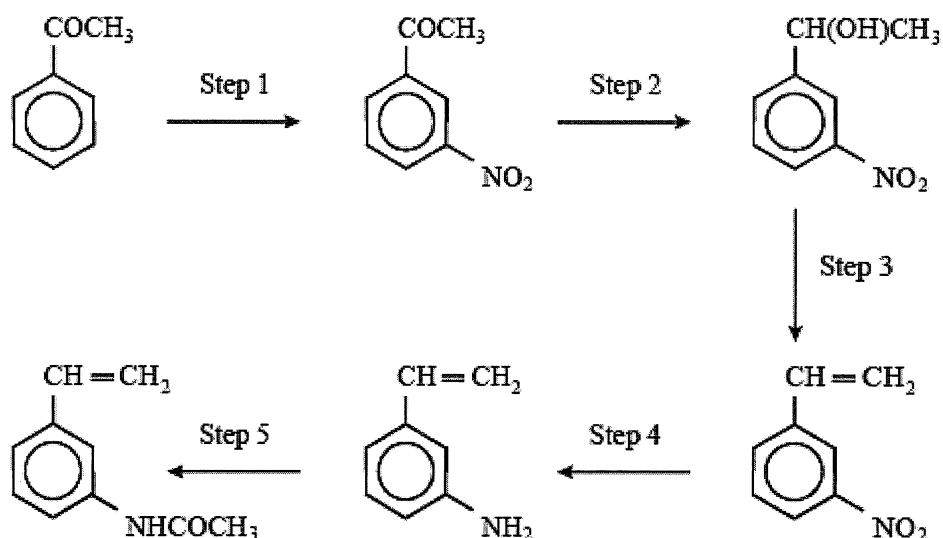


Which one of the following sets of reagents is **not** suitable for the step indicated?

- A** Step 1 HCN (NaCN then dilute HCl)
- B** Step 2 hot ethanolic KOH
- C** Step 3 warm aqueous H<sub>2</sub>SO<sub>4</sub>
- D** Step 4 CH<sub>3</sub>OH with an acid catalyst

**(Total 1 mark)**

Refer to the following reaction sequence for Questions 8, 9 and 10:



8. Which one of the following types of reaction is **not** involved in the above sequence?

- A acylation
- B oxidation
- C reduction
- D dehydration

(Total 1 mark)

9. Which one of the following types of reaction mechanism is **not** involved in the above sequence?

- A electrophilic addition
- B electrophilic substitution
- C addition-elimination
- D elimination

(Total 1 mark)

10. Which one of the following would be the most appropriate to carry out Step 2?

- A  $\text{H}_2$  / Ni
- B Sn / HCl
- C  $\text{NaBH}_4$
- D Fe / HCl

(Total 1 mark)

11. Terylene is made by reacting benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Terylene is

- A an addition polymer.
- B a polyamide.
- C a polyester.
- D a nylon.

**(Total 1 mark)**

# Spectroscopy and organic synthesis

|   |
|---|
| <b>Organic synthesis</b>  |
| <b>T 1.</b> Explain why chemists aim to design processes that do not require a solvent and that use non-hazardous starting materials  |
| <b>T 2.</b> Explain why chemists aim to design production methods with fewer steps that have a high percentage atom economy   |
| <b>T 3.</b> Use reactions in this specification to devise a synthesis, with up to four steps, for an organic compound   |
| <b>NMR spectroscopy</b>   |
| <b>T 1.</b> Explain why TMS is a suitable substance to use as a standard  |
| <b>T 2.</b> Use $^1\text{H}$ NMR and $^{13}\text{C}$ NMR spectra and chemical shift data from the Chemistry Data Booklet to suggest possible structures or part structures for molecules      |
| <b>T 3.</b> Use integration data from $^1\text{H}$ NMR spectra to determine the relative numbers of equivalent protons in the molecule  |
| <b>T 4.</b> Use the $n+1$ rule to deduce the spin-spin splitting patterns of adjacent, non-equivalent protons, limited to doublet, triplet and quartet formation in aliphatic compounds.      |
| <b>Chromatography</b>   |
| <b>T 1.</b> Describe thin-layer chromatography (TLC) – a plate is coated with a solid and a solvent moves up the plate  |
| <b>T 2.</b> Describe column chromatography (CC) – a column is packed with a solid and a solvent moves down the column   |
| <b>T 3.</b> Describe gas chromatography (GC) – a column is packed with a solid or with a solid coated by a liquid, and a gas is passed through the column under pressure at high temperature. |
| <b>T 4.</b> Understand that separation depends on the balance between solubility in the moving phase and retention by the stationary phase.   |
| <b>T 5.</b> The use of mass spectrometry to analyse the components separated by GC.   |
| <b>T 6.</b> Calculate $R_f$ values from a chromatogram  |
| <b>T 7.</b> Compare retention times and $R_f$ values with standards to identify different substances.   |

Exam booklet reflection:

WWW

EBI

Checked by teacher

Doddle quiz homework:

**NMR**

**Score:**

**Chromatography**

**Score:**

**Synthesis and analysis**

**Score:**



# A LEVEL CHEMISTRY

## TOPIC 20 – CHROMATOGRAPHY AND SPECTROSCOPY

### TEST

Answer all questions

Max 50 marks

Name .....

Mark ...../50 .....% Grade .....

1. A tripeptide was heated with hydrochloric acid and a mixture of amino acids was formed. This mixture was separated by column chromatography. Outline briefly why chromatography is able to separate a mixture of compounds. Practical details are **not** required.

.....

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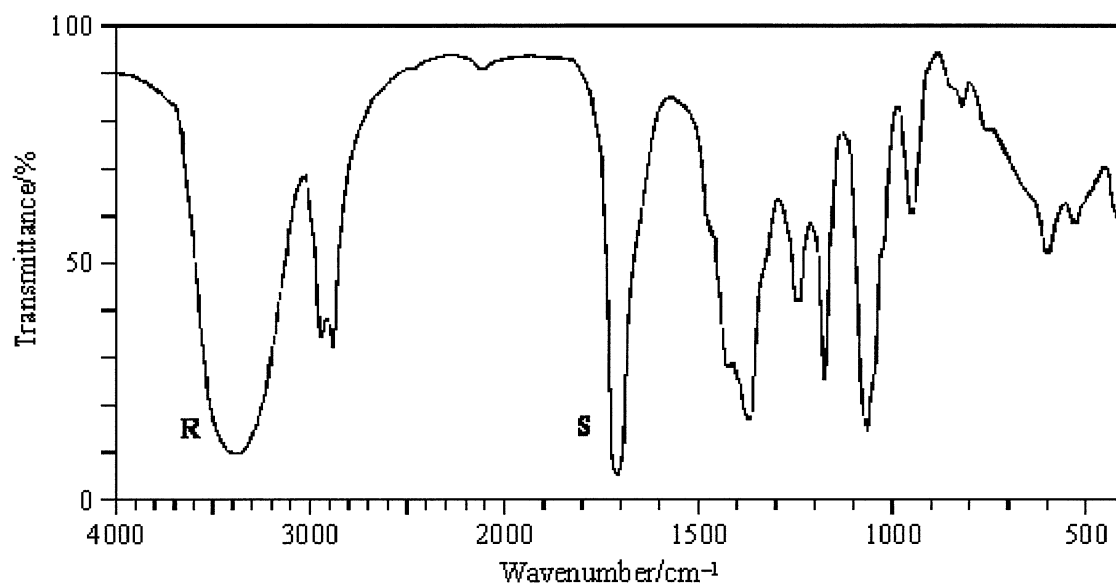
.....

(3)  
(Total 3 marks)

2. Spectral data for use in this question are provided below the Periodic Table (first item on the database).

Compound **Q** has the molecular formula  $C_4H_8O_2$

- (a) The infra-red spectrum of **Q** is shown below.



Identify the type of bond causing the absorption labelled **R** and that causing the absorption labelled **S**.

**R** .....

**S** .....

(2)

- (b) **Q** does not react with Tollens' reagent or Fehling's solution. Identify a functional group which would react with these reagents and therefore cannot be present in **Q**.

.....

(1)

- (c) Proton n.m.r. spectra are recorded using a solution of a substance to which tetramethylsilane (TMS) has been added.

- (i) Give two reasons why TMS is a suitable standard.

Reason 1 .....

Reason 2 .....

- (ii) Give an example of a solvent which is suitable for use in recording an n.m.r. spectrum. Give a reason for your choice.

Solvent .....

Reason .....

(4)

- (d) The proton n.m.r. spectrum of **Q** shows 4 peaks.

The table below gives  $\delta$  values for each of these peaks together with their splitting patterns and integration values.

|                     |         |         |         |         |
|---------------------|---------|---------|---------|---------|
| $\delta/\text{ppm}$ | 2.20    | 2.69    | 3.40    | 3.84    |
| Splitting pattern   | singlet | triplet | singlet | triplet |
| Integration value   | 3       | 2       | 1       | 2       |

What can be deduced about the structure of **Q** from the presence of the following in its n.m.r. spectrum?

- (i) The singlet peak at  $\delta = 2.20$

.....

- (ii) The singlet peak at  $\delta = 3.40$

.....

- (iii) Two triplet peaks

.....

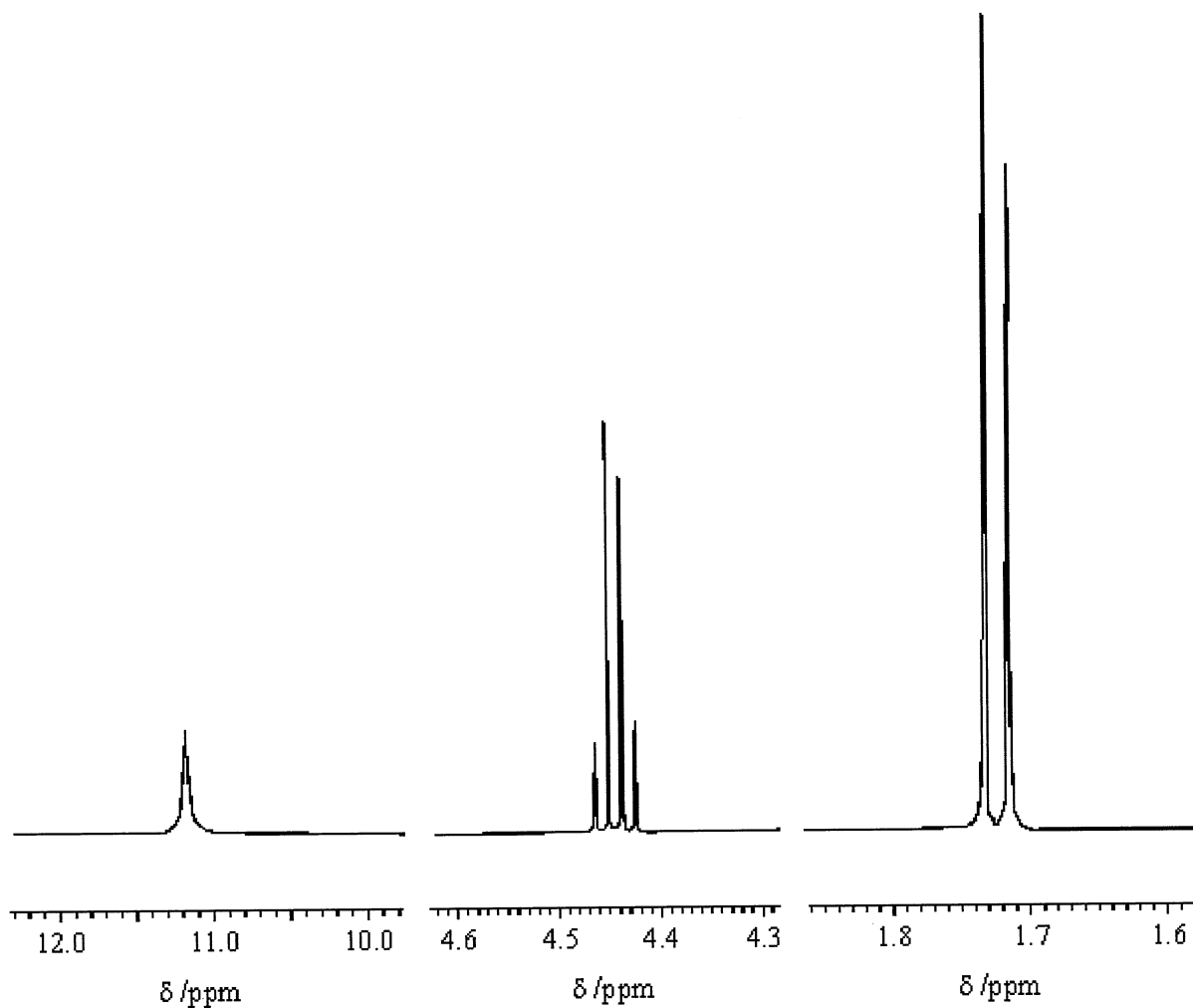
(3)

- (e) Using your answers to parts (a), (b) and (d), deduce the structure of compound **Q**.

(1)

(Total 11 marks)

3. Three sections of the proton n.m.r. spectrum of  $\text{CH}_3\text{CHClCOOH}$  are shown below.



- (a) Name the compound  $\text{CH}_3\text{CHClCOOH}$

.....

(1)

- (b) Explain the splitting patterns in the peaks at  $\delta$  1.72 and  $\delta$  4.44

.....

.....

.....

(2)

- (c) Predict the splitting pattern that would be seen in the proton n.m.r. spectrum of the isomeric compound  $\text{ClCH}_2\text{CH}_2\text{COOH}$

.....

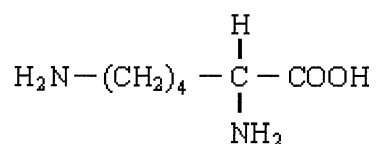
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(1)

- (d) The amino acid *alanine* is formed by the reaction of  $\text{CH}_3\text{CHClCOOH}$  with an excess of ammonia. The mechanism is nucleophilic substitution. Outline this mechanism, showing clearly the structure of *alanine*.

(5)

- (e) The amino acid *lysine* has the structure



Draw structures to show the product formed in each case when lysine reacts with

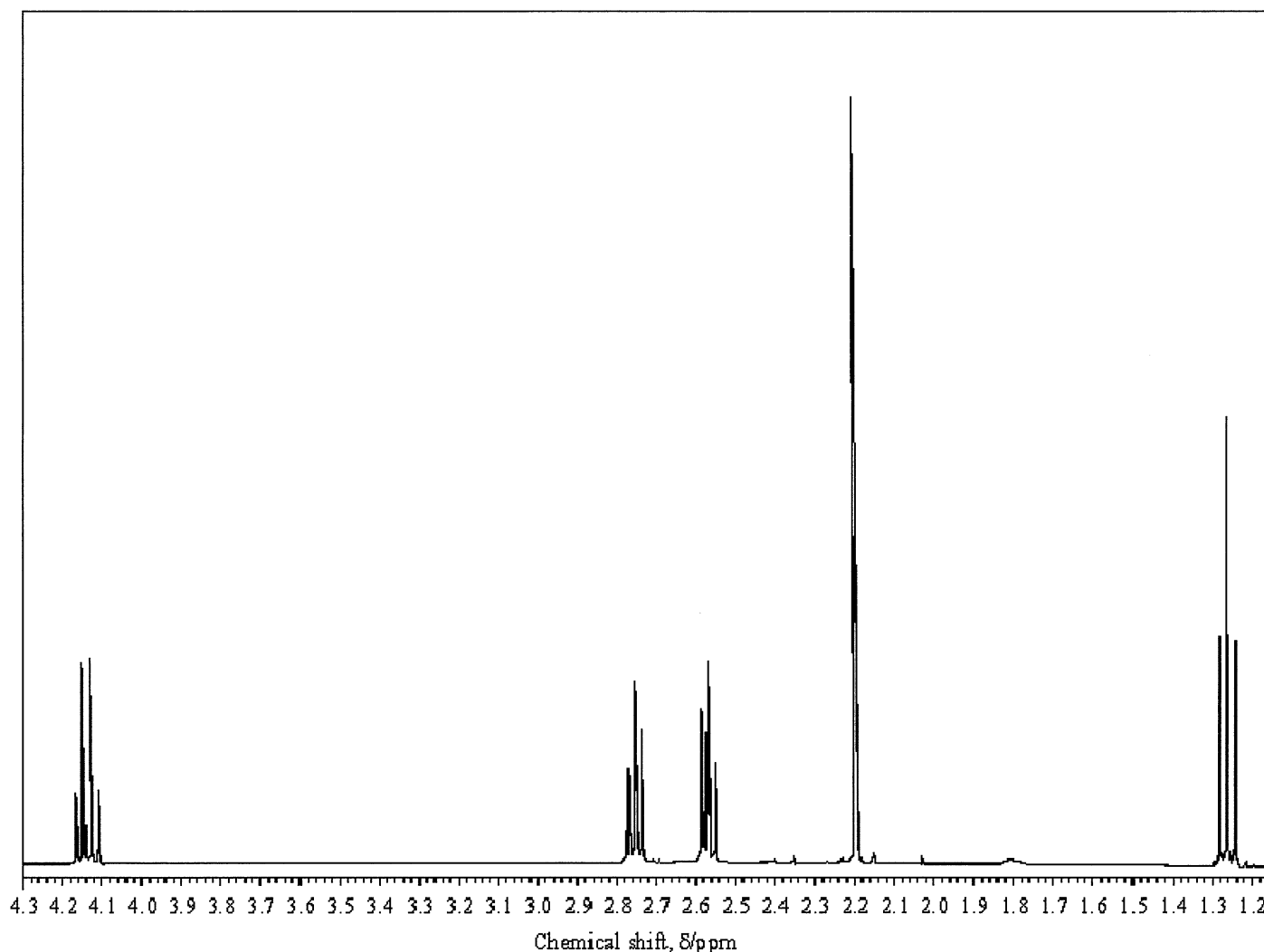
- (i) an excess of aqueous HCl,

- (ii) an excess of aqueous NaOH,

- (iii) another molecule of lysine.

(3)  
(Total 12 marks)

4. The proton n.m.r. spectrum of compound **X** is shown below.



Compound **X**,  $C_7H_{12}O_3$ , contains both a ketone and an ester functional group. The measured integration trace for the peaks in the n.m.r. spectrum of **X** gives the ratio shown in the table below.

|                               |      |      |      |      |      |
|-------------------------------|------|------|------|------|------|
| Chemical shift, $\delta$ /ppm | 4.13 | 2.76 | 2.57 | 2.20 | 1.26 |
| Integration ratio             | 0.8  | 0.8  | 0.8  | 1.2  | 1.2  |

Refer to the spectrum, the information given above and the data below the Periodic Table provided to answer the following questions.

- (a) How many different types of proton are present in compound **X**?

.....

(1)

- (b) What is the whole-number ratio of each type of proton in compound **X**?

.....

(1)

- (c) Draw the part of the structure of **X** which can be deduced from the presence of the peak at  $\delta 2.20$ .

.....

(1)

- (d) The peaks at  $\delta 4.13$  and  $\delta 1.26$  arise from the presence of an alkyl group. Identify the group and explain the splitting pattern.

*Alkyl group* .....

*Explanation* .....

.....

.....

(3)

- (e) Draw the part of the structure of **X** which can be deduced from the splitting of the peaks at  $\delta 2.76$  and  $\delta 2.57$ .

.....

(1)

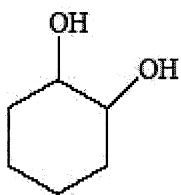
- (f) Deduce the structure of compound **X**.

.....

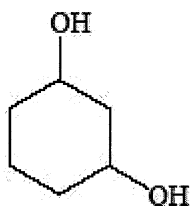
(2)

(Total 9 marks)

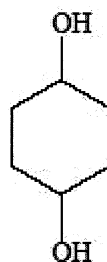
5. Three cyclic alcohols, cyclohexan-1,2-diol, cyclohexan-1,3-diol and cyclohexan-1,4-diol were compared using  $^{13}\text{C}$  n.m.r. spectroscopy.



cyclohexan-1,2-diol

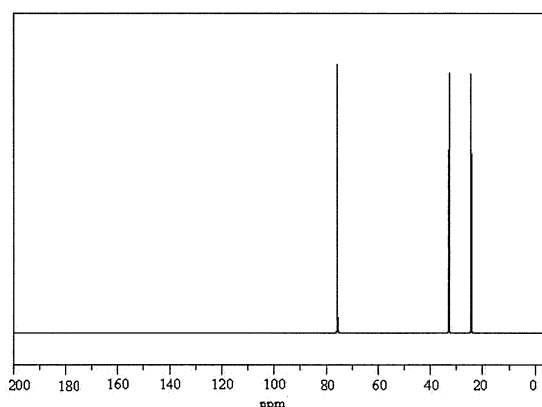


cyclohexan-1,3-diol



cyclohexan-1,4-diol

The  $^{13}\text{C}$  n.m.r. spectrum of cyclohexan-1,2-diol is shown below.



- (a) (i) Explain why there are three peaks.

.....

.....

.....

- (ii) Proton n.m.r. chemical shift data is shown in Table 1 on the reverse of the Periodic Table. Chemical shift values for  $^{13}\text{C}$  vary similarly with chemical environment.

Suggest the  $\delta$  value of the peak in the spectrum above which corresponds to the absorption for carbon atom 1 in cyclohexan-1,2-diol.

.....

- (b) (i) Predict the number of peaks in the  $^{13}\text{C}$  n.m.r. spectrum of cyclohexan-1,3-diol.

.....

- (ii) Predict the number of peaks in the  $^{13}\text{C}$  n.m.r. spectrum of cyclohexan-1,4-diol.

.....

- (c) Suggest why the structures drawn above represents several stereoisomers.

.....

(Total 5 marks)

6. Each of the parts (a) to (e) below concerns a different pair of isomers.

Draw one possible structure for each of the species **A** to **J**, using Table 2 on the Data Sheet where appropriate.

- (a) Compounds **A** and **B** have the molecular formula  $C_5H_{10}$   
**A** decolourises bromine water but **B** does not.

**A**

**B**

(2)

- (b) Compounds **C** and **D** have the molecular formula  $C_2H_4O_2$

Each has an absorption in its infra-red spectrum at about  $1700\text{ cm}^{-1}$  but only **D** has a broad absorption at  $3350\text{ cm}^{-1}$

**C**

**D**

(2)

- (c) Compounds **E** and **F** are esters with the molecular formula  $C_5H_{10}O_2$

The proton n.m.r. spectrum of **E** consists of two singlets only whereas that of **F** consists of two quartets and two triplets.

**E**

**F**

(2)

- (d) Compounds **G** and **H** have the molecular formula  $C_3H_6Cl_2$ . **G** shows optical activity but **H** does not.

**G**

**H**

(2)

- (e) Compounds **I** and **J** have the molecular formula  $C_6H_{12}$ .

Each has an absorption in its infra-red spectrum at about  $1650\text{ cm}^{-1}$  and neither shows geometrical isomerism. The proton n.m.r. spectrum of **I** consists of a singlet only whereas that of **J** consists of a singlet, a triplet and a quartet.

**I**

**J**

(2)  
(Total 10 marks)