An Introduction to Organic Chemistry

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	An Introduction to Organic Chemistry
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 2

Time Allowed: **80 minutes**

Score: **/66**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 The structural formulae of six different compounds, **A – F**, are given below.
Each compound contains four carbon atoms in its molecule.

$CH_3CH=CHCH_3$	$CH_3CH_2COCH_3$	$CH_2=CHCH_2CH_3$
A	**B**	**C**
$CH_3CH_2CH(OH)CH_3$	$HOCH_2CH_2CH_2CH_2OH$	$CH_3CH_2OCH_2CH_3$
D	**E**	**F**

(a) (i) What is the empirical formula of compound **E**? ……

(ii) Draw the skeletal formula of compound **D**.

(iii) Structural formulae do not show all of the isomers that may exist for a given molecular formula. Which **two** compounds **each** show **different** types of isomerism and what type of isomerism does each compound show? Identify each compound by its letter.

compound	type of isomerism

[4]

Compound **D** may be converted into compound **C**.

(b) (i) What type of reaction is this?

……

(ii) What reagent would you use for this reaction?

……

(iii) What is formed when compound **E** undergoes the same reaction using an excess of the same reagent?

…… [3]

Compound **A** may be converted into compound **B** in a two-stage reaction.

$$CH_3CH{=}CHCH_3 \xrightarrow{\text{stage I}} \text{intermediate} \xrightarrow{\text{stage II}} CH_3CH_2COCH_3$$

(c) **(i)** What is the structural formula of the intermediate compound formed in this sequence?

(ii) Outline how stage I may be carried out to give this intermediate compound.

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(iii) What reagent would be used for stage II?

…… [4]

(d) Compounds **D** and **F** are isomers.

What type of isomerism do they show?

…… [1]

[Total: 12]

2 Organic chemistry is the chemistry of carbon compounds. The types of organic reactions that you have studied are listed below.

addition	elimination	hydrolysis
oxidation	reduction	substitution

Addition and substitution reactions are further described as follows.

electrophilic	nucleophilic	free radical

Complete the table below.

Fill in the central column by using **only** the types of reaction given in the lists above. Use **both** lists when appropriate.

In the right hand column give the name(s) or formula(e) of the reagent(s) you would use to carry out the reaction given.

organic reaction	type of reaction	reagent(s)
$CH_3CHO \rightarrow CH_3CH(OH)CN$		
$CH_3CH_2CH_2CH_3 \rightarrow CH_3CH_2CHBrCH_3$		
$CH_3CH(OH)CH_3 \rightarrow CH_3CH{=}CH_2$		
$CH_3CH{=}CH_2 \rightarrow CH_3CH(OH)CH_2OH$		

[Total: 10]

3 By using iron and its compounds as examples, outline the different modes of action of homogeneous and heterogeneous catalysis.
Choose two examples, and for each example you should

- state what the catalyst is, and whether it is acting as a homogeneous or a heterogeneous catalyst,
- write a balanced equation for the reaction.

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.....[8]

[Total: 8]

4 Ethanal reacts with hydrogen cyanide, in the presence of a small amount of NaCN, as shown.

$$CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$$

(a) Use bond energies from the *Data Booklet* to calculate the enthalpy change for this reaction. Include a sign with your answer.

enthalpy change = ... $kJ\,mol^{-1}$ [3]

(b) The product of this reaction shows stereoisomerism as it contains a chiral centre. This reaction produces an equimolar mixture of two optical isomers.

(i) Explain the meanings of the terms *stereoisomerism* and *chiral centre*.

stereoisomerism .....

.....

.....

chiral centre .....

.....

[2]

(ii) Suggest why the two optical isomers are produced in equal amounts by this reaction.

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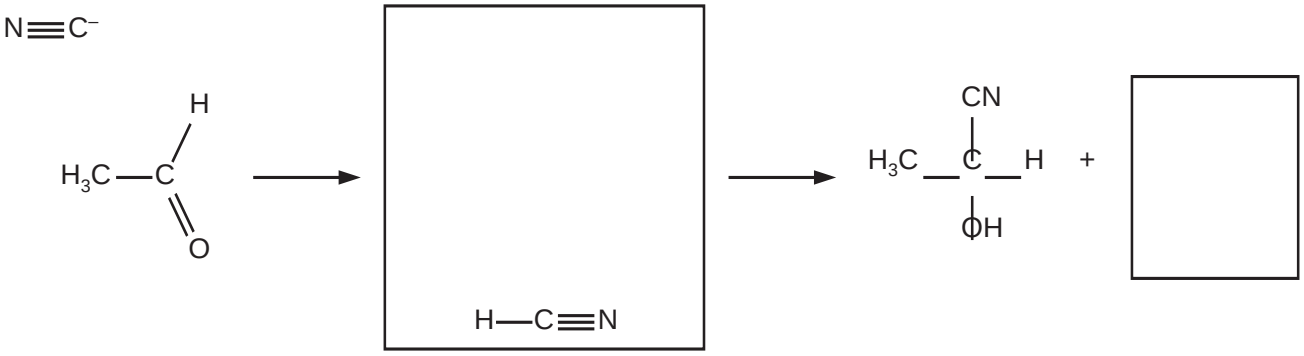
..... [1]

(c) **(i)** Complete the diagram to show the mechanism of this reaction. Include all necessary charges, partial charges, lone pairs and curly arrows and show the structure of the intermediate.



[5]

(ii) With reference to your mechanism in **(i)**, explain the role of the NaCN in this reaction.

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..... [1]

[Total: 12]

5 There are seven structural isomers with the molecular formula $C_5H_{10}O$ that are carbonyl compounds. Four of these are aldehydes.

These four aldehydes, **A**, **B**, **C** and **D**, have the following properties.

- Aldehyde **A** has a straight chain while **B**, **C** and **D** are branched.
- Aldehyde **B** is the only one of the four isomers with a chiral centre and it exists as a pair of optical isomers.
- Aldehyde **C** has two methyl groups in its structure but **D** has three.

(a) Give the structure of each of the four isomers.

A

B

C

D

[4]

(ii) Draw the three-dimensional structures of the two optical isomers of **B**.

[2]

(b) (i) Describe a chemical test that would allow you to distinguish between any of the four isomers **A** to **D** and any of the other three structural isomers of $C_5H_{10}O$, that are carbonyl compounds.

In your answer you should describe any necessary reagents and conditions as well as explaining what you would **see** in each case.

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..... [3]

(ii) Describe a test that would give the same result with all seven carbonyl isomers of $C_5H_{10}O$.

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..... [2]

[Total: 11]

6 Isomerism occurs in many organic compounds. The two main forms of isomerism are structural isomerism and stereoisomerism. Many organic compounds that occur naturally have molecules that can show stereoisomerism, that is *cis-trans* or optical isomerism.

(a) (i) Explain what is meant by *structural isomerism*.

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(ii) State **two** different features of molecules that can give rise to **stereoisomerism**.

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[3]

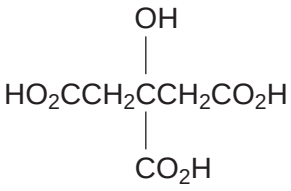
Unripe fruit often contains polycarboxylic acids, that is acids with more than one carboxylic acid group in their molecule.

One of these acids is commonly known as tartaric acid, $HO_2CCH(OH)CH(OH)CO_2H$.

(b) Give the structural formula of the organic compound produced when tartaric acid is reacted with an excess of $NaHCO_3$.

[1]

Another acid present in unripe fruit is citric acid,



(c) Does citric acid show optical isomerism? Explain your answer.

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..... [1]

A third polycarboxylic acid present in unripe fruit is a colourless crystalline solid, **W**, which has the following composition by mass: C, 35.8%; H, 4.5%; O, 59.7%.

(d) (i) Show by calculation that the empirical formula of **W** is $C_4H_6O_5$.

(ii) The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

[3]

A sample of **W** of mass 1.97 g was dissolved in water and the resulting solution titrated with 1.00 mol dm^{-3} NaOH. 29.4 cm^3 were required for complete neutralisation.

(e) (i) Use these data to deduce the number of carboxylic acid groups present in one molecule of **W**.

(ii) Suggest the displayed formula of **W**.

[5]

[Total: 13]