A-Level Chemistry

Optical Isomerism

Question Paper

Time available: 54 minutes
Marks available: 50 marks

1.

(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)

2. This question is about isomerism.

(a) How many isomers are represented by the formula C_5H_{12}?

Tick (✓) **one** box.

2 ☐ 3 ☐ 4 ☐ 5 ☐

(b) Name the type of structural isomerism shown by the isomers of C_5H_{12}

_____

(1)

(c) 2-Hydroxypropanenitrile displays optical isomerism.

Draw three-dimensional representations of the two enantiomers of 2-hydroxypropanenitrile, showing how the two structures are related to each other.

(2)

(d) Describe how separate samples of each of these enantiomers could be distinguished.

_____

_____

_____

_____

(2)

(e) Butan-2-ol reacts with concentrated sulfuric acid to produce three isomeric alkenes.

Name and outline a mechanism to show how any **one** of the alkenes is formed.

Explain how this reaction can lead to the formation of each of these **three** alkenes.

Name of mechanism _____

Mechanism

Explanation _____

_____

_____

_____

_____

_____

_____

_____

_____

(8)

(Total 13 marks)

3. The aldehyde $CH_3CH_2CH_2CH_2CHO$ reacts with KCN followed by dilute acid to form a racemic mixture of the two stereoisomers of $CH_3CH_2CH_2CH_2CH(OH)CN$

(a) Give the IUPAC name of $CH_3CH_2CH_2CH_2CH(OH)CN$

_____

(1)

(b) Describe how you would distinguish between separate samples of the two stereoisomers of $CH_3CH_2CH_2CH_2CH(OH)CN$

_____

_____

_____

_____

_____

(2)

(c) Explain why the reaction produces a racemic mixture.

_____

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_____

(3)

(d) An isomer of $CH_3CH_2CH_2CH_2CHO$ reacts with KCN followed by dilute acid to form a compound that does not show stereoisomerism.

Draw the structure of the compound formed and justify why it does not show stereoisomerism.

Structure

Justification

_____

_____

(2)

(Total 8 marks)

4. Butanone is reduced in a two-step reaction using $NaBH_4$ followed by dilute hydrochloric acid.

(a) Write an overall equation for the reduction of butanone using [H] to represent the reductant.

_____

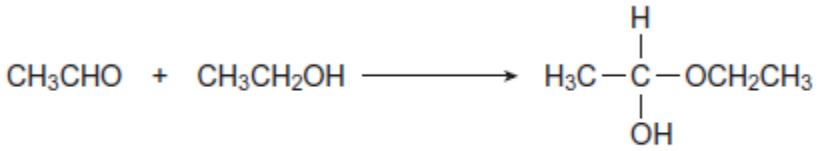
(1)

(b) By considering the mechanism of the reaction, explain why the product has **no** effect on plane polarised light.

(6)

(Total 7 marks)

5. Hemiacetals and acetals are compounds formed by the reaction of aldehydes with alcohols, such as the reaction of ethanal with ethanol.



a hemiacetal

(a) (i) Use your knowledge of carbonyl mechanisms to suggest the name of the mechanism of this reaction.

(1)

(ii) Outline how an ethanol molecule reacts with an ethanal molecule in the first step of this mechanism. Include two curly arrows to show the movement of electron pairs.

(2)

(b) The reaction produces a racemic mixture of chiral molecules.

(i) Explain the meaning of the term racemic mixture.

_____

_____

(1)

(ii) State the relationship between two chiral molecules with the same structural formula.

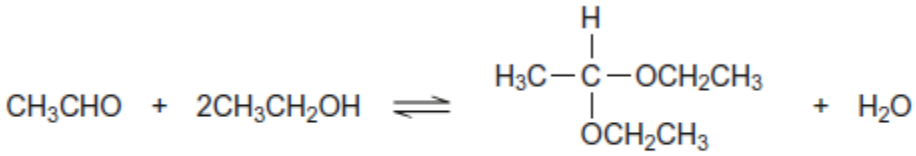
_____

_____

(1)

(c) In the presence of an acid catalyst such as dry hydrogen chloride, ethanal reacts with an excess of ethanol to form an acetal.

The overall reaction of ethanal with an excess of ethanol forms an equilibrium mixture as shown. All reactants and products are liquids.



an acetal

A mixture of 0.75 mol of ethanal and 5.00 mol of ethanol was left to reach equilibrium in the presence of dry hydrogen chloride at a given temperature. The equilibrium mixture contained 0.42 mol of the acetal.

(i) Calculate the amount, in moles, of ethanal and of ethanol in this equilibrium mixture.

Amount of ethanal _____ mol

Amount of ethanol _____ mol

Space for working _____

_____

_____

_____

(2)

(ii) In a different experiment using the same reaction as in part **(c)**, an equilibrium mixture was established at a given temperature.
This mixture contained 0.58 mol of ethanal, 3.76 mol of ethanol, 0.37 mol of the acetal and 0.65 mol of water in a total volume of 310 cm^3.

Write an expression for the equilibrium constant K_c for this reaction.
Calculate a value for K_c at this temperature. Give units with your answer.

K_c _____

_____

Calculation _____

_____

_____

_____

_____

_____

_____

(4)

(d) Draw the structure of the acetal ($C_4H_8O_2$) formed by the reaction of ethanal with ethane-1,2-diol.

(1)
(Total 12 marks)