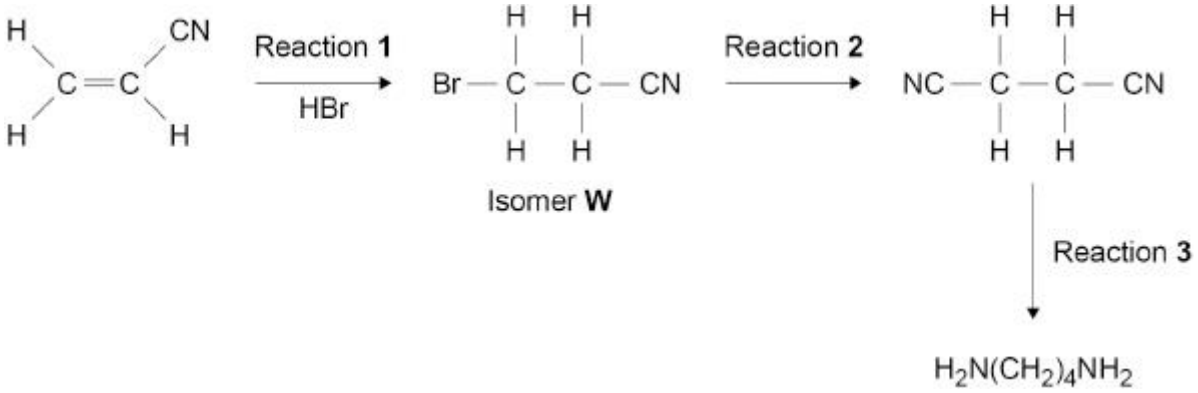
Q1.

Acrylonitrile, $H_2C=CHCN$, can be used as a starting material for the synthesis of butane-1,4-diamine, as shown in this reaction scheme.



(a) Use IUPAC rules to name isomer **W**.

_____

(1)

(b) Reaction **1** produces a mixture of **W** and two other isomers.

Draw the structures of the two other isomers.

Explain, by considering the mechanism of this reaction, why all three isomers are formed.

_____

_____

_____

_____

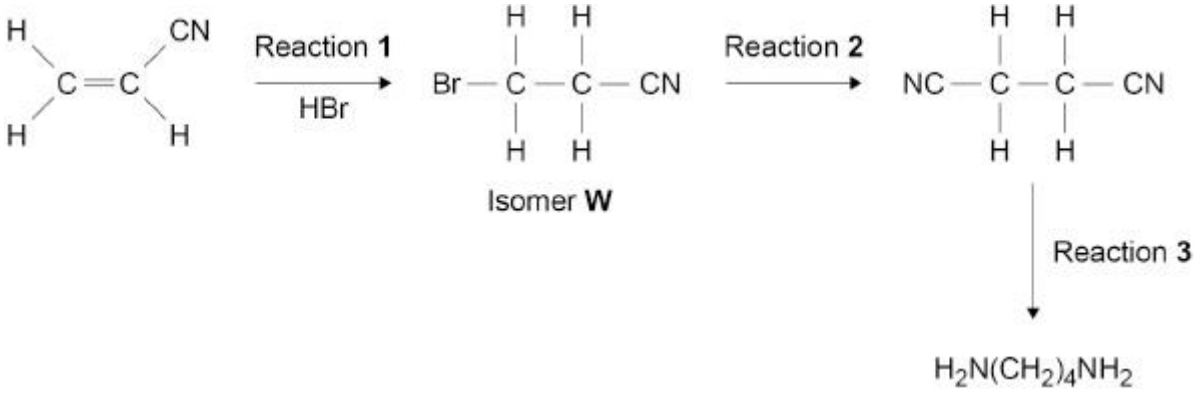
_____

_____

_____

(6)

The reaction scheme is repeated here.



(c) Identify the reagent that is warmed with isomer **W** in reaction **2**.

State the other reaction condition needed.

Reagent _____

Condition _____

(2)

(d) State the reagent and reaction conditions needed for reaction **3**.

Give an equation for reaction **3**.

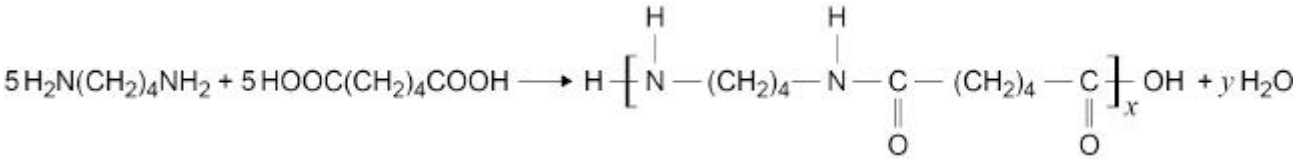
Reagent and conditions _____

Equation

_____

(2)

(e) An incomplete equation for the formation of nylon 4,6 from five molecules of butane-1,4-diamine and five molecules of hexanedioic acid is shown.

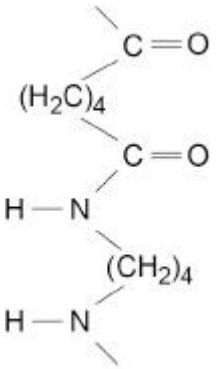


Deduce the values of x and y in this equation.

x _____ y _____

(2)

(f) The figure below shows a section of the nylon 4,6 polymer molecule.



Draw, on the figure above, another section of nylon 4,6 polymer showing two hydrogen bonds between the two sections.

Draw, on the figure above, another section of nylon 4,6 polymer showing two hydrogen bonds between the two sections.

(2)

(Total 15 marks)

Q2.

This question is about isomers with the molecular formula $C_5H_{10}O$

(a) Draw the skeletal formula of a branched chain aldehyde with molecular formula $C_5H_{10}O$ that is optically active.

(1)

(b) Describe how you distinguish between separate samples of the two enantiomers of the branched chain aldehyde $C_5H_{10}O$

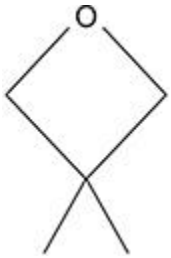
(2)

(c) Draw the *E* and *Z* forms of a structural isomer of $C_5H_{10}O$ that shows **both** optical and geometric isomerism.

E isomer	*Z* isomer

(2)

(d) Isomer J is cyclic and has an ether functional group (C–O–C)
Isomer J has only three peaks in its ^{13}C NMR spectrum.



Isomer J

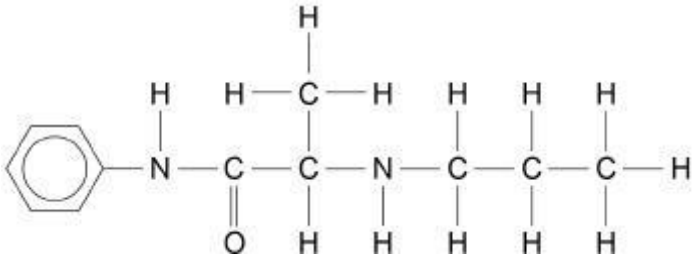
Draw **two** other cyclic isomers of $C_5H_{10}O$ that have an ether functional group and only three peaks in their ^{13}C NMR spectra.

(2)
(Total 7 marks)

Q3.

Prilocaine is used as an anaesthetic in dentistry.
Figure 1 shows the structure of prilocaine.

Figure 1



(a) Draw a circle around any chiral centre(s) in **Figure 1**.

(1)

(b) Identify the functional group(s) in the prilocaine molecule.

Tick (✓) the box(es) corresponding to the functional group(s).

Amide	Amine	Ester	Ketone

(1)

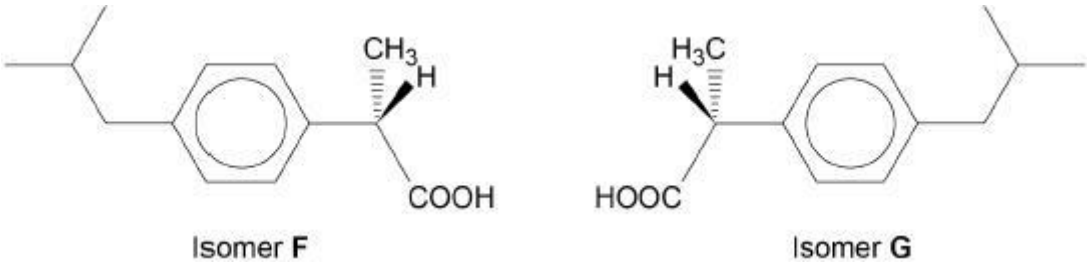
(c) Prilocaine is completely hydrolysed in the human body to give a mixture of products.

Draw the structures of the two organic products formed in the complete hydrolysis of prilocaine in acidic conditions.

(3)

(d) **Figure 2** shows optical isomers **F** and **G**.

Figure 2



Isomer **F** Isomer **G**

Isomer **F** is the active compound in the medicine ibuprofen.

In the manufacture of ibuprofen both isomers **F** and **G** are formed. An enzyme is then used to bind to isomer **G** and catalyse its hydrolysis.

After the products of hydrolysis of **G** are removed, a pure sample of isomer **F** is collected.

Explain how a structural feature of this enzyme enables it to catalyse the hydrolysis of isomer **G** but not the hydrolysis of isomer **F**.

_____

_____

_____

_____

(2)

(Total 7 marks)

Q4.

Ethanal reacts with potassium cyanide, followed by dilute acid, to form 2-hydroxypropanenitrile.

(a) Name the mechanism for the reaction between potassium cyanide and ethanal.

_____

(1)

(b) The 2-hydroxypropanenitrile formed by the reaction in part **(a)** is a mixture of equal amounts of two isomers.

State the name of this type of mixture.

Explain how the structure of ethanal leads to the formation of two isomers.

Draw 3D representations of the two isomers to show the relationship between them.

Name _____

Explanation _____

_____

_____

_____

_____

_____

3D representations

(5)

(c) 2-Hydroxypropanenitrile can be used in the synthesis of the monomer, acrylonitrile, CH_2=CHCN

Suggest a suitable reagent and conditions for the conversion of 2-hydroxypropanenitrile into acrylonitrile.

Reagent _____

Conditions _____

(2)

(d) Draw a section of the polymer polyacrylonitrile, showing three repeating units.

(1)

(Total 9 marks)

Q5.

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.

_____

_____

_____

_____

_____

_____

(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

_____

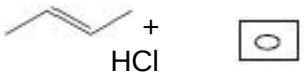
_____

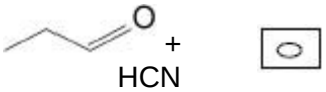
(2)

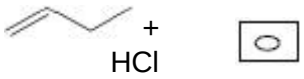
(Total 8 marks)

Q6.

Which pair of compounds does **not** form a racemic mixture when the compounds react?

A  + HCl

B  + HCN

C  + HCl

D  + HCN

(Total 1 mark)

Q7.

Which compound does **not** show stereoisomerism?

A 1,2-dichloropropene ⬭

B 1,2-dichloropropane ⬭

C 1,3-dichloropropene ⬭

D 1,3-dichloropropane ⬭

(Total 1 mark)

Q8.

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)

Q9.

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)

Q10.

Which compound forms optically active compounds on reduction?

A $CH_3CH_2C(CH_3)=CHCH_3$ ⬭

B $CH_3CH_2C(CH_3)=CH_2$ ⬭

C CH_3COCH_3 ⬭

D $CH_3CH_2COCH_3$ ⬭

(Total 1 mark)

Mark schemes

Q1.

(a) 3-bromopropanenitrile

Allow 3-bromopropane-1-nitrile

1

(b)

This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 marks**	All stages are covered and each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3.
Level 2 **3-4 marks**	All stages are covered but stage(s) may be incomplete or may contain inaccuracies **OR** two stages are covered and are generally correct and virtually complete. Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3.
Level 1 **1-2 marks**	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies **OR** only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order.
Level 0 **0 marks**	Insufficient correct chemistry to gain a mark.

Indicative Chemistry content

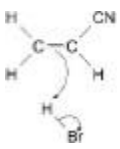
Stage 1 Types of Isomers formed

1a $CH_3CHBrCN$

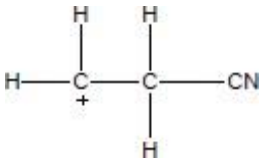
1b Exists as two Optical isomers / enantiomers

Stage 2 Mechanism

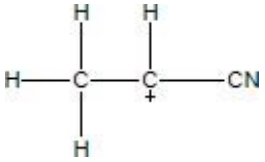
2a 2 curly arrows



2b Intermediate structure primary carbocation OR



2c Alternative Intermediate structure secondary carbocation OR



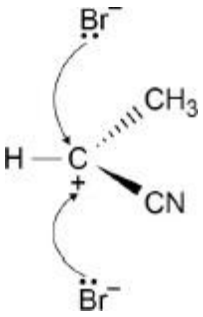
Stage 3 Optical isomerism

3a 2-bromo isomer has chiral carbon / C with four different groups / non superimposable mirror images

OR

3b Optical because (secondary) C^+ planar

3c So can be attacked from above or below



6

(c) M1 KCN or NaCN

Penalise acid in M1

M2 Aqueous AND ethanol (alcohol)

2

(d) M1 H_2 and Ni/Pt/Pd

Allow $LiAlH_4$ and (Dry) ether BUT <u>not</u> $NaBH_4$

M2 $NCCH_2CH_2CN + 4H_2 \rightarrow H_2N(CH_2)_4NH_2$

Allow with 8[H]

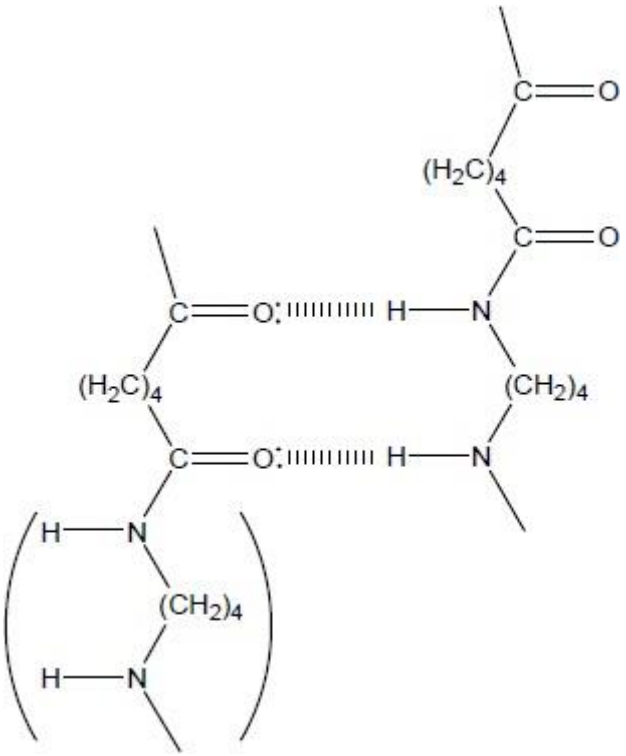
2

(e) M1 $x = 5$

M2 $y = 9$

2

(f)



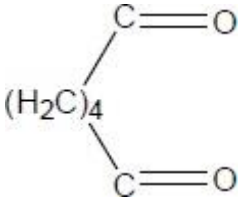
Structure shown on the left of the given structure.

The correct answer is the same irrespective of whether it's drawn on the left or right of the polymer section.

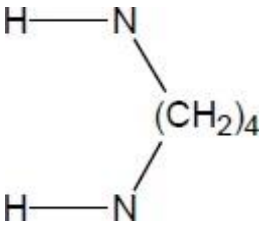
Deduct a mark(s) for error(s)/omission(s)

Must have the following:

• *Minimum correct structure*



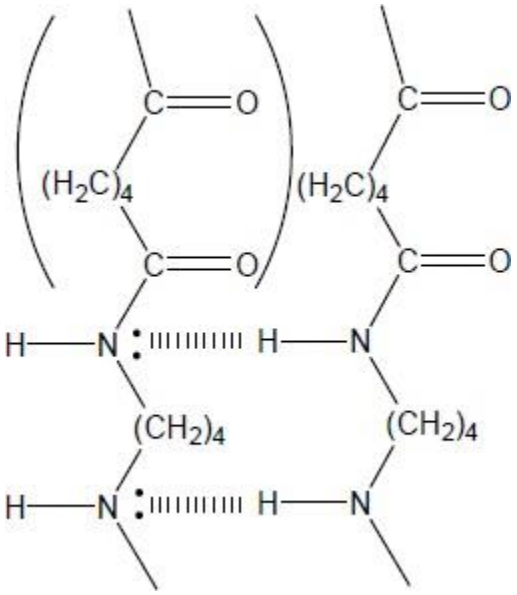
Or



• *Lp on O or N*

• *2 Linear dashed lines from O or N to H*

Allow alternative connection below



2

[15]

Q2.

(a)

1

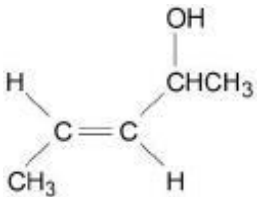
(b) Use Plane polarised light

M1

<u>rotates</u> (the plane of) in opposite directions

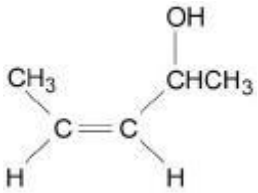
M2

(c)



Must be E isomer

M1

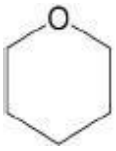


Must be Z isomer

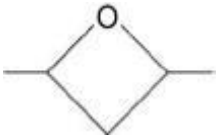
Allow 1 mark out of 2 for 2 correct structures but shown in the wrong boxes

M2

(d)



M1



M2

[7]

Q3.

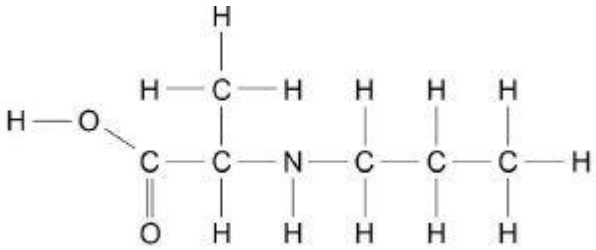
(a) One circled C atom only – The C attached to CH_3/C=O/ H and NH

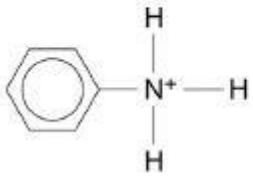
1

(b) Two ticks only for amine and amide

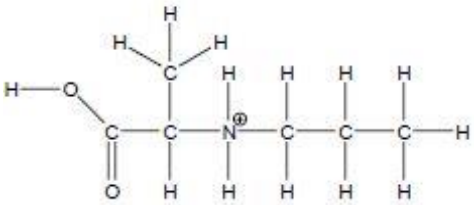
1

(c)





M1 *for choosing the correct bond to hydrolyse*
M2 *and* ***M3*** *for the correct structures of the products*
Allow protonated amino acid for M2



Allow $C_6H_5NH_3^+$ *or + outside a square bracket*

3

(d) **M1** Enzyme has an <u>active site</u>

1

M2

The G-Enantiomer / Enzyme has the correct stereo chemistry / stereospecific
Or
The G-Enantiomer / Enzyme has the complementary shape

For M2 allow opposite argument for F-Enantiomer

1

[7]

Q4.

(a) nucleophilic addition

both words needed

NOT any additional names

1

(b) **M1** racemic (mixture) / racemate

1

M2 planar (around) carbonyl / C=O

***M2** NOT molecule is planar*

Allow flat for planar

1

M3 (equal chance of) attack from each side (by CN^-)

1

M4 a correct structure of 2-hydroxypropanenitrile

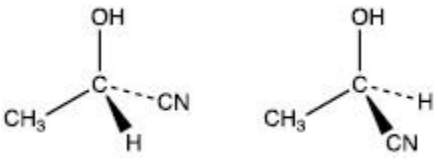
***M4** any correct 2D or 3D structure*

1

M5 correct 3D representations of both isomers, e.g.

***M5** must show at least one wedge bond and one dash bond in each structure and any bonds in the plane cannot be at 180º to each other*

*second structure could be drawn as mirror image of first **or** with same orientation with two groups swapped round, e.g.*



Allow ECF for second structure from incorrect first structure, providing molecule is chiral

1

(c) **M1** conc H_2SO_4 or conc H_3PO_4

***M1** Allow conc to come from conditions line*

1

M2 heat / 170°C

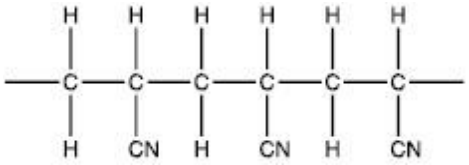
M2** depends on attempt at correct reagent in **M1

Allow high temperature / hot / 100-300°C / 373 – 573 K / reflux
Ignore references to pressure
Ignore warm
NOT ethanolic / alcoholic

1

Alternative answer
M1 *Al_2O_3*
M2 *pass vapour over hot Al_2O_3*

(d)



MUST show trailing bonds
Ignore any brackets or n
NOT C–N or C=N if CN group displayed
Allow structures with CN on either C in each of the three units
Allow –CH_2–CH(CN)–CH_2–CH(CN)–CH_2–CH(CN)–

1

[9]

Q5.

(a) 2-hydroxyhexanenitrile

1

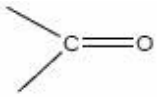
(b) (Plane) polarised light

1

Enantiomers would <u>rotate</u> light in opposite directions
not different alone

1

(c) <u>planar</u> carbonyl group or

<u>planar</u> 

Not planar molecule,
not planar bond, not planar C=O

1

Attack from either side

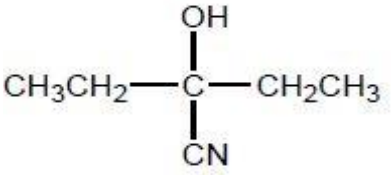
1

With <u>equal</u> probability

OR produces <u>equal</u> amounts (of the two isomers/enantiomers)

1

(d)



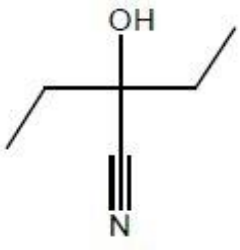
Does not contain a chiral centre

OR does not contain C attached to 4 different groups

OR contains two identical/ethyl groups

OR symmetrical (product)

Allow C_2H_5 or skeletal



M2 dependent on correct M1 (No structure = 0)

If pentan-3-one drawn then allow symmetrical ketone for M2

[8]

Q6.

D

[1]

Q7.

D

[1]

Q8.

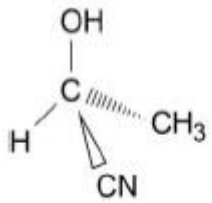
(a) 3

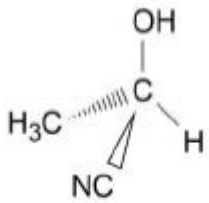
1

(b) Chain.

1

(c)





One 3D enantiomer.

1

Second enantiomer correctly drawn as 3D mirror image of first.

1

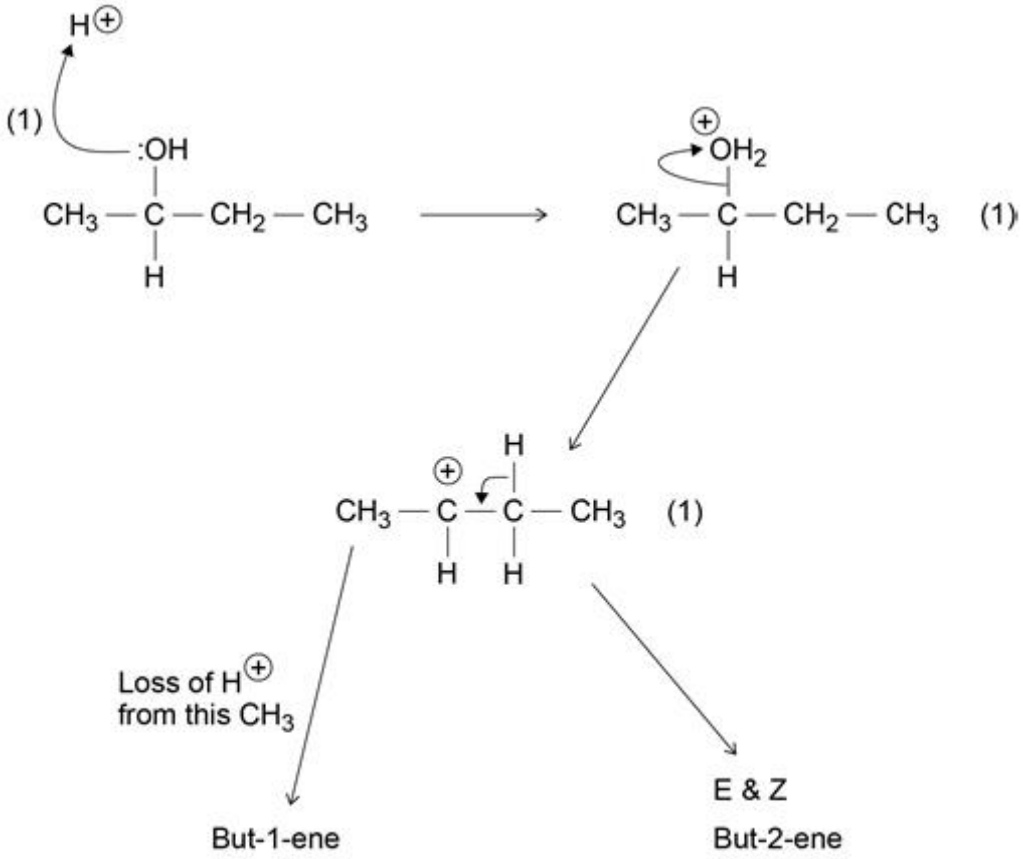
(d) Plane-polarised light.

1

Rotated in opposite directions.

1

(e) Elimination



Extended response question

M1

Mechanism (3 marks)

M2 arrow from lone pair on O to H^+

M3 1st intermediate **and** arrow from C–O^+H_2 bond to O (with loss of H_2O)

M4 2nd intermediate (carbocation) **and** arrow from C–H bond to C–C (with loss of H^+) to form C=C

M3 and M4 can be scored in one step (see alternative mechanism below).

If carbocation incorrect then answer cannot score maximum marks.

Explanation of formation of 3 alkenes

M5 loss of H^+ from C (in carbocation) adjacent to ^+C (to which −OH was attached)

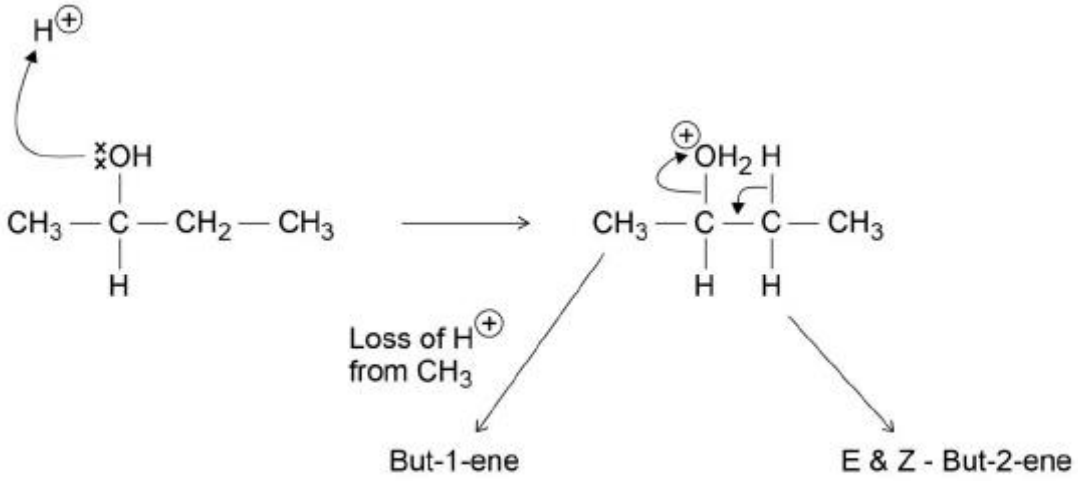
M6 From $^1\mathbf{C}–^2C+–^3C–^4C$ leads to but-1-ene

M7 From $^1C–^2C^+–^3\mathbf{C}–^4C$ leads to but-2-ene

M8 But-2-ene formed as mixture of *E-Z* isomers

8

Alternative mechanism



[14]

Q9.

(a) $CH_3CH_2COCH_3 + 2[H] \longrightarrow CH_3CH_2CH(OH)CH_3$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression from stage 1 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct chemistry to gain a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: Formation of product
- Nucleophilic attack
- Planar carbonyl group
- H^- attacks from either side (stated or drawn)

Stage 2: Nature of product
- Product of step 1 shown
- This exists in two chiral forms (stated or drawn)
- Equal amounts of each enantiomer / racemic mixture formed

Stage 3: Optical activity
- Optical isomers / enantiomers rotate the plane of polarised light equally in
- With a racemic / equal mixture the effects cancel

6

[7]

Q10.

D

[1]