1 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.

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(1)

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

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(6)
(Total 7 marks)

2 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

ethanol ⟶ ethanal ⟶ ethanoic acid

(a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

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(3)

(b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

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(1)

(c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

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(5)

(d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

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(2)

(e) A student obtained a sample of a liquid using the apparatus in part **(c)**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

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(5)
(Total 16 marks)

3 Which alcohol could **not** be produced by the reduction of an aldehyde or a ketone?

A 2-methylbutan-1-ol ⬭

B 2-methylbutan-2-ol ⬭

C 3-methylbutan-1-ol ⬭

D 3-methylbutan-2-ol ⬭

(Total 1 mark)

4 The carbonyl compound CH_3CH_2CHO reacts very slowly with HCN

(a) Name and outline a mechanism for the reaction of CH_3CH_2CHO with HCN

Name of mechanism .....

Mechanism

(5)

(b) The reaction in part (a) produces a pair of enantiomers.

(i) Draw the structure of each enantiomer to show how they are related to each other.

(2)

(ii) State and explain how you could distinguish between the two enantiomers.

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(2)

(c) Give the IUPAC name of the product of the reaction in part (a).

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(1)

(d) In practice, KCN rather than HCN is added to the carbonyl compound.

Given that K_a for HCN = 4.0×10^{-10} mol dm^{-3}, suggest why the reaction with HCN is very slow.

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(2)

(e) Acrylic fibres are used as a substitute for wool. Acrylics are copolymers of acrylonitrile with other compounds.

Acrylonitrile is the common name for the following compound.

$$H_2C = CH - C \equiv N$$

(i) Acrylonitrile can be formed from propene.

Write an equation for the reaction of propene with ammonia and oxygen to form acrylonitrile and one other product.

.....

(1)

(ii) The term copolymer is used to describe the product obtained when two or more different monomers form a polymer.

Draw the repeating unit of the acrylic copolymer that contains 75% acrylonitrile monomer and 25% chloroethene monomer.

(1)

(iii) Name the type of polymerisation involved in part (ii)

.....

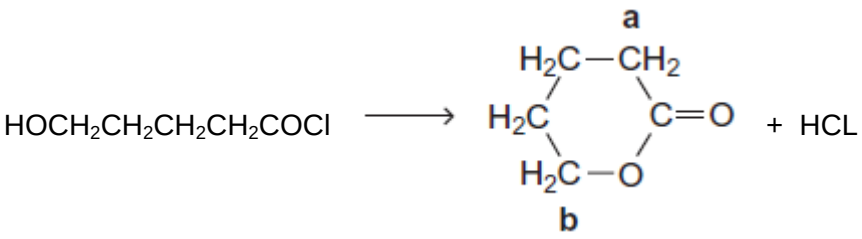
(1)

(Total 15 marks)

5 This question is about some isomers of $C_5H_8O_2$

(a) Compound **H** is a cyclic ester that can be prepared as shown.

On the structure of **H**, two of the carbon atoms are labelled.



H

(i) Name and outline a mechanism for this reaction.

Use **Table C** on the Data Sheet to give the ^{13}C n.m.r. δ value for the carbon atom labelled **a** and the δ value for the carbon atom labelled **b**.

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(7)

(ii) $HOCH_2CH_2CH_2CH_2COCl$ can also react to form a polyester in a mechanism similar to that in part (i).

Draw the repeating unit of the polyester and name the type of polymerisation involved.

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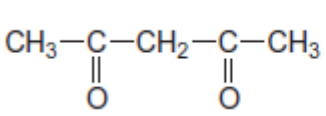
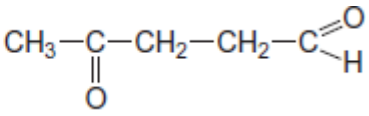
(2)

(b) State how you could distinguish between compounds **J** and **K** by a simple test-tube reaction.

State how you could distinguish between **J** and **K** by giving the number of peaks in the ^1H n.m.r. spectrum of each compound.



J



K

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(5)

(c) Draw the structure of each of the following isomers of $C_5H_8O_2$
Label each structure you draw with the correct letter **L**, **M**, **N**, **P** or **Q**.

L is methyl 2-methylpropenoate.

M is an ester that shows E-Z stereoisomerism.

N is a carboxylic acid with a branched carbon chain and does **not** show stereoisomerism.

P is an optically active carboxylic acid.

Q is a cyclic compound that contains a ketone group and has only two peaks in its ^1H n.m.r. spectrum.

(5)
(Total 19 marks)

6 Lactic acid, $CH_3CH(OH)COOH$, is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose, $C_{12}H_{22}O_{11}$.

(a) (i) Give the IUPAC name for lactic acid.

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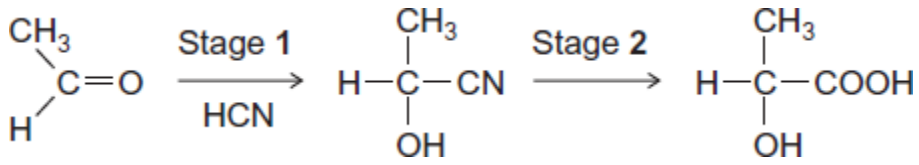
(1)

(ii) Write an equation for the formation of lactic acid from sucrose and water.

.....

(1)

(b) A molecule of lactic acid contains an asymmetric carbon atom.
The lactic acid in the body occurs as a single enantiomer.
A racemic mixture (racemate) of lactic acid can be formed in the following two-stage synthesis.



(i) Name and outline a mechanism for Stage **1**.

Name of mechanism .....

Mechanism

(5)

(ii) Give the meaning of the term *racemic mixture (racemate)*.

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(1)

(iii) Explain how you could distinguish between a racemic mixture (racemate) of lactic acid and one of the enantiomers of lactic acid.

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(2)

(c) A mixture of lactic acid and its salt sodium lactate is used as an acidity regulator in some foods. An acidity regulator makes sure that there is little variation in the pH of food.

(i) Write an equation for the reaction of lactic acid with sodium hydroxide.

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(1)

(ii) The acid dissociation constant K_a for lactic acid has the value 1.38×10^{-4} mol dm^{-3} at 298 K.

Calculate the pH of an equimolar solution of lactic acid and sodium lactate.

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(2)

(iii) Suggest an alternative name for the term *acidity regulator*.
Explain how a mixture of lactic acid and sodium lactate can act as a regulator when natural processes increase the acidity in some foods.

Name .....

Explanation .....

.....

.....

.....

(Extra space) .....

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(3)

(d)

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The cup shown is made from PLA, poly(lactic acid).
PLA is the condensation polymer formed from lactic acid.

The polymer is described as 100% biodegradable and 100% compostable.

Compostable material breaks down slowly in contact with the moist air in a garden bin. This produces compost that can be used to improve soil.

The manufacturers stress that PLA cups differ from traditional plastic cups that are neither biodegradable nor compostable.

(i) Draw a section of PLA that shows **two** repeating units.

(2)

(ii) Name the type of condensation polymer in PLA.

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(1)

(iii) An intermediate in the production of PLA is a cyclic compound ($C_6H_8O_4$) that is formed from two PLA molecules.

Draw the structure of this cyclic compound.

(1)

(iv) Traditional non-biodegradable plastic cups can be made from poly(phenylethene), commonly known as *polystyrene*.

Draw the repeating unit of poly(phenylethene).

(1)

(v) The manufacturers of PLA claim that the material will break down to compost in just 12 weeks.

Suggest **one** reason why PLA in landfill may take longer than 12 weeks to break down.

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(1)

(Total 22 marks)

7 Suggest **one** reason why Tollens' reagent is used as the oxidising agent in the specific test for aldehydes rather than the less expensive acidified potassium dichromate(VI).

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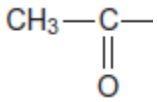
(Total 1 mark)

8 The triiodomethane reaction is often used as a test for aldehydes and ketones that contain the CH_3CO group shown.



The aldehyde or ketone is reacted with an alkaline solution of iodine. Triiodomethane (CHI_3) is formed as a precipitate. Compounds that contain a group that can be oxidised to the CH_3CO group will also give a positive result in this test.

(a) State, with a reason, whether or not ethanol will give a positive result in the triiodomethane reaction.

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(1)

(b) The equation for the reaction of ethanal with an alkaline solution of iodine is

$$CH_3CHO + 3I_2 + 4NaOH \longrightarrow CHI_3 + HCOONa + 3NaI + 3H_2O$$

In an experiment using this reaction, the yield of triiodomethane (CHI_3) obtained by a student was 83.2%.

Calculate the minimum mass of iodine that this student would have used to form 10.0 g of triiodomethane.
Give your answer to the appropriate precision.
Show your working.

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(5)

(c) Triiodomethane can be separated from the reaction mixture by filtration.
State **one** reason why the solid residue is then washed with water after the filtration.

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(1)

(d) State **one** reason, other than cost or availability, why water is suitable for washing this solid residue after the filtration.

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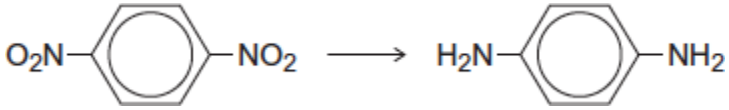
(1)
(Total 8 marks)

9 Each of the following conversions involves reduction of the starting material.

(a) Consider the following conversion.



Identify a reducing agent for this conversion.

Write a balanced equation for the reaction using molecular formulae for the nitrogen-containing compounds and [H] for the reducing agent.

Draw the repeating unit of the polymer formed by the product of this reaction with benzene-1,4-dicarboxylic acid.

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(Extra space) .....

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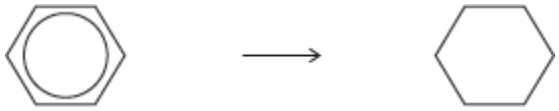
(5)

(b) Consider the following conversion.



Identify a reducing agent for this conversion.

State the empirical formula of the product.

State the bond angle between the carbon atoms in the starting material and the bond angle between the carbon atoms in the product.

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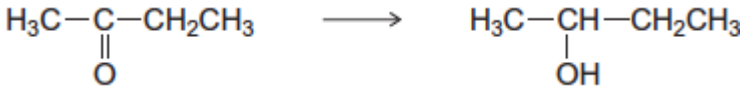
(4)

(c) The reducing agent in the following conversion is $NaBH_4$



(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 17 marks)

10 Chemists have to design synthetic routes to convert one organic compound into another.

Propanone can be converted into 2-bromopropane by a three-step synthesis.

Step 1: propanone is reduced to compound **L**.
Step 2: compound **L** is converted into compound **M**.
Step 3: compound **M** reacts to form 2-bromopropane.

Deduce the structure of compounds **L** and **M**.

For each of the three steps, suggest a reagent that could be used and name the mechanism.

Equations and curly arrow mechanisms are **not** required.

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(Extra space) .....

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(Total 8 marks)

11 (a) Propanoic acid can be made from propan-1-ol by oxidation using acidified potassium dichromate(VI). Propanal is formed as an intermediate during this oxidation.

(i) State the colour of the chromium species after the potassium dichromate(VI) has reacted.

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(1)

(ii) Describe the experimental conditions and the practical method used to ensure that the acid is obtained in a high yield. Draw a diagram of the assembled apparatus you would use.

Conditions .....

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Apparatus

(4)

(iii) Describe the different experimental conditions necessary to produce propanal in high yield rather than propanoic acid.

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(2)

(b) Propan-1-ol is a volatile, flammable liquid.
Give **one** safety precaution that should be used during the reaction to minimise this hazard.

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(1)

(c) A student followed the progress of the oxidation of propan-1-ol to propanoic acid by extracting the organic compounds from one sample of reaction mixture.

(i) Give a chemical reagent which would enable the student to confirm the presence of propanal in the extracted compounds.
State what you would observe when propanal reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(ii) Give a chemical reagent that would enable the student to confirm the presence of propanoic acid in the extracted compounds.
State what you would observe when propanoic acid reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(d) Predict which **one** of the compounds, propan-1-ol, propanal and propanoic acid will have the highest boiling point. Explain your answer.

Prediction .....

Explanation .....

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(3)
(Total 15 marks)

12 Many synthetic routes need chemists to increase the number of carbon atoms in a molecule by forming new carbon–carbon bonds. This can be achieved in several ways including

- reaction of an aromatic compound with an acyl chloride
- reaction of an aldehyde with hydrogen cyanide.

(a) Consider the reaction of benzene with CH_3CH_2COCl

(i) Write an equation for this reaction and name the organic product.
Identify the catalyst required in this reaction.
Write equations to show how the catalyst is used to form a reactive intermediate and how the catalyst is reformed at the end of the reaction.

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(5)

(ii) Name and outline a mechanism for the reaction of benzene with this reactive intermediate.

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(4)

(b) Consider the reaction of propanal with HCN

(i) Write an equation for the reaction of propanal with HCN and name the product.

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(2)

(ii) Name and outline a mechanism for the reaction of propanal with HCN

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(5)

(iii) The rate-determining step in the mechanism in part (b) (ii) involves attack by the nucleophile.
Suggest how the rate of reaction of propanone with HCN would compare with the rate of reaction of propanal with HCN
Explain your answer.

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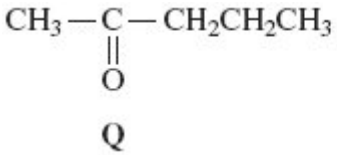
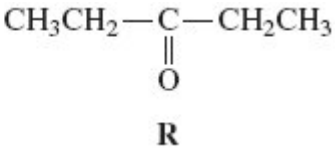
(2)
(Total 18 marks)

13 Two isomeric ketones are shown below.



Q



R

(a) Name and outline a mechanism for the reaction of compound **Q** with HCN and name the product formed.

Name of mechanism ……

Mechanism

Name of product .....

(6)

(b) Some students were asked to suggest methods to distinguish between isomers **Q** and **R**.

One student suggested testing the optical activity of the products formed when **Q** and **R** were reacted separately with HCN.

By considering the optical activity of these products formed from **Q** and **R**, explain why this method would **not** distinguish between **Q** and **R**.

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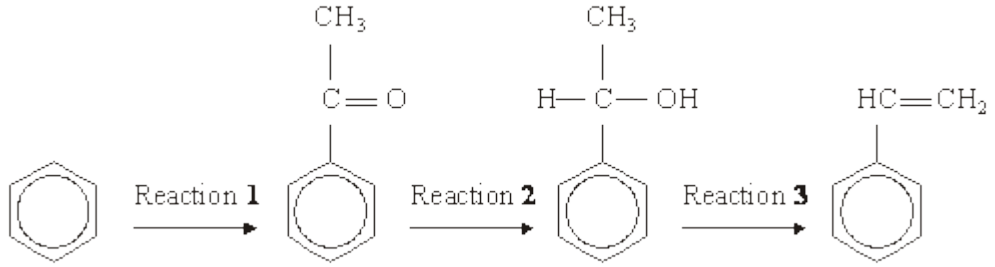
(3)
(Total 9 marks)

14 A possible synthesis of phenylethene *(styrene)* is outlined below.



(a) In Reaction **1**, ethanoyl chloride and aluminium chloride are used to form a reactive species which then reacts with benzene.
Write an equation to show the formation of the reactive species.
Name and outline the mechanism by which this reactive species reacts with benzene.

(6)

(b) $NaBH_4$ is a possible reagent for Reaction **2**.
Name and outline the mechanism for the reaction with $NaBH_4$ in Reaction **2**.
Name the product of Reaction **2**.

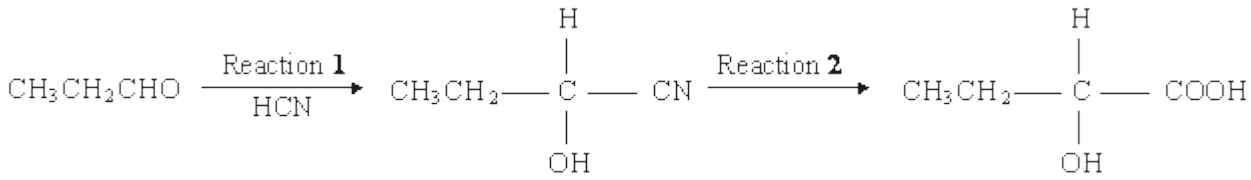
(6)

(c) Name the type of reaction involved in Reaction **3** and give a reagent for the reaction.

(2)

(Total 14 marks)

15 Consider the sequence of reactions below.



P **Q** **R**

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

Name of mechanism .....

Mechanism

(5)

(b) (i) Name compound **Q**

.....

(ii) The molecular formula of **Q** is C_4H_7NO. Draw the structure of the isomer of **Q** which shows geometrical isomerism and is formed by the reaction of ammonia with an acyl chloride.

(3)

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

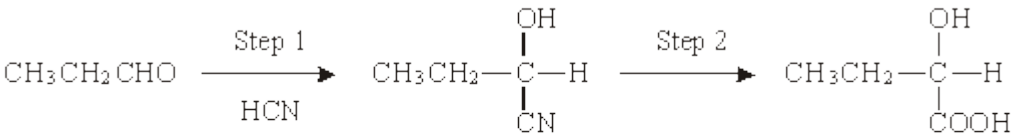
(i) methanol in the presence of a few drops of concentrated sulphuric acid;

(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

(3)
(Total 11 marks)

16 Consider the reaction sequence shown below.



propanal Q

(a) Name and outline a mechanism for the reaction in Step 1.

Name of mechanism .....

Mechanism

(5)

(b) (i) Name compound **Q** formed in Step 2.

.....

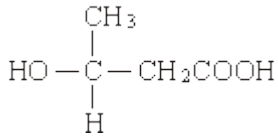
(ii) Two stereoisomers are formed by the dehydration of **Q**. Give the structures of these two isomers and name the type of stereoisomerism shown.

Structures of isomers

Type of stereoisomerism .....

(4)

(c) An isomer of **Q** which has the structure shown below is polymerised to form the biodegradeable polymer known as PHB.



(i) Draw the repeating unit of the polymer PHB.

(ii) Suggest a reason why the polymer is biodegradeable.

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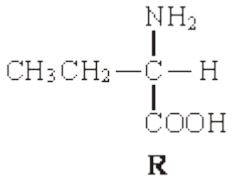
(2)

(d) The amino acid **R** is shown below.



R

(i) Draw the structure of the zwitterion formed by **R**.

(ii) Draw the structure of the major organic product formed when an excess of **R** is reacted with bromomethane.

(iii) Name the mechanism of the reaction which results in the formation of the product given in part (ii).

.....

(3)
(Total 14 marks)

17 Which one of the following reactions will produce an organic compound that has optical isomers?

A dehydration of butan-2-ol by heating with concentrated sulphuric acid

B reduction of pentan-3-one by warming with $NaBH_4$

C addition of Br_2 to 3-bromopropene

D reduction of 2,3-dimethylpent-2-ene with H_2 in the presence of a nickel catalyst

(Total 1 mark)

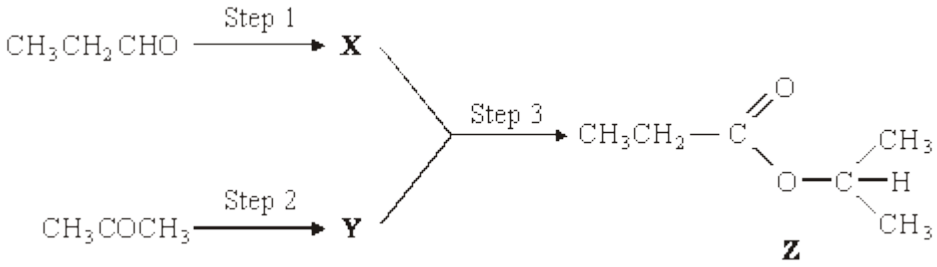
18 (a) Describe how propanal, CH_3CH_2CHO, and propanone, CH_3COCH_3, can be distinguished using

(i) a chemical test and

(ii) the number of peaks in their proton n.m.r. spectra.

(5)

(b) Compound **Z** can be produced by the reaction of compound **X** with compound **Y** as shown in the synthesis outlined below.



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

(10)
(Total 15 marks)

19 (a) Addition reactions to both alkenes and carbonyl compounds can result in the formation of isomeric compounds.

(i) Choose an alkene with molecular formula C_4H_8 which reacts with HBr to form two structural isomers. Give the structures of these two isomers and name the type of structural isomerism shown.

Outline a mechanism for the formation of the major product.

(ii) Using HCN and a suitable carbonyl compound with molecular formula C_3H_6O, outline a mechanism for an addition reaction in which two isomers are produced.
Give the structures of the two isomers formed and state the type of isomerism shown.

(14)

(b) Explain why ethanoyl chloride reacts readily with nucleophiles.
Write an equation for one nucleophilic addition–elimination reaction of ethanoyl chloride.
(A mechanism is not required.)

(4)
(Total 18 marks)

20 In which one of the following mixtures does a redox reaction occur?

A ethanal and Tollens' reagent

B ethanoyl chloride and ethanol

C ethanal and hydrogen cyanide

D ethanoic acid and sodium hydroxide

(Total 1 mark)

21 Propanone can be reduced to form an alcohol. A functional group isomer of the alcohol formed is

A $CH_3CH_2CH_2OH$

B CH_3CH_2CHO

C $CH_3OCH_2CH_3$

D CH_3COCH_3

(Total 1 mark)

22 (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.

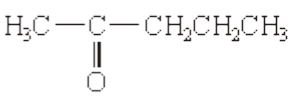
Test reagent .....

Observation with propanone .....

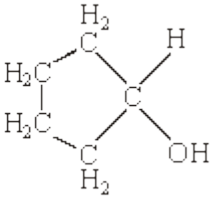
Observation with propanone .....

(4)
(Total 9 marks)

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



C



D

(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) Deduce the number of peaks in the proton n.m.r. spectrum of **C**.

.....

(1)

(d) 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)

(e) 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 9 marks)

24 Which one of the following is **not** a correct general formula for the non-cyclic compounds listed?

A alcohols $C_nH_{2n+2}O$

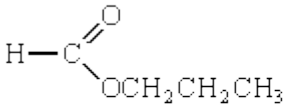
B aldehydes $C_nH_{2n+1}O$

C esters $C_nH_{2n}O_2$

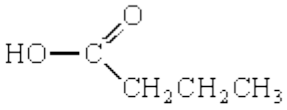
C primary amines $C_nH_{2n+3}N$

(Total 1 mark)

25 (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.

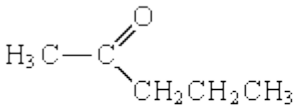
Reagent .....

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

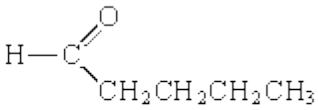
*Observation with **D***.....

(4)

(b) Consider the following pair of isomers.



E



F

(i) Name compound **E**.

.....

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

Reagent .....

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

*Observation with **F***.....

(4)

(c) Draw the structure of the chain isomer of **F** which shows optical isomerism.

(1)
(Total 9 marks)

26 The three compounds $CH_3CH_2CH_2CH_2OH$, $(CH_3)_3COH$ and $CH_3CH_2CH_2CHO$ can be distinguished by use of the following three reagents

1. potassium dichromate(VI) acidified with dilute sulphuric acid
2. Tollens' reagent
3. ethanoic acid, together with a small amount of concentrated sulphuric acid.

(a) Identify which of these three organic compounds would reduce acidified potassium dichromate(VI). Give the structures of the organic products formed. Write a half-equation for the reduction of dichromate(VI) ions in acidic solution.

(6)

(b) Identify which one of these three organic compounds would reduce Tollens' reagent. Give the structure of the organic product formed. Write a half-equation for the reduction of Tollens' reagent.

(3)

(c) Identify which of these three organic compounds would react with ethanoic acid in the presence of concentrated sulphuric acid. In each case, give the structure of the organic product formed.

(4)

(d) State the number of peaks in the proton n.m.r. spectra of $CH_3CH_2CH_2CH_2OH$ and of $(CH_3)_3COH$. (Analysis of peak splitting is not required.)

(2)
(Total 15 marks)

27 (a) Outline a mechanism for the reaction of $CH_3CH_2CH_2CHO$ with HCN and name the product.

Mechanism

Name of product .....

(5)

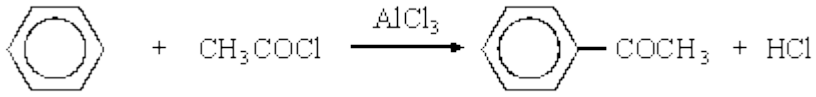
(b) Outline a mechanism for the reaction of CH_3OH with CH_3CH_2COCl and name the organic product.

Mechanism

Name of organic product .....

(5)

(c) 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 14 marks)

28 Which one of the following would **not** reduce an acidified aqueous solution of potassium dichromate(VI)?

A CH_3COOH

B Zn

C CH_3CHO

D $Fe^{2+}(aq)$

(Total 1 mark)

29 Which one of the following statements about but-2-enal, $CH_3CH=CHCHO$, is **not** true?

A It has stereoisomers.

B It shows a strong absorption in the infra-red at about 1700 cm^{-1}.

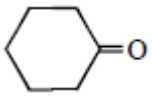
C It will turn an acidified solution of potassium dichromate(VI) green.

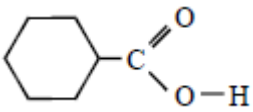
D It can be dehydrated by concentrated sulphuric acid.

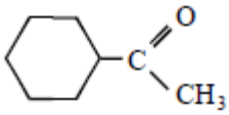
(Total 1 mark)

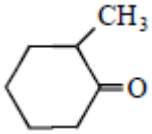
30 The compound lithium tetrahydridoaluminate(III), $LiAlH_4$, is a useful reducing agent. It behaves in a similar fashion to $NaBH_4$. Carbonyl compounds and carboxylic acids are reduced to alcohols. However, $LiAlH_4$ also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following can be reduced by $LiAlH_4$ to a primary alcohol?

A 

B 

C 

D 

(Total 1 mark)

31 Which one of the following can act as an oxidising agent but not as a reducing agent?

A CH_3CHO

B Fe^{2+}

C I^-

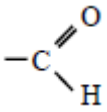
D MnO_4^-

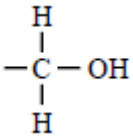
(Total 1 mark)

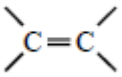
32 Certain chemical tests were performed on the pain-relief drug ibuprofen. The results of these tests are given in the table below.

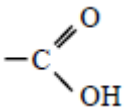
Test	**Result**
Aqueous sodium carbonate	Effervescence
Bromine water	Remained orange
Acidified potassium dichromate(VI) and heat	Remained orange
Fehling's solution and heat	Remained blue

Which one of the following functional groups do these results suggest that ibuprofen contains?

A 

B 

C 

D 

(Total 1 mark)

33 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)

34 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)

35 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)

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

A $(CH_3)_2CHCH(OH)COCH_3$

B $(CH_3)_2C(OH)CH_2COCH_3$

C $(CH_3)_2CHCH(OH)CH_2CHO$

D $(CH_3)_2C(OH)CH_2CH_2CHO$

(Total 1 mark)

1 (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]

2 (a) A mixture of liquids is heated to boiling point for a prolonged time

1

Vapour is formed which escapes from the liquid mixture, is changed back into liquid and returned to the liquid mixture

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

(b) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

1

(c) Mixture heated in a suitable flask / container

A labelled sketch illustrating these points scores the marks

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable cooled collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

(d) Hydrogen bonding in ethanol and ethanoic acid or no hydrogen bonding in ethanal

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:

Add Tollens' reagent / ammoniacal silver nitrate / aqueous silver nitrate followed by 1 drop of aqueous sodium hydroxide, then enough aqueous ammonia to dissolve the precipitate formed

OR

Add Fehling's solution

1

Warm

M2 and M3 can only be awarded if M1 is given correctly

1

Result with Tollen's reagent:

Silver mirror / black precipitate

OR

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

M5 can only be awarded if M4 is given correctly

OR

Reagent; add ethanol and concentrated sulfuric acid and warm

Result; no sweet smell / no oily drops on the surface of the liquid,

hence no acid present

[16]

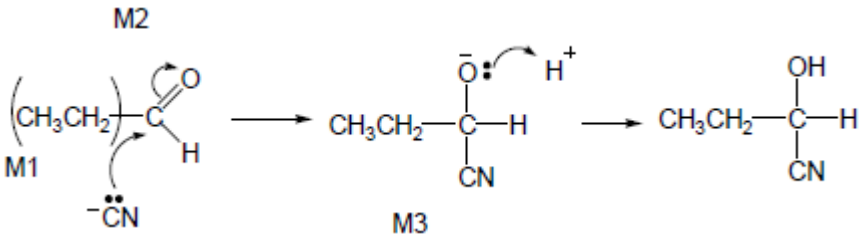
3 B

[1]

4 (a) Nucleophilic addition

1

M4 for lp, arrow and H+

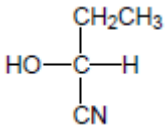


Allow C_2H_{5-} for CH_3CH_{2-}

- *M1 and M4 include lone pair and curly arrow.*
- *Allow: CN^- but arrow must start at lone pair on C.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+.*
- *+ rather than δ+ on C=O loses M2.*
- *Penalise incorrect partial charges.*
- *M3 is for correct structure including minus sign but lone pair is part of M4.*
- *Penalise extra curly arrows in M4.*

4

(b) (i) M1



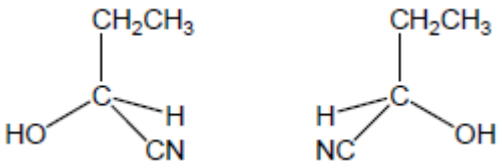
M1 for correct structure of product of part (a).

Allow C_2H_{5-} for CH_3CH_{2-}.

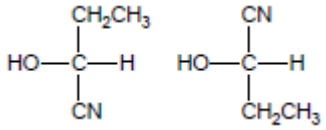
Penalise wrongly bonded, OH or CN or CH_2CH_3 once only in clip.

1

M2

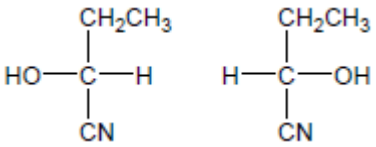


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not <u>show</u> the enantiomers as mirror images.

Students must <u>show</u> an attempt at mirror images, eg allow

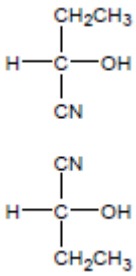


ie vertical groups same and horizontal swapped as if there was a mirror between them

No mirror need be shown

Do not penalize wedge bond when wedge comes into contact with both C & N

However these two could score M2 if placed as below as if with a "mirror" horizontally between them.



1

(ii) M1 (Plane) <u>polarized light</u>

M2 only scores following correct M1

1

M2 <u>Rotated</u> in <u>opposite</u> directions (equally) (only allow if M1 correct or close)

Not just in different directions but allow one rotates light to the left and one to the right.

Not molecules rotate.

1

(c) <u>2-hydroxybutane(-1-)nitrile</u>

1

(d) Weak acid / (acid) only slightly / partially dissociated / ionised

Ignore rate of dissociation.

1

$[CN^-]$ very low

Allow (very) few cyanide ions.

Mark independently.

1

(e) (i) $H_2C{=}CH{-}CH_3 + NH_3 + \frac{3}{2}O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O$

OR

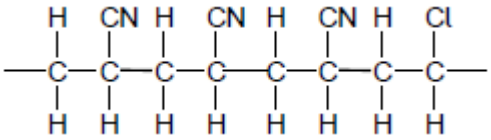
$H_2C{=}CH{-}CH_3 + NH_3 + 3O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O_2$

OR doubled.

Allow C_3H_6 and CH_2CHCN or C_3H_3N on this occasion only.

1

(ii)

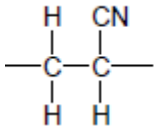
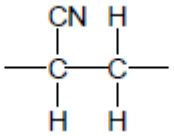
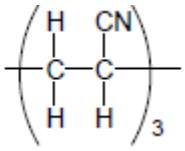


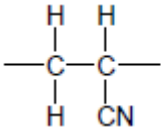
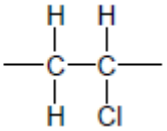
Ignore n.

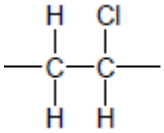
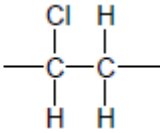
Must show trailing bonds.

Do not penalise C–NC bond here on this occasion.

Must contain, in any order,

3 of  or 3 of  or 

Allow  or 

and one of  or 

Allow –$CH_2CH(CN)CH_2CHCl$– etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

1

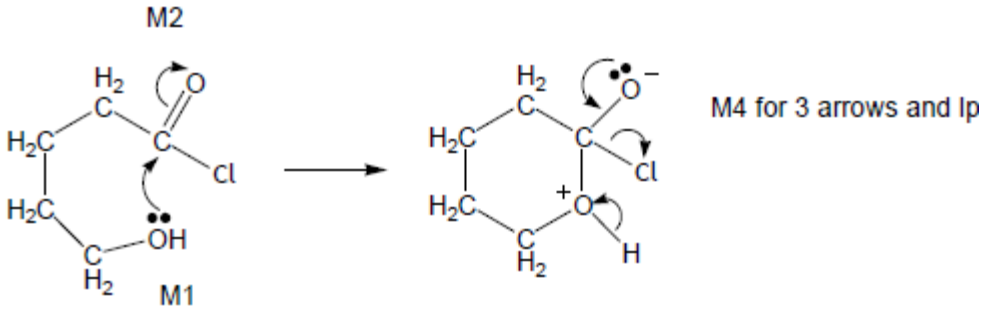
[15]

5 (a) (i) (nucleophilic) addition-elimination

Not electrophilic addition-elimination

Ignore esterification

1



M3 for structure

- *If wrong nucleophile used or O–H broken in first step, can only score M2.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2.*
- *If Cl lost with C=O breaking lose M2.*
- *M3 for correct structure <u>with charges</u> but lone pair on O is part of M4.*
- *Only allow M4 after correct / very close M3.*
- *Ignore HCl shown as a product.*

4

a 20-50 (ppm) or single value or range entirely within this range

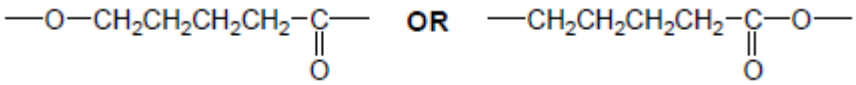
If values not specified as a or b then assume first is a.

1

b 50-90 (ppm) or single value or range entirely within this range

1

(ii)

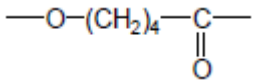


Must have trailing bonds, but ignore n.

1

OR $-OCH_2CH_2CH_2CH_2CO-$ **OR** $-CH_2CH_2CH_2CH_2COO-$

Allow



but not - C_4H_8-

one unit only

Condensation

1

(b)

	Tollens'	Fehling's / Benedicts	Acidified potassium dichromate

Penalise wrong formula for Tollens or missing acid with potassium dichromate but mark on.

1

J	No reaction / no (visible) change / no silver mirror	No reaction / no (visible) change / stays blue / no red ppt	No reaction / no (visible) change / stays orange / does not turn green

Ignore 'clear', 'nothing'.

Penalise wrong starting colour for dichromate.

1

K	Silver <u>mirror</u> / grey <u>ppt</u>	Red <u>ppt</u> (allow brick red or red-orange)	(orange) turns green

1

J Two (peaks)

Allow trough, peak, spike.

1

K Four (peaks)

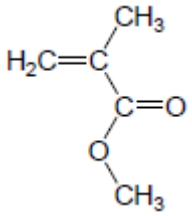
Ignore details of splitting.

If values not specified as J or K then assume first is J.

1

(c) If all the structures are unlabelled, assume that the first drawn ester is L, the second ester is M; the first drawn acid is N, the second P. The cyclic compound should be obvious.

L
ester



OR $H_2C=C(CH_3)COOCH_3$

All $C_5H_8O_2$ L to P must have C=C.

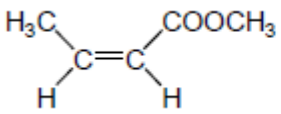
Allow CH_3–.

Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

1

M
ester



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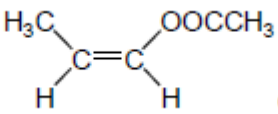

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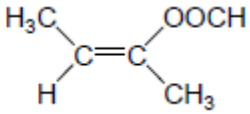
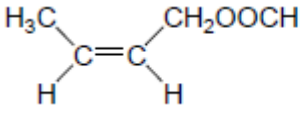
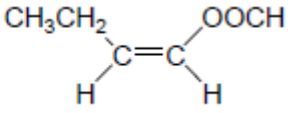


$CH_3CH=CHCOOCH_3$ $CH_3CH=CHOOCCH_3$ $CH_3CH=C(CH_3)OOCH$



OR



OR

$CH_3CH=CHCH_2OOCH$ $CH_3CH_2CH=CHOOCH$

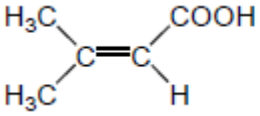
Allow either E–Z isomer.

Allow CH_3- or C_2H_5- but not CH_2CH_3-.

Allow $CH_3CHCHCOOCH_3$ etc.

1

N
acid



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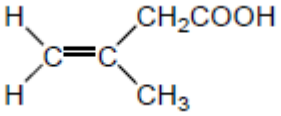
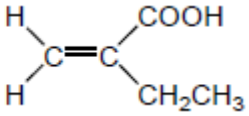


OR



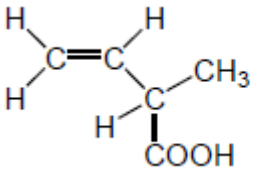
$(CH_3)_2C=CHCOOH$ $H_2C=C(CH_3)CH_2COOH$ $H_2C=C(COOH)CH_2CH_3$

Allow CH_3- or C_2H_5- but not CH_2CH_3-.

Allow $-CO_2H$.

Not cyclic isomers.

Not the optically active isomer.

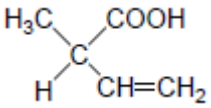


which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P
acid



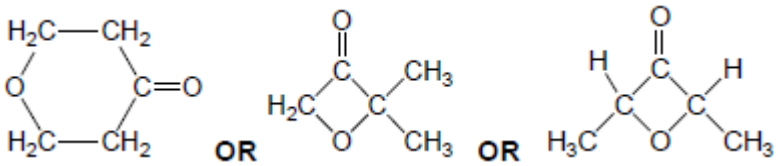
Allow $-CO_2H$.

$CH_3CH(COOH)CH=CH_2$

Allow $CH_3CH(CO_2H)CHCH_2$ or $CH_3CH(CO_2H)C_2H_3$.

1

Q



Not cyclic esters.

1

[19]

6 (a) (i) 2-hydroxypropanoic acid

OR

2-hydroxypropan(-1-)oic acid

Do not penalise different or missing punctuation or extra spaces.

Spelling must be exact and order of letters and numbers as here.

Can ignore −1− before –oic, but penalise any other numbers here.

1

(ii) $C_{12}H_{22}O_{11} + H_2O \longrightarrow 4CH_3CH(OH)COOH$

Allow $4C_3H_6O_3$

OR

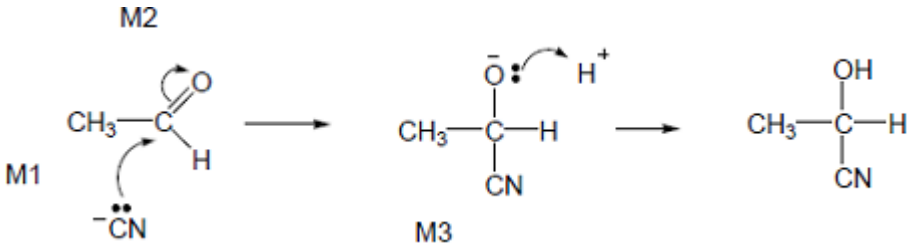
$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2CH_3CH(OH)COOH + C_6H_{12}O_6$

Allow $2C_3H_6O_3$

1

(b) (i) Nucleophilic addition

M4 for lp, arrow and H+



- *M1 lp and minus must be on C*
- *M1 and M4 include lone pair and curly arrow.*
- *M2 not allowed independent of M1, but allow following some attempt at attack on carbonyl C*
- *allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2*
- *M3 is for correct structure including minus sign but lone pair is part of M4*
- *Allow arrow in M4 to H of H-CN with arrow forming cyanide ion.*

5

(ii) Equal mixture of enantiomers / (optical) isomers

1

(iii) (Plane) polarized light

If missing no further mark.

1

(Polarised light) rotated by single enantiomer but unaffected by racemate

Both needed; not allow bend, twist etc.

1

(c) (i) $CH_3CH(OH)COOH + NaOH \rightarrow CH_3CH(OH)COONa + H_2O$

OR $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$

Not ambiguous mol formulae for product - must show COONa or CO_2Na or COO^- or CO_2^-

1

(ii) $[H^+] = K_a$ ***OR*** $pH = pK_a$

1

pH = 3.86

Allow more than 2 decimal places but not fewer.

1

(iii) M1 buffer

Ignore acidic but penalise alkaline or basic.

1

Any two out of the three marks M2 , M3 & M4

M2 Large lactate concentration in buffer
OR sodium lactate completely ionised

M3 added acid reacts with / is removed by lactate ion or A^- or sodium lactate or salt

OR equation $H^+ + A^- \rightarrow HA$

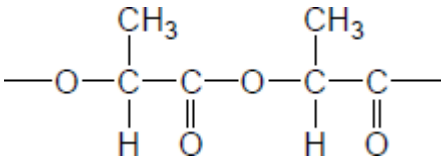
Ignore reaction of H^+ with OH^-
Ignore reference to equilibrium unless it is shown.

M4 ratio $[HA] / [A^-]$ stays almost constant

Ignore H^+ or pH remains constant.

Max 2

(d) (i)



No marks if ester link missing

Correct ester link

allow –COO–

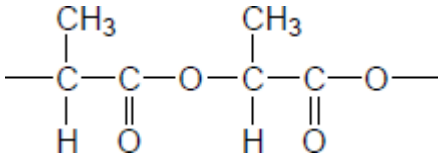
NB Correct answer scores 2

Ignore n here (compare with (d)(iv).

Ignore brackets

1

OR



All rest correct with trailing bonds

If OH or COOH on either or both ends, lose one, ie dimer scores 1

If more than two repeating units, lose 1

1

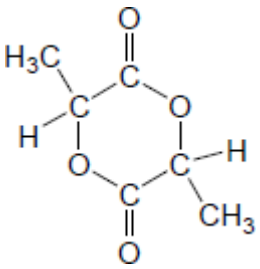
(ii) (Poly)ester ie allow ester

Not terylene.

Ignore spaces and brackets in answer.

1

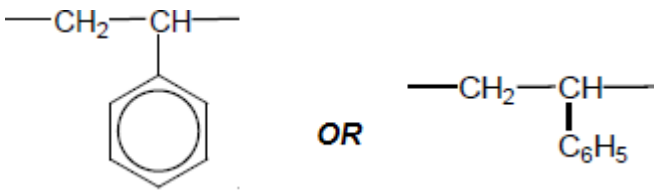
(iii)



Allow any <u>cyclic $C_6H_8O_4$</u>

1

(iv)



Penalise n here (compare with (d)(i)

Ignore brackets.

Not allow Ph for phenyl.

1

(v) In landfill, no air or UV, to assist decay
OR not enough water or moisture (to hydrolyse polyester)

Allow landfill has / contains:

no or few bacteria / micro-organisms / enzymes compared with compost heap

OR *less oxygen*

OR *<u>lower</u> temperature.*

1

[22]

7 Dichromate(VI) will also oxidise / give a positive test with alcohols

Allow 'dichromate'.

Allow 'dichromate(VI) will oxidise other organic molecules / functional groups'.

[1]

8 (a) Yes, because it is oxidised to ethanal / CH_3CHO
OR it is oxidised to a compound that contains CH_3CO group

Ignore 'primary alcohols are oxidised to aldehydes'.

Need 'yes' and an explanation to be awarded the mark.

1

(b) M_r CHI_3 = 393.7 **(M1)**

Allow if clearly shown in a calculation.

Allow 394

1

Moles CHI_3 = 10 / 393.7 = 2.54×10^{-2} **(M2)**

Allow a consequential answer on an incorrect M_r.

*2.54×10^{-2} scores **M1** and **M2**.*

1

Moles I_2 = 7.62×10^{-2} **(M3)**

*Allow 3 × **M2**.*

1

Mass I_2 = $7.62 \times 10^{-2} \times 253.8$ = 19.34g **(M4)**

*Allow **M3** × 253.8 or **M3** × 254*

1

Scaling 19.34 / 0.832 = 23.2g **(M5)**

*Allow **M4** / 0.832*

Lose this mark if the answer is not given to 3 significant figures.

*Answer without working scores **M5** only.*

Allow any chemically correct alternative method.

Calculations which combine several steps in one expression can score the marks for all of these individual steps.

1

(c) Remove soluble impurities

Allow 'remove excess sodium hydroxide / iodine'.

Allow 'remove excess sodium methanoate / sodium iodide'.

Allow 'remove excess reagents'.

1

(d) Will not dissolve solid / solid is insoluble in water

Allow 'will not react with solid'.

1

[8]

9 (a) Sn / HCl ***OR*** Fe / HCl not conc H_2SO_4 nor any HNO_3

Ignore subsequent use of NaOH

Ignore reference to Sn as a catalyst with the acid

Allow H_2 (Ni / Pt) but penalise wrong metal

But NOT $NaBH_4$ $LiAlH_4$ Na / C_2H_5OH

1

Equation must use molecular formulae

$C_6H_4N_2O_4 + 12\,[H]$

12[H] and $4H_2O$ without correct molecular formula scores 1 out of 2

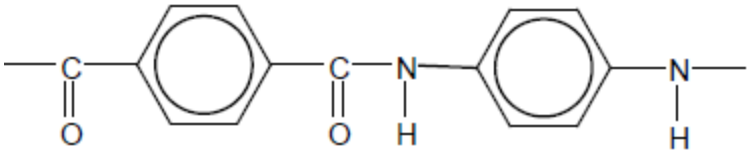
1

$$\rightarrow C_6H_8N_2 + 4H_2O$$

Allow .... + $6H_2$ if H_2 / Ni used

Allow −CONH− or −COHN− or $-C_6H_4-$

1



Mark two halves separately: lose 1 each for

- *error in diamine part*
- *error in diacid part*
- *error in peptide link*
- *missing trailing bonds at one or both ends*
- *either or both of H or OH on ends*

Ignore n

2

(b) H_2 (Ni / Pt) but penalise wrong metal

NOT Sn / HCl, $NaBH_4$ etc.

1

CH_2

1

In benzene 120°

1

In cyclohexane 109° 28’ or 109½°

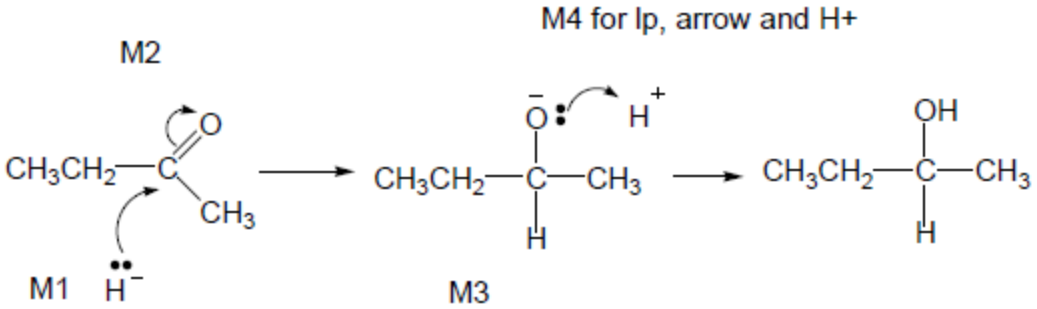
Allow 108° - 110°

If only one angle stated without correct qualification, no mark awarded

1

(c) (i) Nucleophilic addition

1



- *M2 not allowed independent of M1, but allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2*
- *M3 is for correct structure including minus sign but lone pair is part of M4*
- *Allow C_2H_5*
- *M1 and M4 include lp and curly arrow*
- *Allow M4 arrow to <u>H</u> in H_2O (ignore further arrows)*

4

(ii) M1 Planar C=O (bond / group)

Not just planar molecule

1

M2 Attack (equally likely) from either side

Not just planar bond without reference to carbonyl

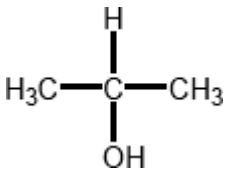
1

M3 (about product): Racemic mixture formed ***OR*** 50:50 mixture or each enantiomer equally likely

1

[17]

10 **L**



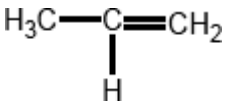
Allow $(CH_3)_2CHOH$ or $CH_3CH(OH)CH_3$

Allow name propan–2–ol

Penalise contradiction of name and structure

1

M



Allow $CH_3CH=CH_2$

Allow name propene

ignore -1- but penalise other numbers

Penalise contradiction of name and structure

1

Step 1 $NaBH_4$ or $LiAlH_4$

Zn/HCl or Sn/HCl

or H_2/Ni or H_2/Pt

Ignore name if formula is correct

ignore solvent

ignore acid (for 2nd step) but penalise acidified $NaBH_4$

Apply list principle for extra reagents and catalysts.

M1

1

(nucleophilic) addition

Addition (not nucleophilic)

Penalise electrophilic

Ignore reduction

M2

1

Step 2 <u>conc</u> H_2SO_4 or <u>conc</u> H_3PO_4 or Al_2O_3

Apply list principle for extra reagents and catalysts.

M3

1

elimination

Independent from M3

penalise nucleophilic or electrophilic

ignore dehydration

M4

1

Step 3 HBr

Apply list principle for extra reagents and catalysts.

M5

1

electrophilic addition

Independent from M5

M6

1

[8]

11 (a) (i) Green

Ignore shades of green.

1

(ii) Excess acidified potassium dichromate(VI)

1

Reflux (for some time)

1

In the diagram credit should be given for

- a vertical condenser

Lose M3 and M4 for a distillation apparatus.

1

- an apparatus which would clearly work

Do not allow this mark for a flask drawn on its own.

Penalise diagrams where the apparatus is sealed.

1

(iii) Distillation

1

Immediately (the reagents are mixed)

1

(b) Keep away from naked flames

Allow heat with water-bath or heating mantle.

If a list is given ignore eye protection, otherwise lose this mark.

1

(c) (i) Tollens' or Fehling's reagents

*Incorrect reagent(s) loses **both** marks.*

Accept mis-spellings if meaning is clear.

1

Silver mirror / red ppt. formed

Accept 'blue to red' but not 'red' alone.

1

(ii) Sodium carbonate (solution) / Group II metal

Allow indicator solutions with appropriate colours.

Accept any named carbonate or hydrogen carbonate.

1

Effervescence / evolves a gas

Accept 'fizzes'.

1

(d) Propanoic acid

If this mark is lost allow one mark if there is reference to stronger intermolecular forces in the named compound.

Lose M1 and M3.

1

Contains hydrogen bonding

1

Some comparison with other compounds explaining that the intermolecular forces are stronger in propanoic acid

1

[15]

12 (a) (i) $C_6H_6 + CH_3CH_2COCl \rightarrow C_6H_5COCH_2CH_3 + HCl$

OR

$C_6H_6 + CH_3CH_2CO^+ \rightarrow C_6H_5COCH_2CH_3 + H^+$

allow C_2H_5

penalise C_6H_5–CH_3CH_2CO

allow + on C or O in equation

1

Phenylpropanone

OR ethylphenylketone **OR** phenylethylketone

Ignore 1 in formula, but penalise other numbers

1

$AlCl_3$

can score in equation

1

$CH_3CH_2COCl + AlCl_3 \rightarrow CH_3CH_2CO^+ + AlCl_4^-$

allow C_2H_5

allow + on C or O in equation

1

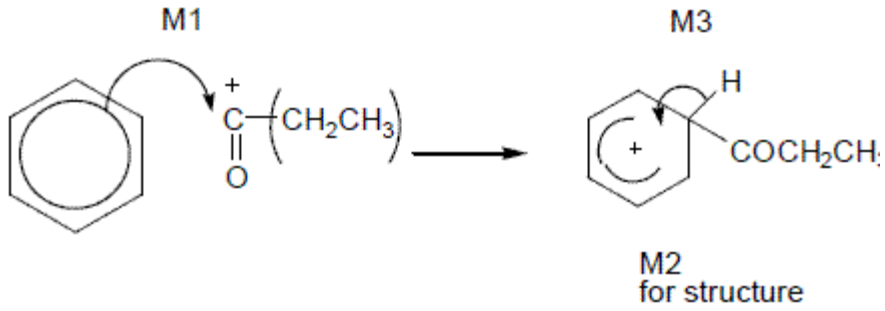
$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$

1

(ii) electrophilic substitution

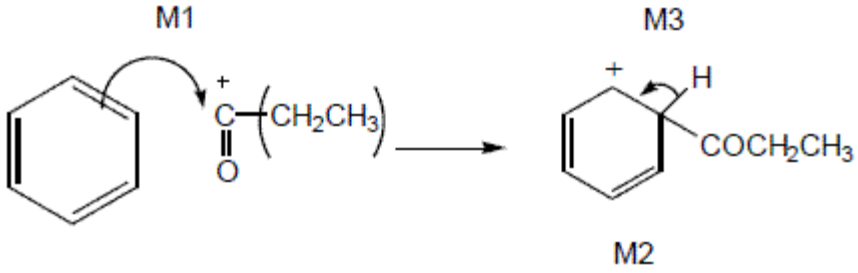
can allow in (a)(i) if no contradiction

1



M2
for structure

OR



M2

M1 arrow from circle or within it to C or to + on C
horseshoe must not extend beyond C2 to C6 but can be smaller
+ not too close to C1

M2 penalise C_6H_5–CH_3CH_2CO (even if already penalized in (a)(i))

M3 arrow into hexagon unless Kekule

allow M3 arrow independent of M2 structure

ignore base removing H in M3

3

(b) (i) $CH_3CH_2\underline{CHO} + HCN \rightarrow CH_3CH_2CH(OH)CN$ **OR** $C_2H_5CH(OH)CN$

aldehyde must be –CHO brackets optional

1

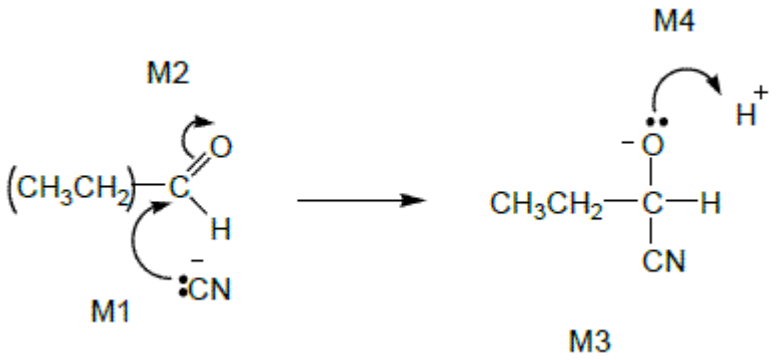
2-hydroxybutanenitrile **OR** 2-hydroxybutan<u>o</u>nitrile

no others

1

(ii) nucleophilic addition

1



M1 includes lp and arrow to Carbonyl C and minus charge (on either C or N)

Not allow M2 before M1, but allow M1 to C^+ after non-scoring carbonyl arrow

Ignore δ+, δ– on carbonyl group, but if wrong way round or full + charge on C lose M2

M3 for correct structure including minus sign. Allow C_2H_5

M4 for lp and curly arrow to H^+

4

(iii) (propanone) slower ***OR*** propanal faster

1

inductive effects of alkyl groups
OR
C of C=O less δ+ in propanone
OR
alkyl groups in ketone hinder attack
OR
easier to attack at end of chain

if wrong, no further marks

1

[18]

13 (a) nucleophilic addition

1

Attack by HCN loses M1 and M2
M2 not allowed independent of M1, but
allow M1 for correct attack on C+
+C=O loses M2
M2 only allowed if correct carbon attacked
allow minus charge on N i.e. :CN⁻

4

M3 for completely correct structure not including lp

allow C_3H_7 in M3

M4 for lp and arrow

allow without –

1

2-hydroxy-2-methylpentan(e)nitrile

allow 2-hydroxy-2-methylpentanonitrile

(b) Product from **Q** is a racemic mixture/equal amounts of enantiomers

if no reference to products then no marks;

1

racemic mixture is inactive or inactive explained

*not **Q** is optically active or has a chiral centre etc*

1

Product from **R** is inactive (molecule) or has no chiral centre

1

[9]

14 (a) $CH_3COCl + AlCl_3 \rightarrow CH_3\overset{+}{C}O + AlCl_4^-$

(1) equation (1)

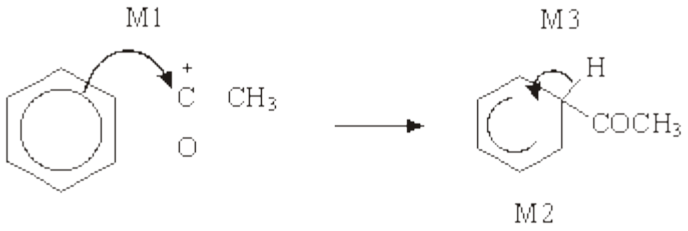
2

penalise wrong alkyl group once at first error
position of + on electrophile can be on O or C or outside [ ]
penalise wrong curly arrow in the equation or lone pair on $AlCl_3$ else ignore

Electrophilic substitution

NOT F/C acylation

1



horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1

M3 arrow into hexagon unless Kekule

allow M3 arrow independent of M2 structure

M1 arrow from within hexagon to C or to + on C

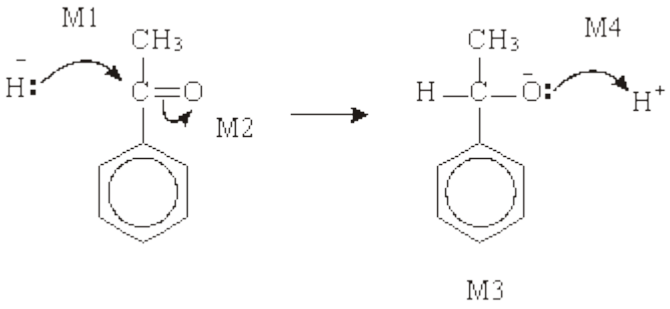
+ must be on C of $\overset{+}{\text{RCO}}$

3

(b) Nucleophilic addition

NOT reduction

1



M2 not allowed independent, but can allow M1 for attack of H^- on C+ formed

4

1–phenylethan(–1–)ol or (1–hydroxyethyl)benzene

l

(c) dehydration or elimination

1

(conc) H_2SO_4 or (conc) H_3PO_4

allow dilute and Al_2O_3

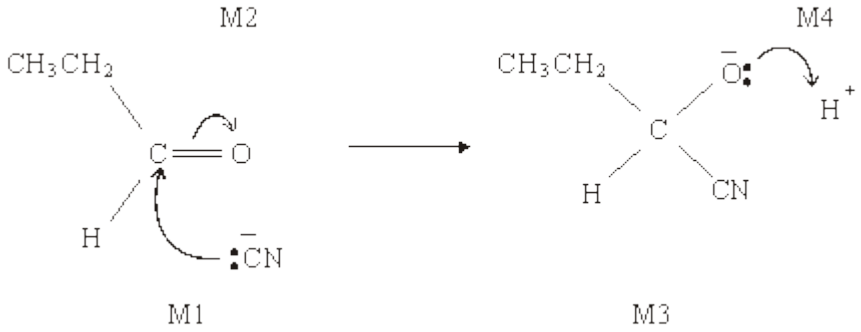
Do not allow iron oxides

1

[14]

15 (a) nucleophilic addition

1

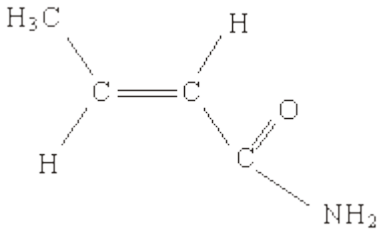


4

(b) (i) 2-hydroxybutanenitrile

1

(ii)

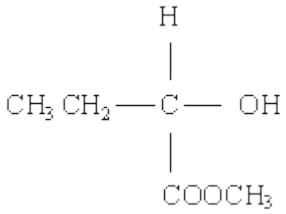


(allow 1 for amide even if not C_4H_7NO, i.e. $RCONH_2$)

(if not amide, allow one for any isomer of C_4H_7NO which shows geometric isomerism)

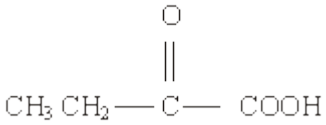
2

(c) (i)



1

(ii)



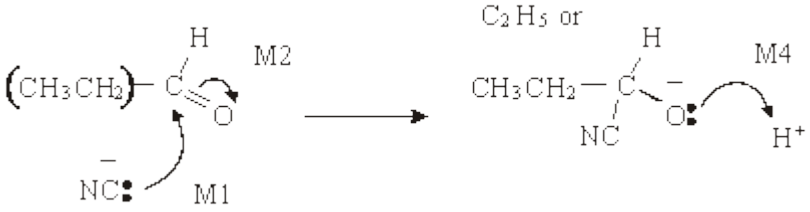
1

(iii) $CH_3CH=CHCOOH$

1

[11]

16 (a) necleophilic addition;



1

M3 structure;

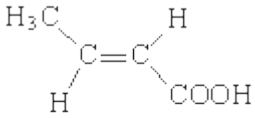
(be lenient on position of charge on CN–)
(M2 not allowed independent of M1,
but allow M1 for correct attack on C+
if M2 show as independent first.)
(+on C of C=O loses M2 but ignore δ+ if correct)
(M4 for arrow and lone pair (only allow for correct M3 or close))

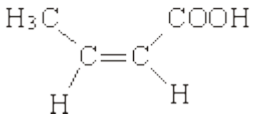
4

(b) (i) 2-hydroxybutanoic acid

1

(ii)



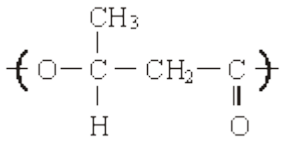


1

geometric(al) or cis-trans

1

(c) (i)



(one unit only) (ignore brackets or n) (trailing bonds are needed)

1

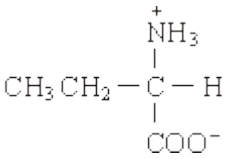
(ii) can be hydrolysed

OR

can be reacted with/attacked by acid/base/nucleophiles/H_2O/OH^-;

1

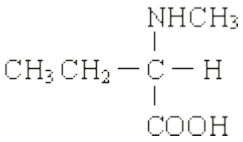
(d) (i)



(allow $-NH_3^+$)

1

(ii)



(or zwitterions product)

1

(iii) nucleophilic substitution;

1

[14]

17 D

[1]

18 (a) (i)

Reagent	Tollens	Fehlings or Benedicts	$K_2Cr_2O_7/H^+$ or acidified	$KMnO_4/H^+$	I_2/NaOH
Propanal	silver (mirror)	red ppt or goes red *(not red solution)*	goes green	goes colourless	No reaction
Propanone	no reaction	no reaction	no reaction	no reaction	Yellow (ppt)

(penalise incomplete reagent e.g. $K_2Cr_2O_7$ or $Cr_2O_7^{2-}/H^+$ then mark on)

3

(ii) propanal 3 peaks

ignore splitting even if wrong

1

propanone 1 peak

1

(b) **X** is CH_3CH_2COOH or propanoic acid if both name and formula given, both must be correct, but

1

Y is $CH_3CH(OH)CH_3$ or propan-2-ol allow propanol with correct formula

1

Mark the type of reaction and reagent/condition independently.
The reagent must be correct or close to score condition

Step 1 Oxidation

$K_2Cr_2O_7/H^+$ or other oxidation methods as above
allow $Cr_2O_7^{2-}H^+$ if penalised above (ecf)
reflux (not Tollens/Fehlings) or heat or warm

1

Step 2

reduction or nucleophilic addition	reduction or nucleophilic addition	reduction or hydrogenation	**1**
$NaBH_4$	$LiAlH_4$	H_2	**1**
in (m)ethanol or water or ether or dry	ether or dry	Ni / Pt etc	**1**

Step 3 esterification or (nucleophilic) addition-elimination or condensation

1

(conc) H_2SO_4 or HCl

1

warm (allow without acid reagent if **X** and **Y** given as reagents)

1

or reflux or heat

1

[15]

19 (a) (i) An appropriate alkene; $CH_3CH_2CHCH_2$ or $(CH_3)_2CCH_2$

1

Isomer 1

1

Isomer 2

1

Position isomerism

1

Mechanism

electrophilic attack and electron shift to Br (Unless H^+ used)

1

carbocation

1

reaction with carbocation

[Allow mechanism marks for the alkene $CH_3CHCHCH_3$]
[Allow one mark if mechanism for minor product given]

1

(ii) An appropriate carbonyl; CH_3CH_2CHO

1

Mechanism nucleophilic attack and electron shift to O

1

anion intermediate

1

reaction with anion

[Allow mechanism marks for the carbonyl $(CH_3)_2CO$]

1

Isomer 1

1

Isomer 2

1

Optical isomerism

NB Isomer structures must be tetrahedral

NB Penalise "stick" structures once in part (a)

1

(b) QoL

Large charge on carbonyl carbon atom due to bonding to O and Cl

1

Nucleophiles have electron pairs which can be donated

1

Equation Species

1

Balanced

1

[18]

20 A

[1]

21 C

[1]

22 (a) (i) Potassium (OR sodium) dichromate(VI) OR <u>correct</u> formula
OR potassium manganate(VII)

(Oxidation state not needed, but must be correct if included)

(Penalise errors in the formula or oxidation state, but mark conditions)

1

Acidified OR H_2SO_4 / HCl (*NOT with* $KMnO_4$) / H_3PO_4 / HNO_3

(Ignore heat or reflux)

(Credit "acidified" as part of reagent)

1

Oxidation or redox

1

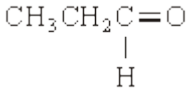
(ii) $NaBH_4$ OR $LiAlH_4$ OR H_2/Ni

1

$CH_3COCH_3 + 2[H] \rightarrow CH_3CH(OH)CH_3$

(Credit H_2 in the equation if H_2 has been chosen as reagent)

1

(b) (i) 

(Structure must show aldehyde structure)

(Credit C_2H_5 as alternative to CH_3CH_2)

(ii)

M1	Tollens' reagent OR ammoniacal silver nitrate OR $AgNO_3 + NH_3$	OR Fehling's solution	OR <u>acidified</u> potassium dichromate

1

M2	stays colourless	stays blue	stays orange

1

(Provided reagent is correct, credit "no reaction", "no change", "nothing", "no observation" for M2)

M3	silver <u>mirror</u> / <u>deposit</u> OR black / grey <u>precipitate</u>	red / brown / orange <u>precipitate / solid</u>	goes green

1

(Credit other correct reagents and observation)

(For M1, penalise $AgNO_3$ alone, penalise $Ag(NH_3)_2^+$, penalise "potassium dichromate", etc., but, in each case, mark on and credit correct M2 and M3)

(If totally wrong reagent or no reagent, CE = no marks for M1,M2 or M3)

1

[9]

23 (a) Pentan-2-one

1

(b) (i) 1680 – 1750 (cm^{-1})

1

(ii) 3230 – 3550 or 1000 – 1300 (cm^{-1})

1

(iii) 4

1

(c)

Reagent	$K_2Cr_2O_7/H^+$	$KMnO_4/H^+$	Na	CH_3COOH/H_2SO_4
with **C**	no reaction	no reaction	no reaction	no reaction
with **D**	goes green	goes colourless	effervescence	smell

1 **1** **1**

(penalise incomplete reagent e.g. $K_2Cr_2O_7$ or $Cr_2O_7^{2-}/H^+$ then mark on)

(d)

Reagent	Tollens	Fehlings or Benedicts
with **E**	silver (mirror)	red ppt or goes red *(not red solution)*

1

1

[9]

24 B

[1]

25 (a) (i) propyl methanoate **(1)**

not propanyl

- *A wrong reagent or no reagent scores zero*
- *An incomplete reagent such as silver nitrate for Tollens, or potassium dichromate loses the reagent mark, but can get both observation marks*
- *penalise observations which just say colour change occurs or only state starting colour*

(ii) *Reagent*: $NaHCO_3$ **(1)**

*Observation with **C***: no reaction **(1)**

*Observation with **D***: effervescence **(1)**

*for **C** and **D** NOT Tollens*

Test	an identified (hydrogen) carbonate	acidified $K_2Cr_2O_7$	acidified $KMnO_4$	correct metal	UI or stated indicator	PCl_5
Observation with C	no reaction	goes green	goes colourless	no reaction	no change	no reaction
observation with D	bubbles or CO_2	no change	no change	bubbles or H_2	red or correct colour pH 3 – 6.9	(misty) fumes

4

(b) (i) *Reagent*: pentan-2-one **(1)**

or 2-pentanone

but not pent-2-one or pentyl

(ii) *Reagent*: Tollen's or Fehling's **(1)**

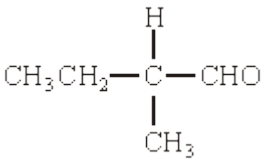
*Observation with **E***: no reaction **(1)**

*Observation with **F***: silver mirror or red ppt **(1)**

for **E** and **F**

Test	Tollens	Fehlings or Benedicts	iodoform or I_2/NaOH	acidified $K_2Cr_2O_7$	Schiff's
observation with E	no reaction	no reaction	yellow (ppt)	no change	no reaction
observation with F	silver or mirror or grey or ppt	red or ppt not red solution	no reaction	goes green	goes pink

4

(c)  **(1)**

must be aldehyde. Allow C_2H_5 for CH_3CH_2 otherwise this is the only answer

1

[9]

26 (a) $K_2Cr_2O_7/H_2SO_4$ reuced by

$CH_3CH_2CH_2CH_2OH$ **(1)**

oxidised to $CH_3(CH_2)_2CHO$ **(1)**
and $CH_3(CH_2)_2COOH$ **(1)**

$CH_3CH_2CH_2CHO$ **(1)**

oxidised to $CH_3(CH_2)_2COOH$ **(1)**

Equation: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ **(1)**

Note: Deduct one if all three compounds given as reducing agents.

6

(b) Tollens' reduced by

$CH_3CH_2CH_2CHO$ **(1)**

oxidised to $CH_3(CH_2)_2COOH$ **(1)**

Equation $[Ag(NH_3)_2]^+ + e^- \rightarrow Ag + 2NH_3$ **(1)**

3

(c) $CH_3CH_2CH_2CH_2OH$ **(1)**

Product $CH_3CH_2CH_2CH_2OOCCH_3$ **(1)**

$(CH_3)_3COH$

Product $(CH_3)_3COOCCH_3$ **(1)**

4

(d) $CH_3CH_2CH_2OH$ has five peaks **(1)**

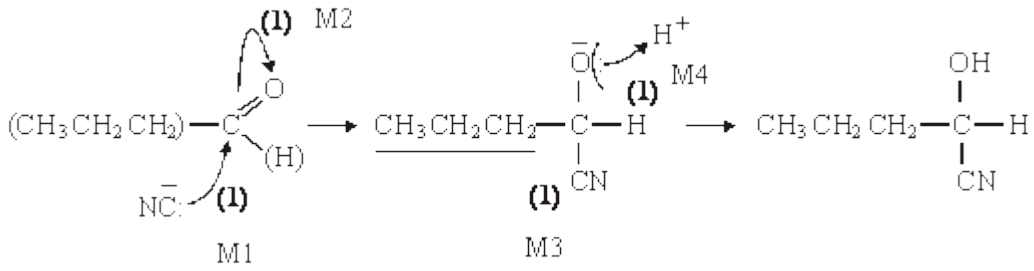
$(CH_3)_3COH$ has two peaks **(1)**

2

[15]

27

(a) *Mechanism*



Allow C_3H_7 if structure shown elsewhere

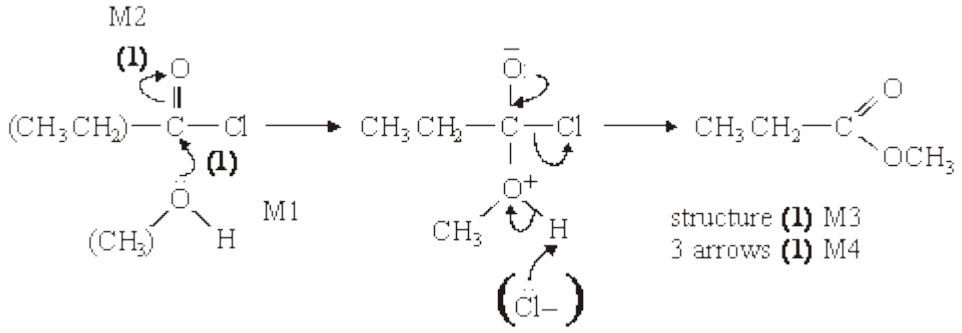
penalise HCN splitting if wrong

Name of product: 2-hydroxypenta(neo)nitrile **(1)**

or 1-cyanobutan-1-ol

5

(b) *Mechanism*

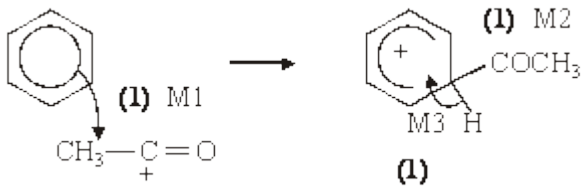


Name of organic product: methylpropanoate **(1)**

5

(c) (i) ([] CH_3CO [])$^+$ **(1)**

(ii)



4

Notes

(abc) extra curly arrows are penalised

(a) be lenient on position of negative sign on : CN^- but arrow must come from lp

(a)/(b) C=O alone loses M2 but can score M1 for attack on C+, similarly C—Cl

(a) allow 2-hydroxypentanonitrile or 2-hydroxypenta(ne)nitrile ... pentylnitrile

(b) in M4, allow extra: Cl^- attack on H, showing loss of H^+

(c) (i) allow formula in an "equation"(balanced or not)
be lenient on the position of the + on the formula

(ii) for M1 the arrow must go to the C or the + on the C
don't be too harsh about the horseshoe, but + must not be close to the saturated C
M3 must be final step not earlier; allow M3 even if structure (M2) is wrong

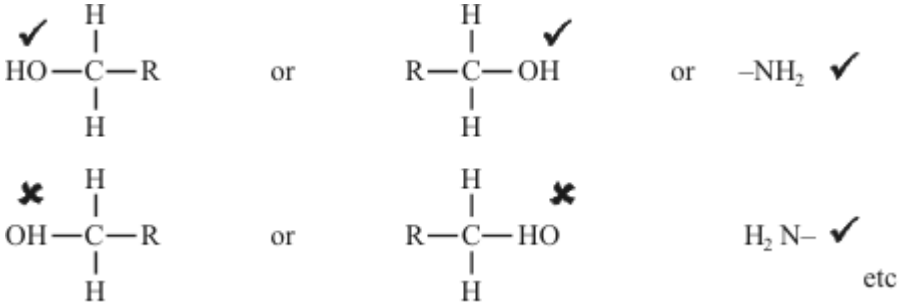
[14]

Organic points

(1) Curly arrows: must show movement of a pair of electrons,
i.e. from bond to atom or from lp to atom / space
e.g.

(2) Structures

penalise sticks (i.e. ) once per paper



Penalise once per paper

allow CH_3– or $–CH_3$ or  or CH_3
or H_3C–

28 A **[1]**

29 D **[1]**

30 B **[1]**

31 D **[1]**

32 D **[1]**

33 B **[1]**

34 C **[1]**

35 [1]

36 [1]