

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.3.8 ALDEHYDES AND KETONES

SCORE

/323

PERCENTAGE

%

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Q1.

Acyl chlorides are useful reagents in synthesis. They react with aromatic compounds and also with alcohols.

- (a) $\text{CH}_3\text{CH}_2\text{COCl}$ reacts with benzene in the presence of AlCl_3 in an electrophilic substitution reaction.

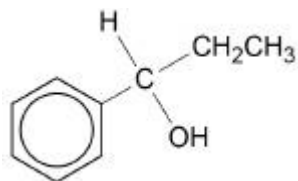
Give an equation for the reaction of $\text{CH}_3\text{CH}_2\text{COCl}$ with AlCl_3 to form the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

Equation _____

Mechanism _____

(4)

- (b) The organic product in **part (a)** can be converted into the alcohol shown.



Give the IUPAC name of the alcohol.

Give the reagent needed for this reaction and name the mechanism.

IUPAC name _____

Reagent _____

Name of mechanism _____

(3)

- (c) The alcohol shown in **part (b)** reacts with ethanoyl chloride to form an ester.

Describe what would be observed when the alcohol reacts with ethanoyl chloride.

Name the mechanism for the reaction to form the ester.

Draw the structure of the ester.

Observation _____

Name of mechanism _____

(3)
(Total 10 marks)

Q2.

How many structural isomers with the molecular formula $C_5H_{10}O$ react with Tollens' reagent?

- | | | |
|----------|---|-----------------------|
| A | 3 | ☐ |
| B | 4 | ☐ |
| C | 5 | ☐ |
| D | 6 | ☐ |

(Total 1 mark)

Q3.

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 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$ 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

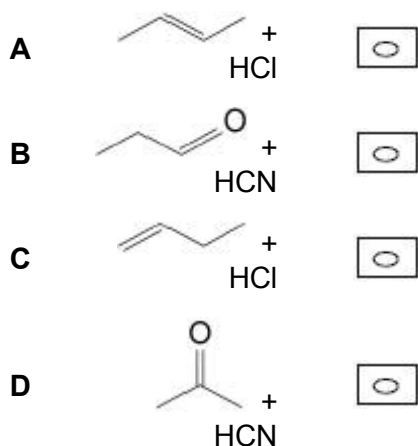
Justification

(2)

(Total 8 marks)

Q4.

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



(Total 1 mark)

Q5.

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



- B** 2-methylbutan-2-ol ☐
- C** 3-methylbutan-2-ol ☐
- D** pentan-3-ol ☐

(Total 1 mark)

Q6.

Which compound forms a racemic mixture when reacted with KCN followed by dilute acid?

- A** HCHO ☐
- B** CH₃CHO ☐
- C** CH₃COCH₃ ☐
- D** (CH₃CH₂)₂CO ☐

(Total 1 mark)

Q7.

Butanone is reduced in a two-step reaction using NaBH₄ 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.

Q8.

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



- (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.

(3)

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

(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.

(5)

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

(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.

(5)

(Total 16 marks)

Q9.

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

☐

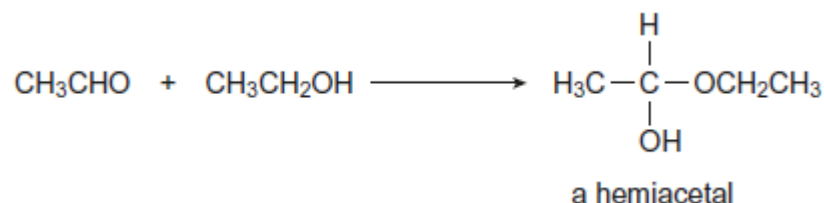
C 3-methylbutan-1-ol ☐

D 3-methylbutan-2-ol ☐

(Total 1 mark)

Q10.

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



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

(1)

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

(2)

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

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

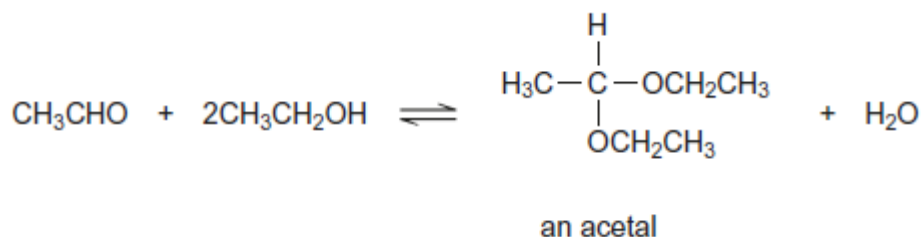
(1)

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

(1)

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

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



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

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

Amount of ethanal _____ mol

Amount of ethanol _____ mol

Space for working _____

(2)

- (ii) In a different experiment using the same reaction as in part (c), an equilibrium mixture was established at a given temperature.

This mixture contained 0.58 mol of ethanal, 3.76 mol of ethanol, 0.37 mol of the acetal and 0.65 mol of water in a total volume of 310 cm³.

Write an expression for the equilibrium constant K_c for this reaction.

Calculate a value for K_c at this temperature. Give units with your answer.

K_c _____

Calculation _____

(4)

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

(1)

(Total 12 marks)

Q11.

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.

(2)

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

_____ (1)

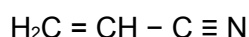
- (d) In practice, KCN rather than HCN is added to the carbonyl compound.

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

_____ (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.



- (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)

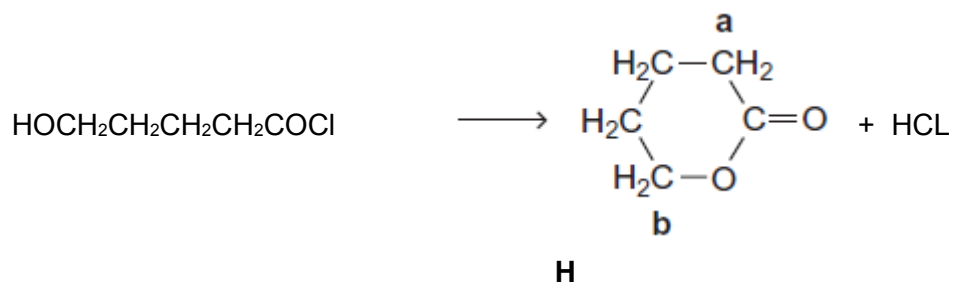
(Total 15 marks)

Q12.

This question is about some isomers of C₅H₈O₂

- (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.



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

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

(7)

- (ii) $\text{HOCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COCl}$ can also react to form a polyester in a mechanism similar to that in part (i).

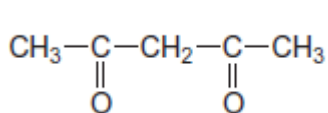
Draw the repeating unit of the polyester and name the type of polymerisation

involved.

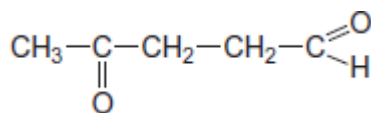
(2)

- (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

(5)

- (c) Draw the structure of each of the following isomers of $\text{C}_5\text{H}_8\text{O}_2$
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)

Q13.

Lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$, is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.

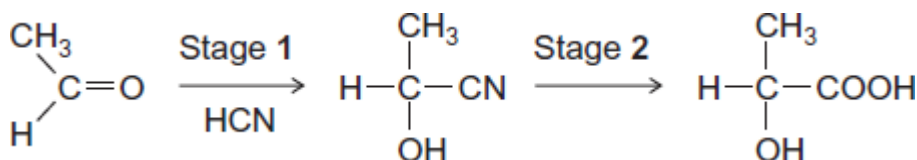
- (a) (i) Give the IUPAC name for lactic acid.

_____ (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)*.

(1)

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

(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.

(1)

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

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

(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 _____

(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.

(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.

(1)

(Total 22 marks)

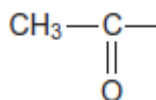
Q14.

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).

(Total 1 mark)

Q15.

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.

(1)

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



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.

(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.

(1)

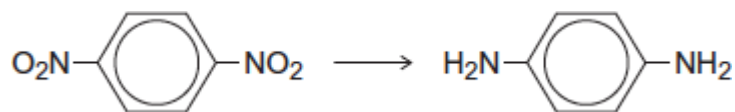
- (d) State **one** reason, other than cost or availability, why water is suitable for washing this solid residue after the filtration.

(1)

Q16.

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

- (a) Consider the following conversion.



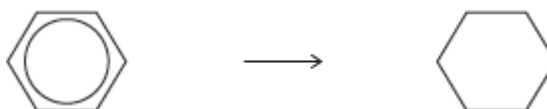
Identify a reducing agent for this conversion.

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.

(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.

(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.

(3)

(Total 17 marks)

Q17.

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.

(Total 8 marks)

Q18.

- (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.

(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 _____

Apparatus

(4)

- (iii) Describe the different experimental conditions necessary to produce propanal

in high yield rather than propanoic acid.

(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.

(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 _____

(3)

(Total 15 marks)

Q19.

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 $\text{CH}_3\text{CH}_2\text{COCl}$

- (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.

(5)

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

(4)

(b) Consider the reaction of propanal with HCN

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

(2)

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

(5)

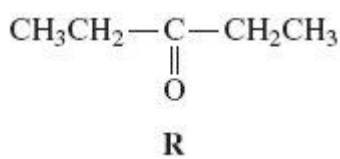
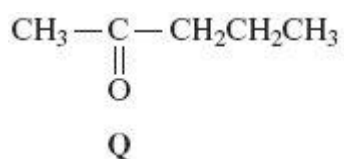
- (iii) The rate-determining step in the mechanism in part (b) (ii) involves attack by the nucleophile.
Suggest how the rate of reaction of propanone with HCN would compare with the rate of reaction of propanal with HCN
Explain your answer.

(2)

(Total 18 marks)

Q20.

Two isomeric ketones are shown below.



- (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.

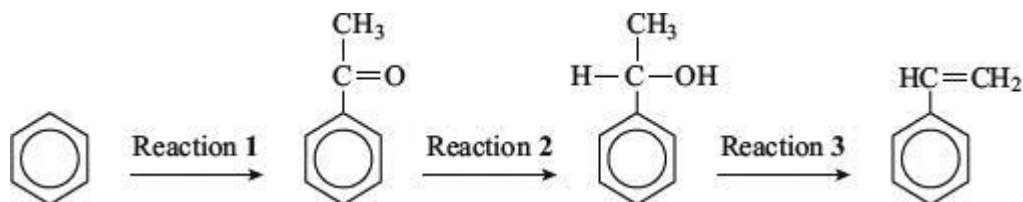
By considering the optical activity of these products formed from **Q** and **R**, explain why this method would **not** distinguish between **Q** and **R**.

(3)

(Total 9 marks)

Q21.

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.

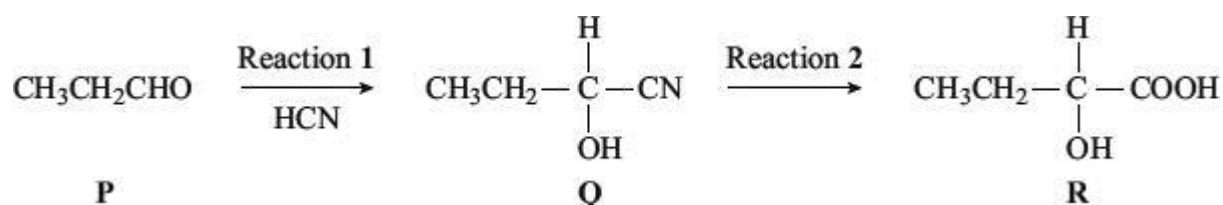
(6)

- (6)

(2)
(Total 14 marks)

Q22.

Consider the sequence of reactions below.



- (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 $\text{C}_4\text{H}_7\text{NO}$. 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);

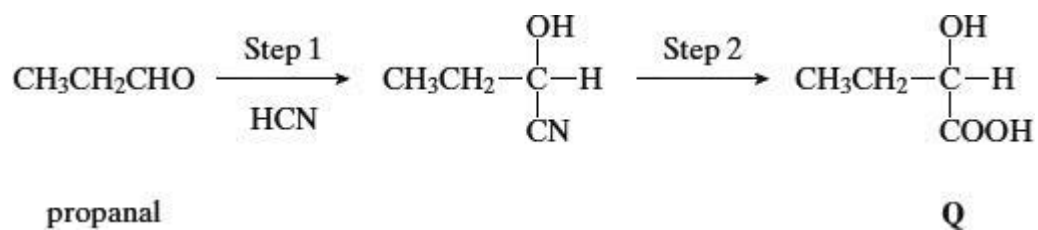
(iii) concentrated sulphuric acid in an elimination reaction.

(3)

(Total 11 marks)

Q23.

Consider the reaction sequence shown below.



- (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.

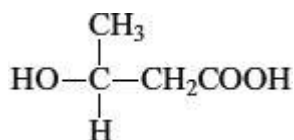
- (ii) Two stereoisomers are formed by the dehydration of **Q**. Give the structures of these two isomers and name the type of stereoisomerism shown.

Structures of isomers

Type of stereoisomerism _____

(4)

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

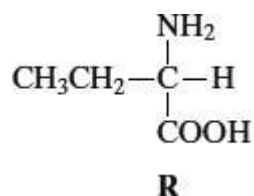


- (i) Draw the repeating unit of the polymer PHB.

- (ii) Suggest a reason why the polymer is biodegradable.

(2)

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



- (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)

Q24.

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)

Q25.

- (a) Describe how propanal, $\text{CH}_3\text{CH}_2\text{CHO}$, and propanone, CH_3COCH_3 , can be

distinguished using

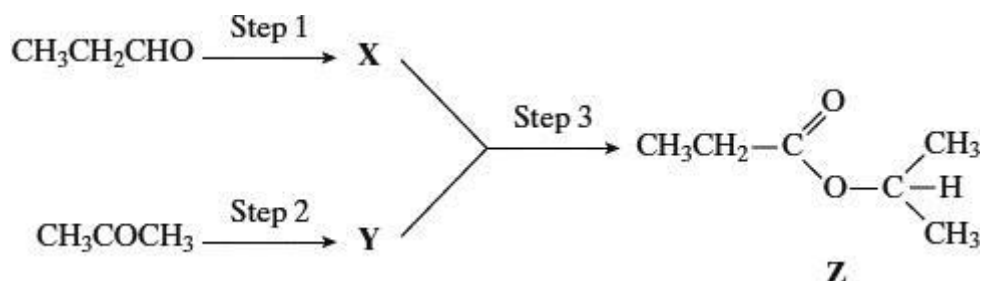
- (i) a chemical test and

(3)

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

(2)

- (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.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(10)

(Total 15 marks)

Q26.

- (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.

(7)

- (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.

(7)

- (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)

Q27.

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)

Q28.

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

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- B $\text{CH}_3\text{CH}_2\text{CHO}$
- C $\text{CH}_3\text{OCH}_2\text{CH}_3$
- D CH_3COCH_3

(Total 1 mark)

Q29.

- (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 _____

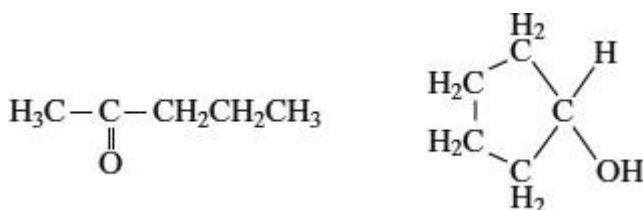
Observation with propanone _____

(4)

(Total 9 marks)

Q30.

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**, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$, is also an isomer of $\text{C}_5\text{H}_{10}\text{O}$

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)

Q31.

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

A alcohols $\text{C}_n\text{H}_{2n+2}\text{O}$

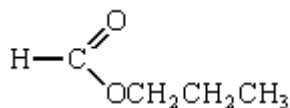
B aldehydes $\text{C}_n\text{H}_{2n+1}\text{O}$

- C** esters $C_nH_{2n}O_2$
D primary amines $C_nH_{2n+3}N$

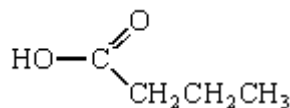
(Total 1 mark)

Q32.

- (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.

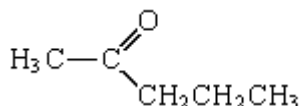
Reagent _____

Observation with **C** _____

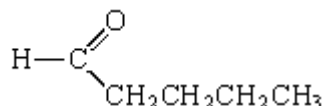
Observation with **D** _____

(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.

Q33.

The three compounds $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, $(\text{CH}_3)_3\text{COH}$ and $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ 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 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ and of $(\text{CH}_3)_3\text{COH}$. (Analysis of peak splitting is not required.)

(2)

(Total 15 marks)

Q34.

- (a) Outline a mechanism for the reaction of $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ with HCN and name the product.

Mechanism

Name of product _____

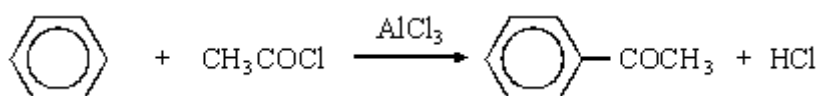
(5)

- (b) Outline a mechanism for the reaction of CH_3OH with $\text{CH}_3\text{CH}_2\text{COCl}$ and name the organic product.

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)

Q35.

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 $\text{Fe}^{2+}(\text{aq})$

(Total 1 mark)

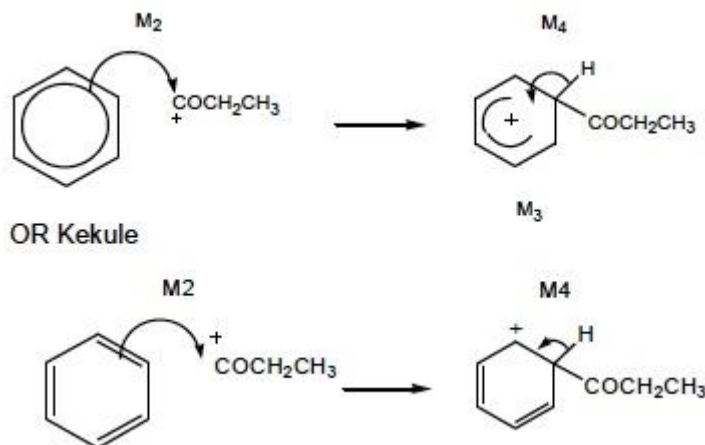
Mark schemes

Q1.



Allow + on C or O in equation –
But must be on C in mechanism

M1



M2 Arrow from inside hexagon to C or + on C

1

M3 Structure of intermediate

- horseshoe centred on C1 and must not extend beyond C2 and C6, but can be smaller
- + in intermediate not too close to C1 (allow on or "below" a line from C2 to C6)

1

M4 Arrow from bond into hexagon (Unless Kekule)

- Can allow M4 arrow independent of wrong M3 structure
- + on H in intermediate loses M3 not M4
- Ignore Cl⁻ and AlCl₄⁻
- used in M4

1

(b) Either...

1-phenylpropan-1-ol

1

NaBH₄ / LiAlH₄

1

Nucleophilic addition

1

Or...

1-phenylpropan-1-ol

1

H₂ with Ni/Pd/Pt

Addition/hydrogenation

1

Both numbers needed for names

Ignore solvents

1

- (c) Misty fumes / steamy fumes

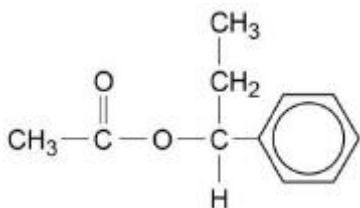
Allow sweet/fruity smell / white fumes

Not smoke

1

(Nucleophilic) addition-elimination

1



1

[10]

Q2.

B

[1]

Q3.

- (a) 2-hydroxyhexanenitrile

1

- (b) (Plane) polarised light

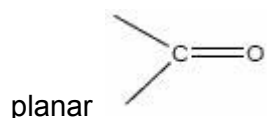
1

Enantiomers would rotate light in opposite directions

not different alone

1

- (c) planar carbonyl group or



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

1

Attack from either side

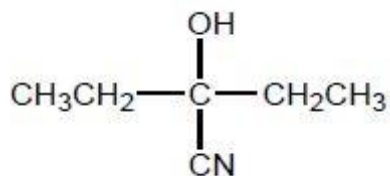
1

With equal probability

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

1

(d)



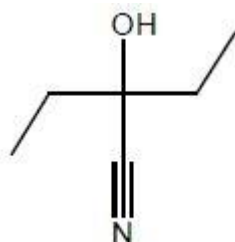
Does not contain a chiral centre

OR does not contain C attached to 4 different groups

OR contains two identical/ethyl groups

OR symmetrical (product)

Allow C₂H₅ or skeletal



M2 dependent on correct M1 (No structure = 0)

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

[8]

Q4.

D

[1]

Q5.

B

[1]

Q6.

B

[1]

Q7.



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]

Q8.

- (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) $\text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{O} \longrightarrow \text{CH}_3\text{COOH} + 4\text{H}^+ + 4\text{e}^-$

1

(c)	Mixture heated in a suitable flask / container	
	<i>A labelled sketch illustrating these points scores the marks</i>	1
	With still head containing a thermometer	1
	Water cooled condenser connected to the still head and suitable <u>cooled</u> 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	
	<i>M2 and M3 can only be awarded if M1 is given correctly</i>	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
	<i>M5 can only be awarded if M4 is given correctly</i>	
	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]

Q9.

B

[1]

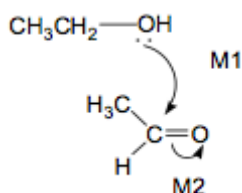
Q10.

(a) (i) Nucleophilic addition

Any extra loses the mark

Allow minor spelling errors e.g. nucleophyllic

1



(ii)

M1 for arrow from lone pair on oxygen in ethanol to C of C=O (or to space half way between O and C)

M2 for arrow from C=O bond to oxygen in ethanal

Do not allow M2 as first step without nucleophilic attack, but can allow M1 for attack on C⁺ produced

+ rather than δ⁺ on C=O loses M2

Ignore any further steps

Mark independently

1

1

(b) (i) Equal mixture of enantiomers/optical isomers OWTTE

1

(ii) (Non-superimposable) mirror images

Ignore rotates light in opposite directions

Ignore stereoisomers

1

(c) (i) **Ethanal** 0.33

1

Ethanol 4.16

Allow 4.2 for ethanol

1

$$K_c = \frac{[\text{acetal}][H_2O]}{[CH_3CHO][CH_3CH_2OH]^2} \text{ or with names}$$

$$(ii) \quad \frac{(0.37/0.31)(0.65/0.31)}{(0.58/0.31)(3.76/0.31)^2} \quad \text{OR} \quad \frac{(0.37)(0.65)}{(0.58)(3.76)^2} \times 0.31$$

Ignore slips in acetal structure or formula $C_6H_{14}O_2$

If K_c wrong, allow M4 only for units consequent to their K_c

If volume omitted (gives 2.93×10^{-2}) may only score M1 and M4

If volume used = 310 cm^3 allow M2 then award M3 for $9.08 - 9.23$ only and M4 for $\text{mol}^{-1} \text{ cm}^3$ only

Treat error in converting 310 cm^3 to dm^3 as AE

M1
M2

$$9.1 \times 10^{-3}$$

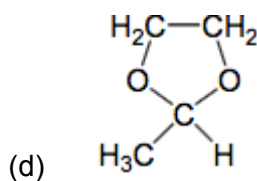
Allow range $9.08 \times 10^{-3} - 9.23 \times 10^{-3}$

M3

$$\text{mol}^{-1} \text{dm}^3$$

Not $\text{moles}^{-1} \text{dm}^3$

M4



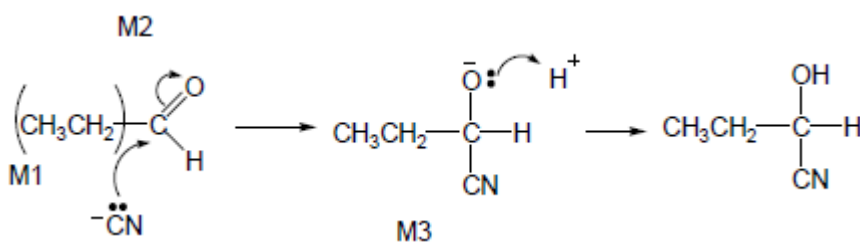
1
[12]

Q11.

(a) Nucleophilic addition

1

M4 for lp, arrow and H^+

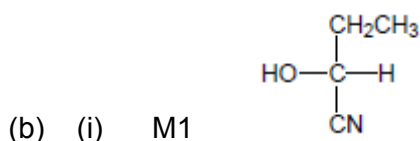


Allow C_2H_5- for CH_3CH_2-

- 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



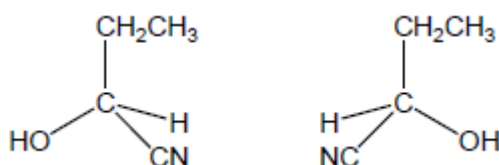
M1 for correct structure of product of part (a).

Allow C_2H_5- for CH_3CH_2- .

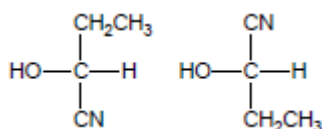
Penalise wrongly bonded, OH or CN or CH_2CH_3 once only in clip.

1

M2

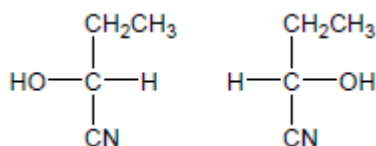


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not show the enantiomers as mirror images.

Students must show an attempt at mirror images, eg allow

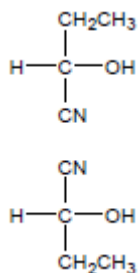


ie vertical groups same and horizontal swapped as if there was a mirror between them

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) polarized light
M2 only scores following correct M1

1

M2 Rotated in opposite 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) 2-hydroxybutane(-1-)nitrile

1

- (d) Weak acid / (acid) only slightly / partially dissociated / ionised
Ignore rate of dissociation.

1

[CN⁻] very low

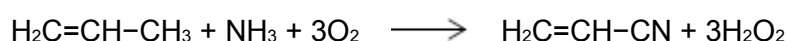
Allow (very) few cyanide ions.

Mark independently.

1

- (e) (i) $\text{H}_2\text{C}=\text{CH}-\text{CH}_3 + \text{NH}_3 + \frac{3}{2}\text{O}_2 \longrightarrow \text{H}_2\text{C}=\text{CH}-\text{CN} + 3\text{H}_2\text{O}$

OR

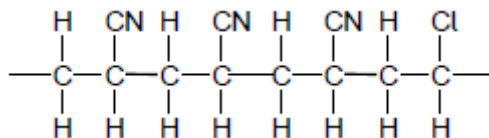


OR doubled.

Allow C₃H₆ and CH₂CHCN or C₃H₃N on this occasion only.

1

- (ii)

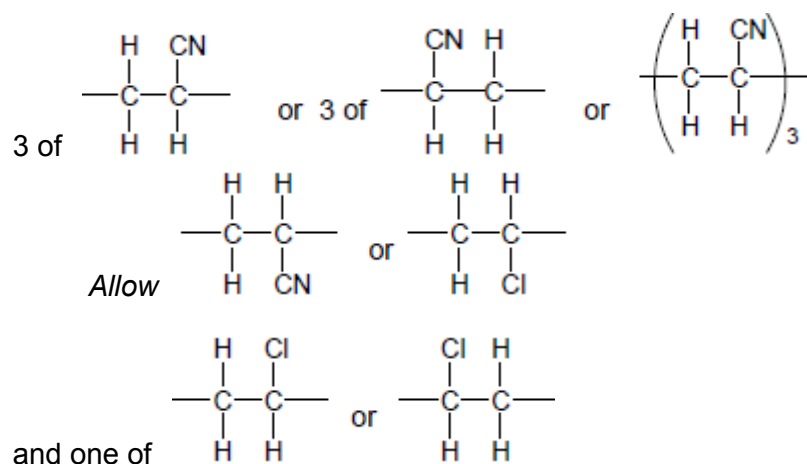


Ignore n.

Must show trailing bonds.

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

Must contain, in any order,



Allow $-\text{CH}_2\text{CH}(\text{CN})\text{CH}_2\text{CHCl}-$ etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

1

[15]

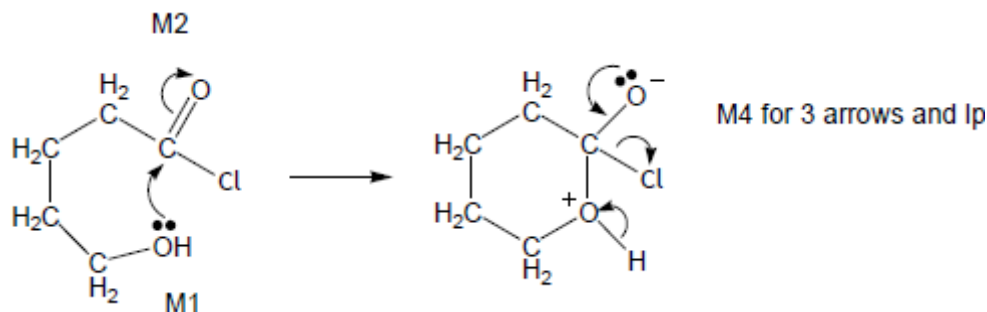
Q12.

(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 $\delta+$ on C=O loses M2.
- If Cl lost with C=O breaking lose M2.
- M3 for correct structure with charges 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

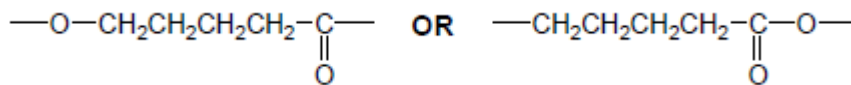
If values not specified as a or b then assume first is a.

1

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

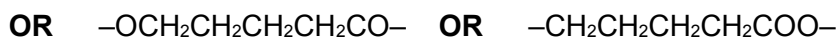
1

(ii)

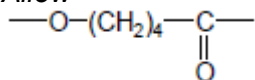


Must have trailing bonds, but ignore n.

1



Allow



but not $\text{—C}_4\text{H}_8\text{—}$

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.

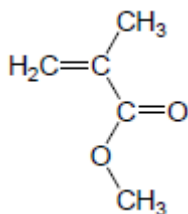
If values not specified as J or K then assume first is J.

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 $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{COOCH}_3$

All $\text{C}_5\text{H}_8\text{O}_2$ L to P must have $\text{C}=\text{C}$.

Allow CH_3 -.

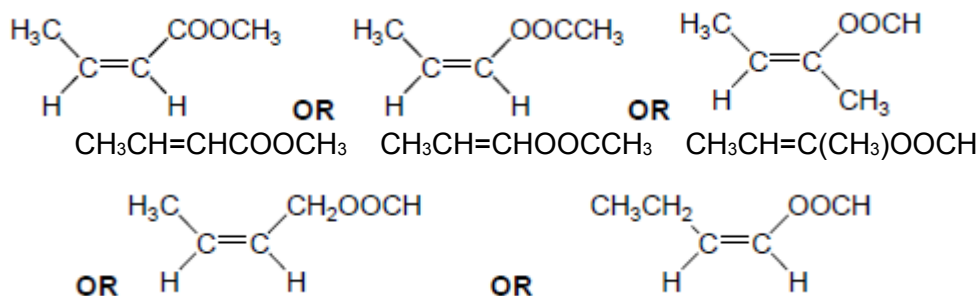
Allow $-\text{CO}_2\text{CH}_3$ etc.

Allow $\text{CH}_2\text{C}(\text{CH}_3)\text{COOCH}_3$.

1

M

ester



$\text{CH}_3\text{CH}=\text{CHCH}_2\text{OOCH}$

$\text{CH}_3\text{CH}_2\text{CH}=\text{CHOOCH}$

Allow either E-Z isomer.

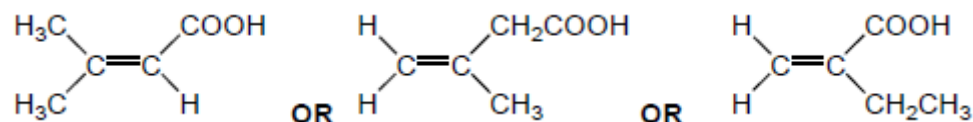
Allow CH_3 - or C_2H_5 - but not CH_2CH_3 -.

Allow $\text{CH}_3\text{CHCHCOOCH}_3$ etc.

1

N

acid



$(\text{CH}_3)_2\text{C}=\text{CHCOOH}$

$\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{CH}_2\text{COOH}$

$\text{H}_2\text{C}=\text{C}(\text{COOH})\text{CH}_2$

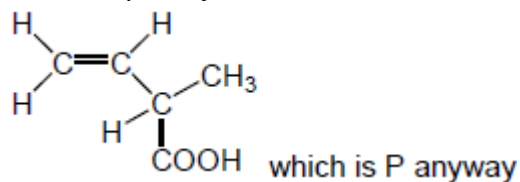
CH_3

Allow CH_3 - or C_2H_5 - but not CH_2CH_3 -.

Allow $-\text{CO}_2\text{H}$.

Not cyclic isomers.

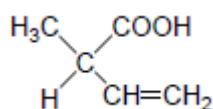
Not the optically active isomer.



Allow $(\text{CH}_3)_2\text{CCHCOOH}$ etc.

1

P
acid



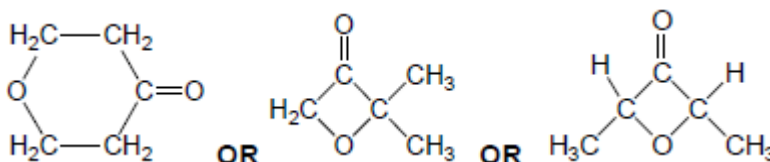
Allow $-\text{CO}_2\text{H}$.



Allow $\text{CH}_3\text{CH}(\text{CO}_2\text{H})\text{CHCH}_2$ or
 $\text{CH}_3\text{CH}(\text{CO}_2\text{H})\text{C}_2\text{H}_3$.

1

Q



Not cyclic esters.

1

[19]

Q13.

- (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.

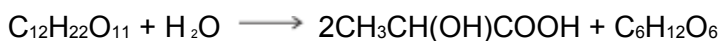
Can ignore -1- before -oic, but penalise any other numbers here.

1

- (ii) $\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{O} \longrightarrow 4\text{CH}_3\text{CH}(\text{OH})\text{COOH}$

Allow $4\text{C}_3\text{H}_6\text{O}_3$

OR

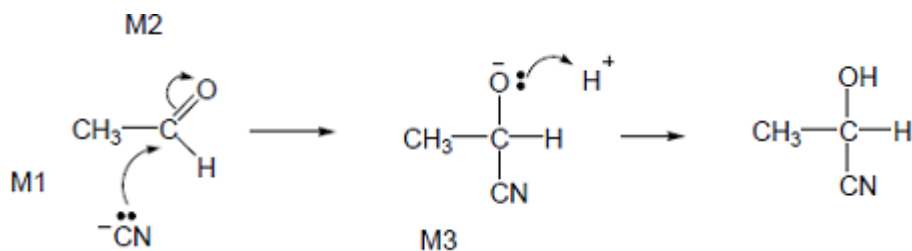


Allow $2\text{C}_3\text{H}_6\text{O}_3$

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) $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COONa} + \text{H}_2\text{O}$
OR $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}$
Not ambiguous mol formulae for product - must show COONa or CO₂Na or COO⁻ or CO₂⁻

1

(ii) $[\text{H}^+] = K_a$ **OR** $\text{pH} = \text{p}K_a$

1

$\text{pH} = 3.86$

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^-

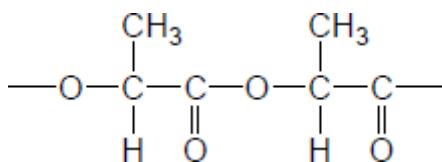
Ignore reference to equilibrium unless it is shown.

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 $-COO-$

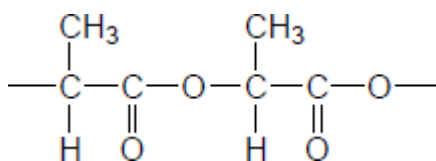
NB Correct answer scores 2

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

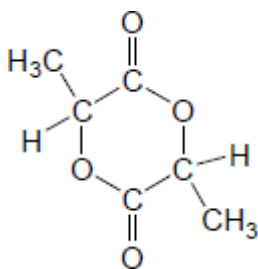
(ii) (Poly)ester ie allow ester

Not terylene.

Ignore spaces and brackets in answer.

1

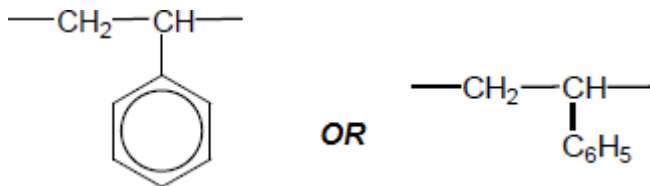
(iii)



Allow any cyclic $C_6H_8O_4$

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 lower temperature.

1

[22]

Q14.

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

Allow 'dichromate'.

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

[1]

Q15.

- (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) $M_r \text{ CHI}_3 = 393.7$ (**M1**)

Allow if clearly shown in a calculation.

Allow 394

1

$$\text{Moles CHI}_3 = 10 / 393.7 = 2.54 \times 10^{-2} \text{ (M2)}$$

Allow a consequential answer on an incorrect M_r .

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

1

$$\text{Moles I}_2 = 7.62 \times 10^{-2} \text{ (M3)}$$

Allow 3 $\times$ **M2**.

1

$$\text{Mass I}_2 = 7.62 \times 10^{-2} \times 253.8 = 19.34\text{g (M4)}$$

Allow **M3** $\times$ 253.8 or **M3** $\times$ 254

1

Scaling $19.34 / 0.832 = 23.2\text{g}$ (**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]

Q16.

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

Ignore subsequent use of NaOH

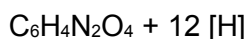
Ignore reference to Sn as a catalyst with the acid

Allow H_2 (Ni / Pt) but penalise wrong metal

But NOT NaBH_4 LiAlH_4 Na / $\text{C}_2\text{H}_5\text{OH}$

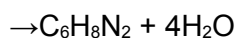
1

Equation must use molecular formulae



12[H] and $4\text{H}_2\text{O}$ without correct molecular formula scores 1 out of 2

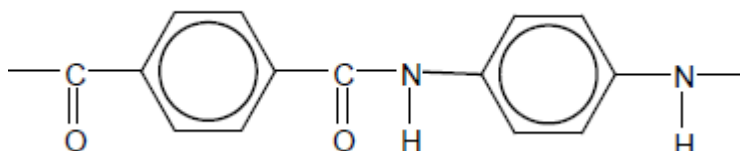
1



Allow + 6H_2 if H_2 / Ni used

Allow -CONH- or -COHN- or $-\text{C}_6\text{H}_4-$

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) H₂ (Ni / Pt) but penalise wrong metal
NOT Sn / HCl, NaBH₄ etc.

1

CH₂

1

In benzene 120°

1

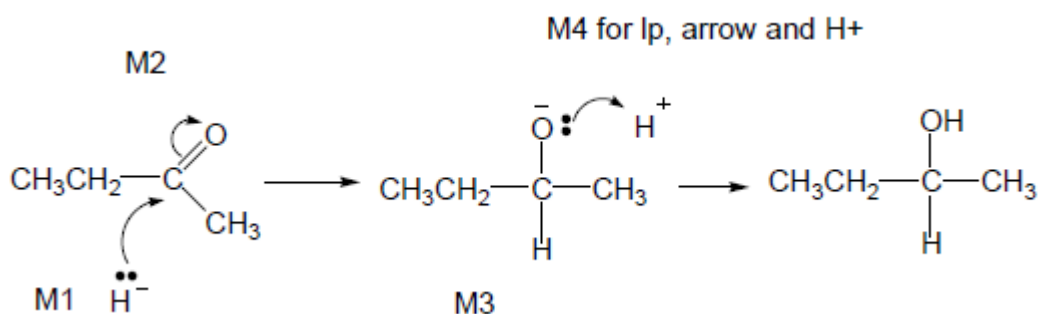
In cyclohexane 109° 28' or 109½°
Allow 108° - 110°

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 C₂H₅
- M1 and M4 include lp and curly arrow
- Allow M4 arrow to H in H₂O (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

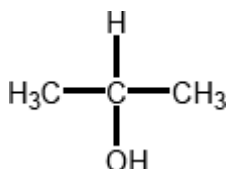
M3 (about product): Racemic mixture formed **OR** 50:50 mixture or each enantiomer equally likely

1

[17]

Q17.

L



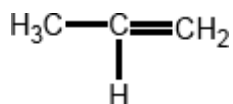
Allow $(\text{CH}_3)_2\text{CHOH}$ or $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$

Allow name propan-2-ol

Penalise contradiction of name and structure

1

M



Allow $\text{CH}_3\text{CH}=\text{CH}_2$

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 conc H_2SO_4 or conc 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

1 M4

Step 3 HBr

Apply list principle for extra reagents and catalysts.

1 M5

electrophilic addition

Independent from M5

1 M6

[8]

Q18.

(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]

Q19.

- (a) (i) $\text{C}_6\text{H}_6 + \text{CH}_3\text{CH}_2\text{COCl} \rightarrow \text{C}_6\text{H}_5\text{COCH}_2\text{CH}_3 + \text{HCl}$
OR
 $\text{C}_6\text{H}_6 + \text{CH}_3\text{CH}_2\text{CO}^+ \rightarrow \text{C}_6\text{H}_5\text{COCH}_2\text{CH}_3 + \text{H}^+$
allow C₂H₅
penalise C₆H₅—CH₃CH₂CO
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

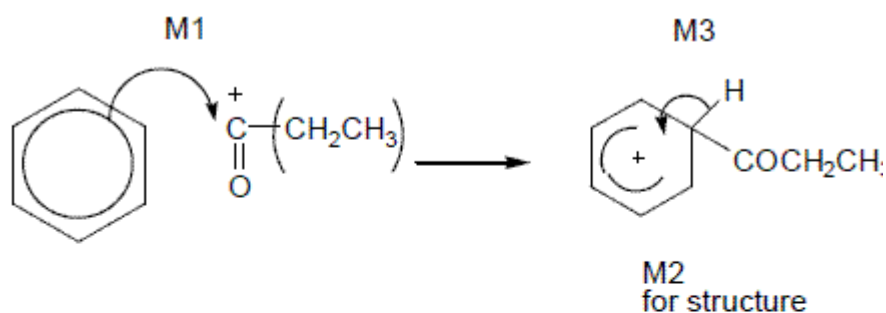
$\text{CH}_3\text{CH}_2\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CO}^+ + \text{AlCl}_4^-$
allow C₂H₅
allow + on C or O in equation

1

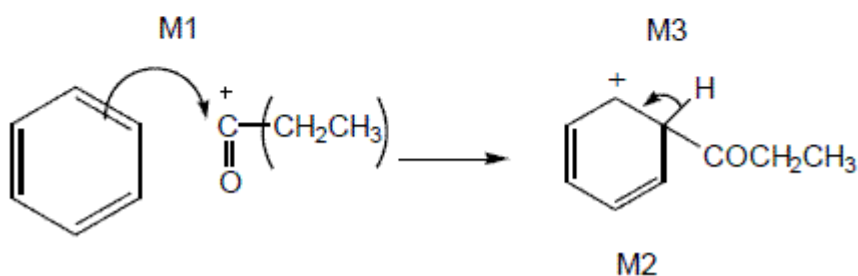
$\text{AlCl}_4^- + \text{H}^+ \rightarrow \text{AlCl}_3 + \text{HCl}$

1

- (ii) electrophilic substitution
can allow in (a)(i) if no contradiction



OR



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



aldehyde must be $-CHO$ brackets optional

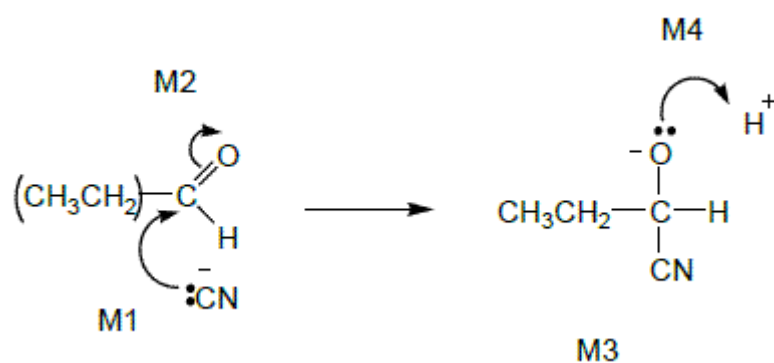
1

2-hydroxybutanenitrile OR 2-hydroxybutanonitrile
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 C₂H₅
 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

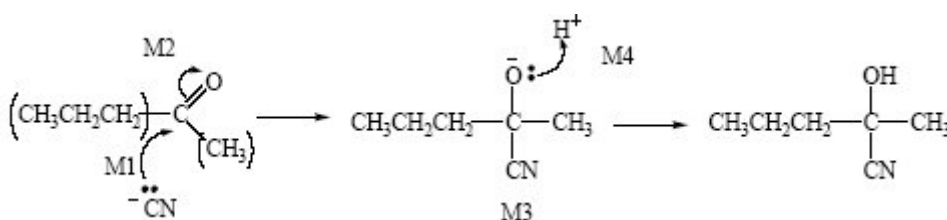
1

[18]

Q20.

(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 C₃H₇ 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

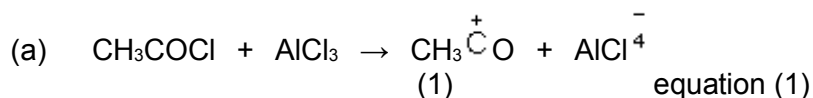
1

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

1

[9]

Q21.

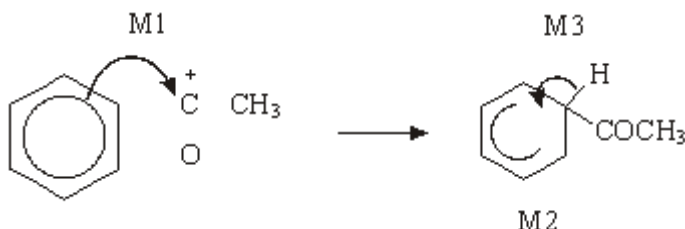


2

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

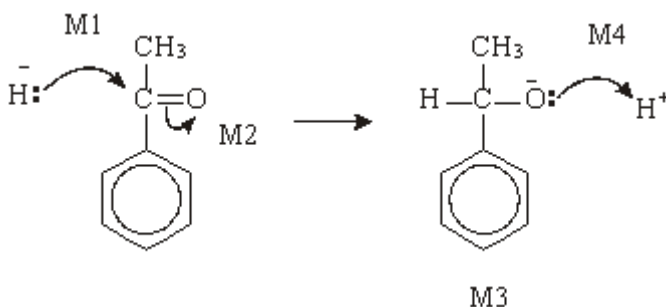
M1 arrow from within hexagon to C or to + on C

+ must be on C of 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

1

(c) dehydration or elimination

1

(conc) H₂SO₄ or (conc) H₃PO₄

allow dilute and Al₂O₃

Do not allow iron oxides

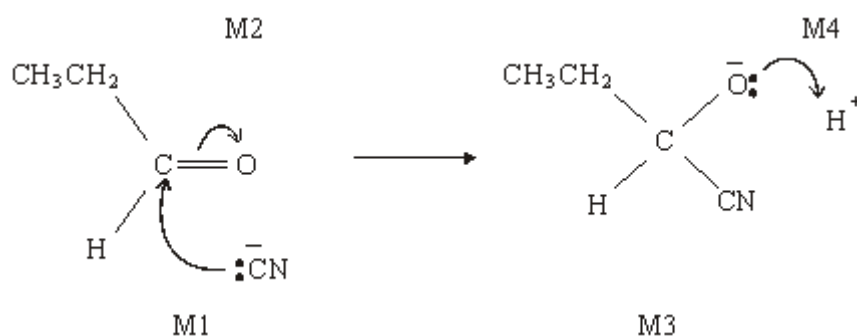
1

[14]

Q22.

(a) nucleophilic addition

1

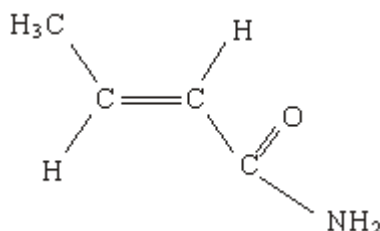


4

(b) (i) 2-hydroxybutanenitrile

1

(ii)

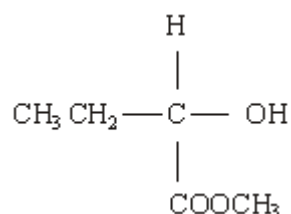


(allow 1 for amide even if not C₄H₇NO, i.e. RCONH₂)

(if not amide, allow one for any isomer of C₄H₇NO which shows geometric isomerism)

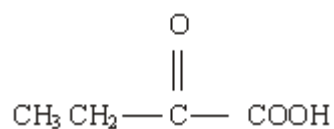
2

(c) (i)



1

(ii)



1

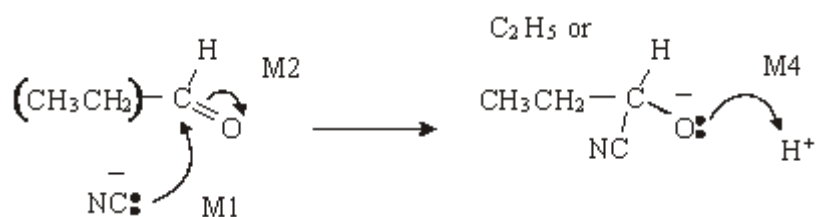
(iii) $\text{CH}_3\text{CH}=\text{CHCOOH}$

1

[11]

Q23.

(a) nucleophilic addition;



1

M3 structure;

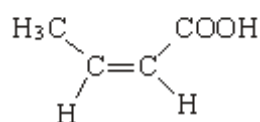
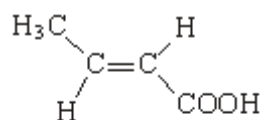
*(be lenient on position of charge on CN⁻)**(M2 not allowed independent of M1,**but allow M1 for correct attack on C⁺**if M2 show as independent first.)**(+on C of C=O loses M2 but ignore δ⁺ if correct)**(M4 for arrow and lone pair (only allow for correct M3 or close))*

4

(b) (i) 2-hydroxybutanoic acid

1

(ii)

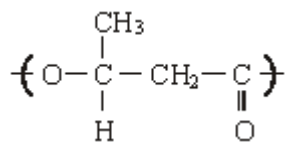


1

geometric(al) or cis-trans

1

(c) (i)



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

1

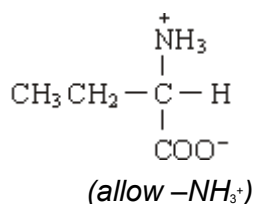
(ii) can be hydrolysed

OR

can be reacted with/attacked by acid/base/nucleophiles/H₂O/OH⁻;

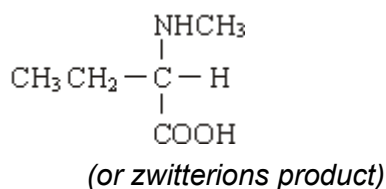
1

(d) (i)



1

(ii)



1

(iii) nucleophilic substitution;

1

[14]

Q24.

D

[1]

Q25.

(a) (i)

Reagent	Tollens	Fehlings or Benedicts	K ₂ Cr ₂ O 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. K₂Cr₂O₇ or Cr₂O₇²⁻/H⁺ then mark on)

3

(ii) propanal 3 peaks
ignore splitting even if wrong

1

propanone 1 peak

1

(b) **X** is $\text{CH}_3\text{CH}_2\text{COOH}$ or propanoic acid if both name and formula given,
both must be correct, but

1

Y is $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ 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

$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$ or other oxidation methods as above
allow $\text{Cr}_2\text{O}_7^{2-}-\text{H}^+$ 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
NaBH_4	LiAlH_4	H_2
in (m)ethanol or water or ether or dry	ether or dry	Ni / Pt etc

1

1

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]

Q26.

(a) (i) An appropriate alkene; $\text{CH}_3\text{CH}_2\text{CHCH}_2$ or $(\text{CH}_3)_2\text{CCH}_2$

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	
<i>[Allow mechanism marks for the alkene CH₃CHCHCH₃]</i>	
<i>[Allow one mark if mechanism for minor product given]</i>	1
(ii) An appropriate carbonyl; CH ₃ CH ₂ CHO	1
Mechanism nucleophilic attack and electron shift to O	1
anion intermediate	1
reaction with anion	
<i>[Allow mechanism marks for the carbonyl (CH₃)₂CO]</i>	1
Isomer 1	1
Isomer 2	1
Optical isomerism	
<i>NB Isomer structures must be tetrahedral</i>	
<i>NB Penalise "stick" structures once in part (a)</i>	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]

Q27.

A

[1]

Q28.

C

[1]

Q29.

- (a) (i) Potassium (OR sodium) dichromate(VI) OR correct 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

$\text{CH}_3\text{COCH}_3 + 2[\text{H}] \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
(Credit H_2 in the equation if H_2 has been chosen as reagent)

1

- (b) (i)
$$\begin{array}{c} \text{CH}_3\text{CH}_2\text{C}=\text{O} \\ | \\ \text{H} \end{array}$$

(Structure must show aldehyde structure)
(Credit C_2H_5 as alternative to CH_3CH_2)

- (ii)

M1	Tollens' reagent OR ammoniacal silver nitrate OR $\text{AgNO}_3 + \text{NH}_3$	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</u> / <u>solid</u>	goes green
----	--	--	------------

1

(Credit other correct reagents and observation)

(For M1, penalise AgNO_3 alone, penalise $\text{Ag}(\text{NH}_3)_2^+$,

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]

Q30.

(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 ₂ Cr ₂ O ₇ /H ⁺	KMnO ₄ /H ⁺	Na	CH ₃ COOH/ H ₂ SO 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. K₂Cr₂O₇ or Cr₂O₇²⁻/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]

Q31.

B

[1]

Q32.

(a) (i) propyl methanoate (1)

not propenyl

- 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: NaHCO₃ (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)

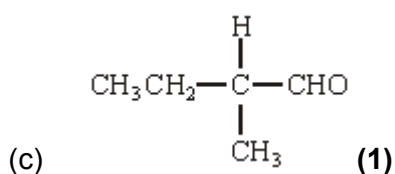
Observation with **E**: no reaction (1)

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



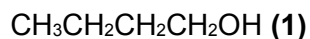
must be aldehyde. Allow C_2H_5 for CH_3CH_2 otherwise this is the only answer

1

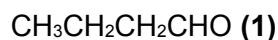
[9]

Q33.

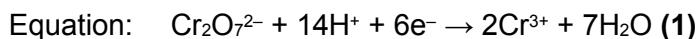
(a) $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}_2\text{SO}_4$ reduced by



oxidised to $\text{CH}_3(\text{CH}_2)_2\text{CHO}$ (1)
and $\text{CH}_3(\text{CH}_2)_2\text{COOH}$ (1)



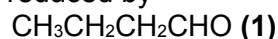
oxidised to $\text{CH}_3(\text{CH}_2)_2\text{COOH}$ (1)



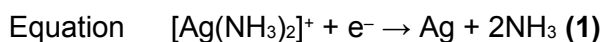
Note: Deduct one if all three compounds given as reducing agents.

6

(b) Tollens' reduced by



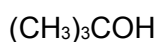
oxidised to $\text{CH}_3(\text{CH}_2)_2\text{COOH}$ (1)



3

(c) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (1)

Product $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OOCCH}_3$ (1)



Product $(\text{CH}_3)_3\text{COOCCH}_3$ (1)

4

(d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ has five peaks (1)

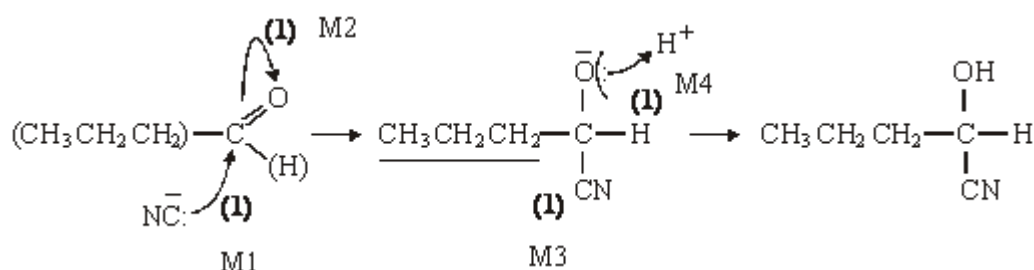
$(\text{CH}_3)_3\text{COH}$ has two peaks (1)

2

[15]

Q34.

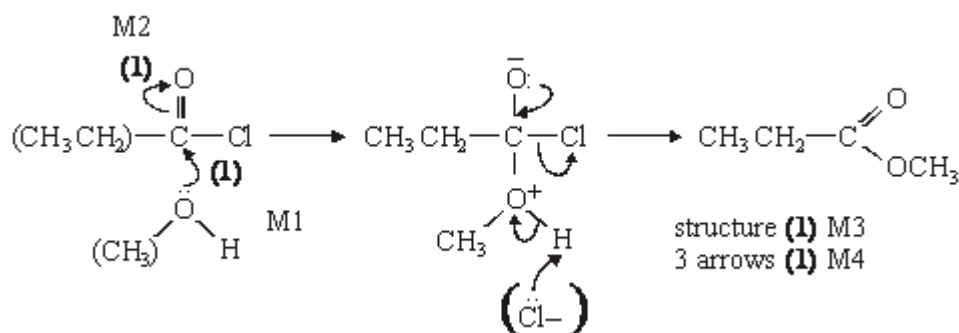
(a) Mechanism



*Allow C_3H_7 if structure shown elsewhere
penalise HCN splitting if wrong*

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

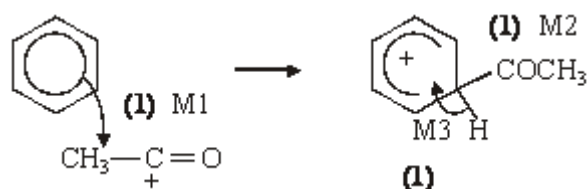
(b) *Mechanism*



Name of organic product: methylpropanoate (1)

(c) (i) (1) CH₃CO (1)⁺ (1)

(ii)



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) $\text{C}=\text{O}$ alone loses M2 but can score M1 for attack on C⁺, similarly $\text{C}-\text{Cl}$

(a) allow 2-hydroxypentanitrile or 2-hydroxypenta(ne)nitrile ... pentynitrile

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

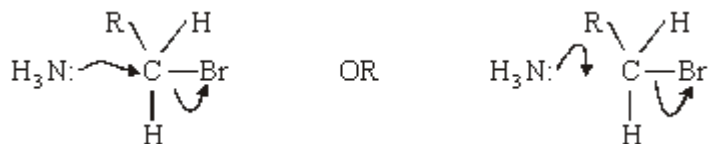
(c) (i) allow formula in an "equation" (balanced or not)
be lenient on the position of the + on the formula

(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]

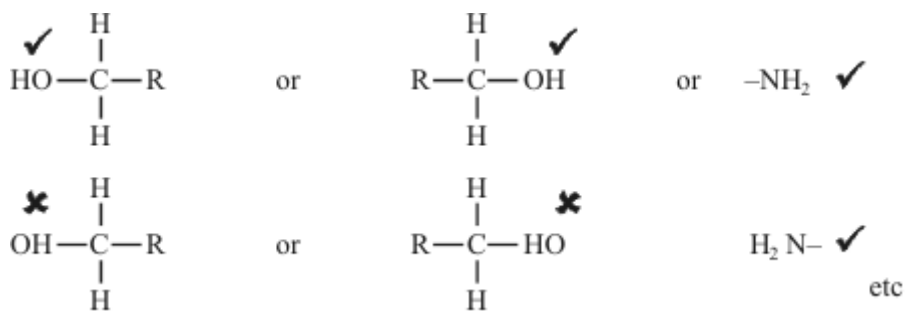
Organic points

(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. $\begin{array}{c} | \\ -\text{C}- \\ | \end{array}$) once per paper



Penalise once per paper

allow CH_3- or $-\text{CH}_3$ or $\begin{array}{c} \text{CH}_3 \\ | \end{array}$ or CH_3
 or $\text{H}_3\text{C}-$

Q35.

A

[1]

Examiner reports

Q1.

- (a) This was a straightforward question on a familiar topic and many good students (46.5%) scored full marks. However, some drew structures, such as the horseshoe in the mechanism, with insufficient care and consequently failed to gain marks. Others omitted charges on the ions in the equation (especially on AlCl_4^-), or in the mechanism did not draw the + on the carbonyl carbon in the electrophile.
- (b) In this question, although some students struggled with the name, a number failed to gain the mark due to a failure to label 1-phenyl in an otherwise correct name. Most identified a correct reagent but “electrophilic addition” and “reduction” were frequent wrong answers for the name of the mechanism.
- (c) This question was generally answered well, especially the name of the mechanism and the structure of the ester. A common error was to give the name of the product, i.e. ‘HCl gas’, rather than an observation as required, or alternatively to describe this as a ‘white precipitate’.

Q2.

A was the commonest incorrect response to this question which had a 47% success rate. This suggests there were many students who recognised that the answer is an aldehyde, but who then missed a possible isomer. Drawing out possible structures in a logical sequence is the key here. Students are advised to start with a 5C chain, then 4C and find possible positions for the fifth C (carbon 2 or carbon 3), and finally a 3C chain and find positions for the remaining two carbons (both on carbon 2).

Q3.

- (a) As usual, naming nitriles proved difficult for some, but 56% of students gave the correct answer.
- (b) Although this question was answered well by most, an appreciable number of students were careless with language and appeared to say that the enantiomers themselves rotate, or that the plane polarised light is ‘refracted’ or ‘bent’ rather than ‘rotated in opposite directions’.
- (c) The first mark was less commonly scored than expected as many students wrote about a planar molecule or a planar bond rather than planar carbonyl group; the other two marks were frequently awarded.
- (d) A significant number were not able to deduce the correct product and many incorrect products were seen. These included the cyanohydrin formed from pentanal. This showed a lack of care in reading the question.

Q10.

Both parts of question (a) were answered very well and it was good to see the correct use of curly arrows. Part (b)(i) was well done but in (b)(ii) many students simply stated what stereoisomers do to plane polarised light and so failed to answer the question. Part (c)(i) was answered extremely well and the K_c expression in part (c)(ii) was also answered well. The calculation was well done but a frequent error was to use amounts, in moles, rather than concentrations by not using the volume. Better students answered part (d) correctly

while others showed only one hydroxyl group from the diol reacting and so produced an answer for the acetal which did not match the given molecular formula.

Q11.

In part (a), the nucleophilic addition mechanism was very well done; common errors included missing the charge on the nucleophile or on the intermediate structure and showing a bond between the carbonyl carbon and the N of CN in the intermediate. In part (b)(i), students were not used to drawing 3D structures, and credit was given where attempts showed a pair of mirror images. Again there were some problems with wrongly bonded OH, CN and CH₂CH₃ groups in these structures. The method needed to distinguish between two enantiomers was well known, although to gain M2 polarised light had to be 'rotated' not turned or reflected, and rotated in 'opposite' directions not just different directions. A few students suggested wrongly that the molecules polarised the light or that the molecules themselves were rotated. The name in part (c) was well answered but part (d) was answered poorly. There was confusion of K_a , the acid dissociation constant, with a rate constant, and many students missed the link to low concentrations of cyanide ions from the weak acid HCN and focused mainly on the rate of the dissociation of the acid. Parts (e)(i) and (e)(iii) were answered well but responses to part (e)(ii) sometimes included the C=C bond or the CN group as part of the polymer chain.

Q12.

The nucleophilic addition-elimination mechanism in part (a)(i) presented a real challenge to many students, who were confused by the cyclic nature of the product, failed to identify the correct nucleophile and suggested either separate nucleophiles such as H₂O, CH₃OH and OH⁻ or alternatively loss of the proton from the OH group before nucleophilic attack. Most students gave the correct range for the carbon atom labelled **b**, but often the range for the carbon atom labelled **a** was given as 160–185 as for a carbonyl carbon. In part (a)(ii), the repeating unit for the polyester was answered well although some students gave twice the repeating unit.

The distinguishing test in part (b) was well done, although a significant number of students thought that substance **K** was an acid and wrongly suggested NaHCO₃ or Na₂CO₃ to distinguish between the compounds. It was common for students to fail to see the symmetry of **J** and so to predict, incorrectly, three peaks in its proton n.m.r. spectrum. Five peaks was a common incorrect answer for **K**, suggesting that students had misread the question and given the ¹³C n.m.r. result.

Part (c) of this question proved to be very challenging and fewer than 10% of students scored full marks. Isomer **Q** was found particularly difficult where many students omitted one of the O atoms from their suggested structure. Other common errors included missing the double bond in **L**, giving the structure of **P** as the structure of **N** (which suggests a failure to recognise that optical isomerism is a form of stereoisomerism) or writing an unbranched carbon chain for the acid **N**. Answers to part (c) were often very badly presented, with a great deal of crossing out, duplication of answers and poor labelling of structures.

Q13.

Parts (a), (b)(i) and (b)(ii) were answered well. In part (b)(iii), students often correctly identified that polarised light could be used but then failed to gain the marks because they did not mention the effect of a racemic mixture on the light. Another concern was that answers appeared to suggest that the light caused the molecules themselves to rotate.

Parts (c)(i) and (c)(ii) were answered well but very few students scored full marks for part

(c)(iii) where explanations were often muddled or referred to unspecified equilibria.

Part (d) was generally well attempted, with the main errors being in part (d)(i), where many gave three or more repeating units or failed to show an ester linkage, in part (d)(iv), where many gave the formula of the polymer or missed this part out completely, and in part (d)(v), where hydrogen bonding was often offered as an explanation.

Part (d)(iii) contained an unfortunate typographical error, which was identified after the examination had taken place. The end of the first sentence should have read "...from two lactic acid molecules" rather than ".....from two PLA molecules". AQA apologises for this error. The expected answer was given by about a quarter of the students. To ensure that students were not disadvantaged, a mark was also awarded to those students who drew any correct cyclic compound with molecular formula $C_6H_8O_4$. The number of students who did not attempt this question was low and in line with other question parts on this paper. The most common errors involved attempts to draw a cyclic compound but with one or more carbons having fewer than four bonds or oxygens with fewer than two bonds.

Q14.

In this Question, many students stated that Tollens' Reagent is specific to aldehydes and were allowed the mark. This answer did little more than reword the question. A specific reference to potassium dichromate(VI) was needed to earn the mark.

Q15.

In this part (a), many students gave the answer 'primary alcohols are oxidised to aldehydes'. Since ethanol is the only primary alcohol which will give a positive triiodomethane test this answer missed the point, and teachers were told to ignore that answer in the Marking Guidelines. However, sometimes teachers wrongly allowed a mark for this answer. This was another question where answers that included a disqualifier, such as 'ethanol is oxidised to ethanal, CH_3CO ', were often incorrectly allowed a mark despite the absence of 'Yes' and use of an incorrect formula for ethanal.

The calculation in this part (b) was answered well. Many teachers did not penalise students who did not give their final answer to 3 significant figures. Some did not always give credit for alternative methods, such as employing the scaling to 100% yield at the start of the calculation. The omission of the word 'soluble' in this part (c) often went unpunished while part (d) was answered well.

Q16.

In part (a), many students thought $NaBH_4$ or $LiAlH_4$ could be used as the reducing agent. Most did not give the molecular formulae in the equation but could balance it correctly; the repeating unit of the polymer was very well done.

Similarly, in part (b), $NaBH_4$ was often suggested as the reducing agent and the empirical formula was frequently wrong. Students found the bond angles difficult, with many failing to deduce that there is a tetrahedral arrangement around a C atom in cyclohexane and appearing simply to guess any angle. Only the most able scored both marks for the bond angles.

There was a good spread of marks in the mechanism with over 40% gaining full marks. In part (c)(ii), most realised that the product was a racemic mixture and that it was produced as a result of attack on the ketone from both sides, but often this was thought to be by an electrophile or an H^+ ion. Some thought that a carbocation intermediate was attacked.

Q17.

This three-step synthesis was slightly easier than the three-step synthesis in last year's paper. The question discriminated very well; there were many excellent answers and some very poor ones, too. Many students were able to see their way through this synthetic route and had clearly learned reagents and types of mechanism very thoroughly. Others struggled to get started. Common errors included giving L as propan-1-ol, naming M as prop-2-ene, omitting the concentrated condition from sulfuric acid and calling the mechanism in step 2 dehydration rather than elimination.

Q18.

The colour change in part (a)(i) was well known but most candidates failed to score both marks for the conditions for the reaction in part (a)(ii). Many markers treated the word 'excess' as an optional extra and awarded a mark to candidates who just repeated information in the stem of the question. Most candidates were able to draw an acceptable diagram for reflux. The usual mistake was to seal the condenser and many markers failed to punish this serious error.

Part (a)(iii) was poorly answered, even by the better candidates. Distillation was often appreciated but the concept of removal of the aldehyde immediately when it is formed was rarely seen. Some centres were very generous indeed when marking this question.

The tests in part (c) were well known and better candidates scored all four marks. Some candidates lost a mark by giving an incorrect formula for a reagent. Centres are reminded that if the candidate chooses an incorrect test reagent the mark for the observation cannot be awarded.

Most candidates could make some progress in part (d), and the presence of hydrogen bonding in the acid and alcohol were known to the better candidates. Some centres were very generous when marking this question. The final mark was often given for references to stronger van der Waals forces in the carboxylic acid.

Q19.

As is usual, mechanism questions such as this discriminate well. In part (a)(i), 13% of the candidates gained all five marks whereas a similar number scored only one mark. Many candidates omitted the name of the product in an otherwise perfect answer. In part (a)(ii), two fifths of the candidates gained full marks.

In part (b)(i), a number of candidates lost a mark because they gave the formula of the aldehyde propanal as $\text{CH}_3\text{CH}_2\text{COH}$ rather than as $\text{CH}_3\text{CH}_2\text{CHO}$. For clarification of acceptable formulae styles, candidates and teachers are advised to consult the document "General principles applied to marking CHEM4 papers by CMI+ January 2011" which is available with the Mark Scheme for this paper.

The mechanism in part (b)(ii) was well known and two fifths of candidates gained full marks.

Part (b)(iii) was a How Science Works question where candidates were not required to know the answer, but were expected to apply understanding gained from other areas of the specification. The inductive effect of alkyl groups is part of the explanation of the relative stability of carbocations. A similar effect using two alkyl groups will reduce the δ^+ nature of the carbonyl carbon in propanone more than the single alkyl group does for the carbonyl carbon in propanal. Hence it can be predicted that the nucleophile will attack propanal more easily than propanone. About a third of the candidates gained both marks; most of these gave an answer based on inductive effects as above, but others correctly discussed steric effects and this answer was also accepted.

Q20.

In part (a), large numbers of candidates were able to write a correct mechanism for the nucleophilic addition of HCN to ketone **Q**. By contrast, most found it difficult to name the product correctly and so only 15% scored full marks overall. In part (b) many answers discussed the optical activity of the original ketones **Q** and **R** rather than that of the products of their reactions with HCN. Many also thought that both ketones produced racemic mixtures.

Q21.

Part (a) was well answered and many candidates scored highly. The mechanism in part (b) proved more difficult and some candidates tried to use BH_4^- instead of H^- as expected. The name of the product proved very difficult for most candidates and many made no attempt to answer the question. In part (c), many confused Reaction 3, which is a dehydration or an elimination of water, with the removal of hydrogen from ethylbenzene using iron oxides.

Q22.

As usual, better candidates find organic mechanisms straightforward and many good answers were seen to part (a). In part (b)(i) the name 2-hydroxybutanenitrile, was usually given correctly. The abbreviation 2-hydroxybutanenitrile was not allowed.

The structure of the isomer of $\text{C}_4\text{H}_7\text{NO}$ was found difficult. It was possible to score one mark for a structure with the correct molecular formula which showed geometric isomerism. Sadly many candidates did not recognise that an acyl chloride reacts with ammonia form an amide.

In part (c), there were many pentavalent carbons shown in the structures drawn, especially in part (ii). The elimination of water in part (iii) to form an alkene was the least well-known reaction.

Q23.

The name of the mechanism was well answered in part (a) but the actual mechanism itself was much more discriminating. Too many candidates are still careless in their drawing of curly arrows and fail to start every arrow either at a bond or a lone pair. Attack by the cyanide ion must show a lone pair on the carbon atom as the source of the curly arrow. The carbonyl group carbon has a δ^+ charge not a full positive charge as suggested by several. Part (b) was less well done. Although many answered part (b)(i) correctly, several omitted the number 2 in the name or failed to count the number of carbons carefully. Part (b)(ii) was misread by many, who simply drew the two optical isomers of **Q** rather than the two geometrical isomers of the dehydration product of **Q**. The repeating unit was usually correct in part (c) although some gave an extra oxygen in their structure and others gave more than the single repeating unit requested. The zwitterion in part (d)(i) was generally well known, but many drew incorrectly a quaternary ammonium salt in part (d)(ii).

Q25.

Part (a) was answered well. Most candidates were able to describe a correct chemical test to distinguish between the aldehyde, propanal, and the ketone, propanone. However, many thought that propanone had two peaks in its proton n.m.r. spectrum.

In part (b), better candidates had no difficulty in identifying propanoic acid as **X** and propan-2-ol as **Y** and in giving correct descriptions of oxidation in Step 1, reduction in Step 2 and esterification in Step 3. Weaker candidates lost marks for incorrect reagents or for

wrong or missing conditions in the reactions.

Q26.

Part (a)(i) was well answered. Many candidates chose a correct alkene, gave two structural isomers formed in the reaction with HBr and named the type of structural isomerism. Candidates who chose an incorrect alkene were able to score three marks for a correct mechanism. In (a)(ii) choosing a carbonyl compound with the molecular formula C_3H_6O which forms two isomers when HCN is added proved more difficult and many candidates gave the incorrect carbonyl $(CH_3)_2CO$. Marks were again allowed for a correct mechanism even when the carbonyl was incorrect. Candidates were only allowed to score a mark for stating that the isomers formed were optically active if the isomers given had an asymmetric carbon. As square planar molecules are not optically active, structure marks were only awarded when isomers were shown as tetrahedral arrangements. Almost all candidates were able to write an equation for a nucleophilic addition-elimination reaction of ethanoyl chloride but equations involving NH_3 were only given full marks if NH_4Cl rather than HCl was given as a product. Many candidates omitted to state the polarising effects of both the oxygen and the chlorine atoms when explaining why the reactions occur readily. Most also failed to state that nucleophiles are able to react because they have a lone electron pair which they can donate.

Q29.

This was a relatively high scoring question. In part (a), many correct answers were seen, although answers to part (a)(ii) often included unbalanced equations or an incorrect formula for propanone. The intended answer in (a)(ii) was $NaBH_4$, but due credit was given to those candidates who chose to use Ni/H_2 and ignored the requirement to use $[H]$ in the equation. The structure of propanal was generally well known and the choice of a suitable reagent for the test to distinguish propanone from propanal caused few problems; Tollens' reagent being the most common choice. Many candidates received full credit for part (b)(ii), but some credit was withheld when an incomplete reagent was used e.g. $[Ag(NH_3)_2]^+$ or the results were recorded the wrong way around.

Q30.

Compound **C** was named correctly by the more able, but the requirement for the number 2 was not appreciated by the weaker candidates. Part (b) was answered well by most, although some did not distinguish between the O-H absorption in alcohols such as compound **D** and the O-H absorption in carboxylic acids. A surprising number of candidates gave the answer 5 in part (c) rather than the expected 4. Answers to part (d) were disappointing even from otherwise good candidates. It seemed that as soon as the ketone **C** was seen, then tests using Fehlings or Tollens' solutions were suggested, without the candidates noticing that **D** was an alcohol and not an aldehyde. Those who chose a correct test usually scored well. Answers to part (e) were better.

Q32.

This question discriminated well and better candidates were able to score full marks. Weaker candidates were unable to recognise the ester **C** and acid **D** in part (a) and hence could not distinguish correctly between them. As expected, methyl propanoate was a common wrong answer in part (a)(i) and only the better candidates named **E** correctly as pentan-2-one. Reagents distinguishing between the ketone **E** and the aldehyde **F** were better known, but the term "chain isomer" was missed by many who failed to draw a correct structure for 2-methylbutanal, the only possible answer.

Q33.

Although many candidates were able to identify which of the three organic compounds would reduce acidified potassium dichromate(VI), as required in part (a), only a relatively small number gave a correct half-equation for the reduction of dichromate(VI) ions. In part (b), many candidates correctly identified the aldehyde as the compound which reduces Tollens' reagent. Some also gave the correct silver complex present in Tollens' reagent but few gave a correct half-equation for the reduction of this species to silver metal. The formation of two esters by the reactions of the two alcohols with ethanoic acid was quite well known and many correct equations for their formation were given in answers to part (c). Part (d) proved, as expected, to be more challenging and only the best candidates were able to deduce correctly the number of peaks in the proton n.m.r. spectra of the two compounds given.

Q34.

In organic mechanisms, a curly arrow must start at a lone pair or at a bond. This idea was still forgotten by some candidates. In part(a), several used a lone pair on the nitrogen atom rather than one on the carbon of the cyanide ion. A few confused the nucleophilic addition in part (a) with the addition-elimination in part (b) and tried in part (a) to reform a carbon to oxygen double bond. An appreciable number thought that the name of the product was a propanenitrile instead of 2-hydroxypentanenitrile. In both parts (a) and (b) the C=O bond should not be shown breaking before the nucleophile attacks. The ester was often correctly named as methyl propanoate but many other suggestions were also seen. Part (c) discriminated well. Only the better candidates were able to identify the correct electrophile, join it correctly to the benzene ring, draw the correct intermediate and show the loss of H⁺ correctly.