Q1. Esters are used as raw materials in the production of soaps and biodiesel.

(a) A student prepared an ester by two different methods.

Method **1** alcohol + acid anhydride

Method **2** alcohol + acyl chloride

(i) An ester was prepared using method **1**, by reacting $(CH_3)_2CHOH$ with $(CH_3CO)_2O$

Write an equation for this reaction and give the IUPAC name of the ester formed.

Equation

.....

IUPAC name of the ester .....

(2)

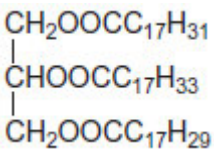
(ii) The same ester was prepared using method **2** by reacting $(CH_3)_2CHOH$ with CH_3COCl

Outline a mechanism for this reaction.

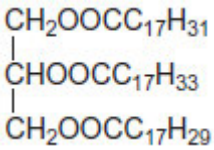
(4)

(b) The ester shown occurs in vegetable oils.

It can be hydrolysed to make soap and can also be used to produce biodiesel.



(i) Write an equation for the reaction of this ester with sodium hydroxide to form soap.



.....

(2)

(ii) Give the formula of the biodiesel molecule with the highest M_r that can be produced by reaction of this ester with methanol.

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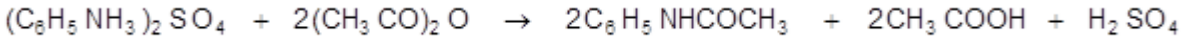
(1)

(Total 9 marks)

Q2. N-phenylethanamide is used as an inhibitor in hydrogen peroxide decomposition and also in the production of dyes.

N-phenylethanamide can be produced in a laboratory by the reaction between phenylammonium sulfate and an excess of ethanoic anhydride:

(a) A student carried out this preparation using 1.15 g of phenylammonium sulfate (M_r = 284.1) and excess ethanoic anhydride.



(i) Calculate the maximum theoretical yield of N−phenylethanamide that could be produced in the reaction. Record your answer to an appropriate precision.

Show your working.

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(3)

(ii) In the preparation, the student produced 0.89 g of N−phenylethanamide.

Calculate the percentage yield for the reaction.

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(1)

(b) The student purified the crude solid product, N−phenylethanamide, by recrystallisation.

(i) Outline the method that the student should use for this recrystallisation.

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(4)

(ii) Outline how you would carry out a simple laboratory process to show that the recrystallised product is a pure sample of N−phenylethanamide.

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(3)

(iii) Assume that the reaction goes to completion.

Suggest **two** practical reasons why the percentage yield for this reaction may **not** be 100%.

1 .....

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2 .....

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(2)

(c) The reaction to form N−phenylethanamide would happen much more quickly if the student used ethanoyl chloride instead of ethanoic anhydride.

Explain why the student might prefer to use ethanoic anhydride, even though it has a slower rate of reaction.

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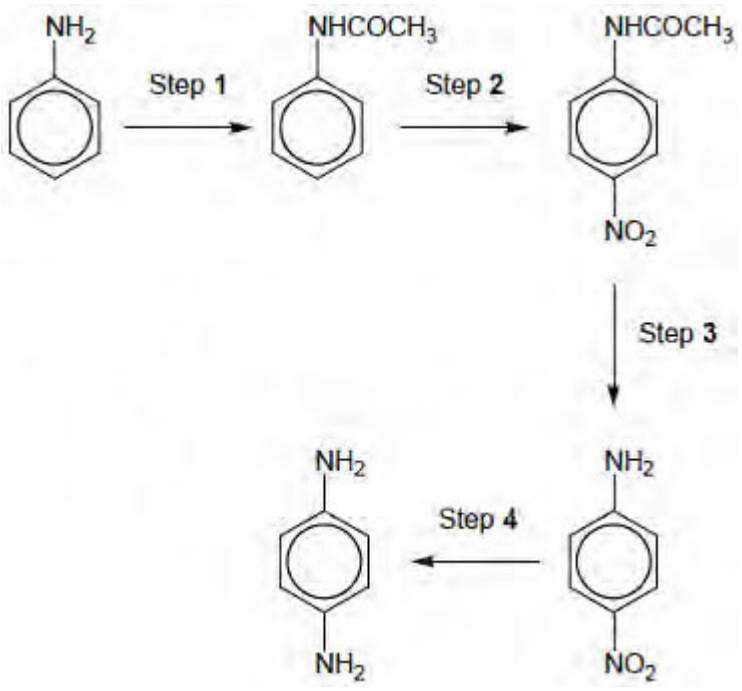
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(2)
(Total 15 marks)

Q3. 1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in the following

figure.



(a) A suitable reagent for step **1** is CH_3COCl

Name and draw a mechanism for the reaction in step **1**.

Name of mechanism .....

Mechanism

(5)

(b) The product of step **1** was purified by recrystallisation as follows.

The crude product was dissolved in **the minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature**. The crystals formed were filtered off using a Buchner funnel and a clean cork was used **to compress the crystals in the funnel. A little cold water was then**

poured through the crystals.
After a few minutes, the crystals were removed from the funnel and weighed.
A small sample was then used to find the melting point.

Give reasons for each of the following practical steps.

The minimum quantity of hot water was used

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The flask was cooled to room temperature before the crystals were filtered off

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The crystals were compressed in the funnel

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A little cold water was poured through the crystals

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(4)

(c) The melting point of the sample in part (b) was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.

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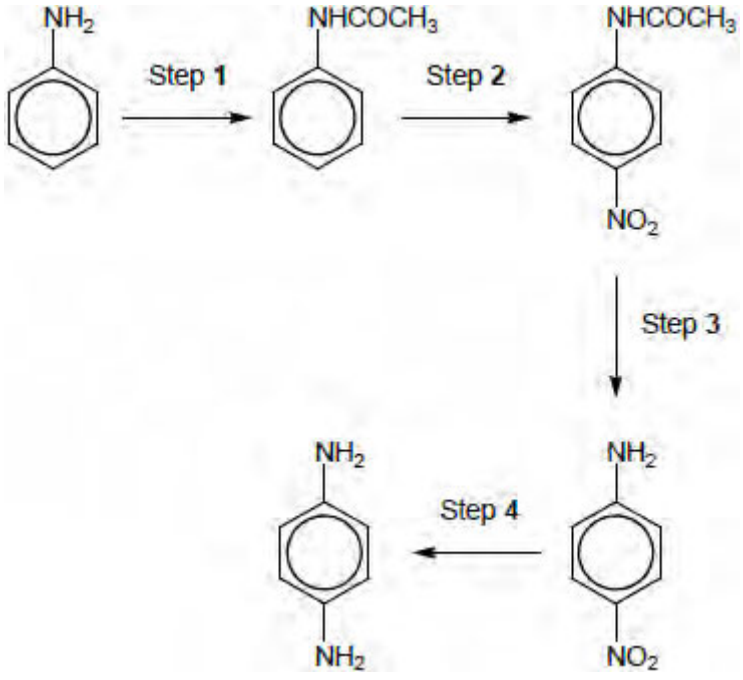
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(2)

The figure above is repeated here to help you answer the following questions.



(d) In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step **1**.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures.

Percentage yield = ...%

(3)

(e) A reagent for step **2** is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step **2**.

.....

(1)

(f) Name a mechanism for the reaction in step **2**.

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(1)

(g) Suggest the type of reaction occurring in step **3**.

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(1)

(h) Identify the reagents used in step **4**.

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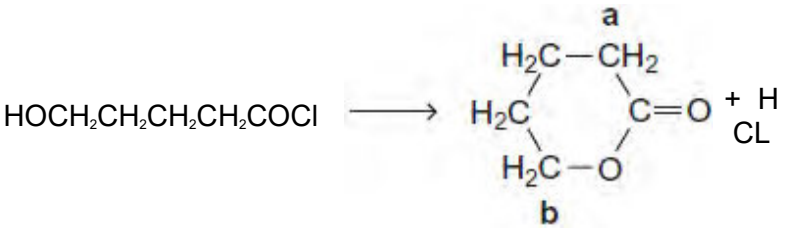
(1)

(Total 18 marks)

Q1. This question is about some isomers of $C_5H_8O_2$

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

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



H

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

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

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(7)

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

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

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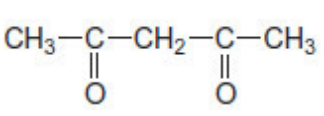
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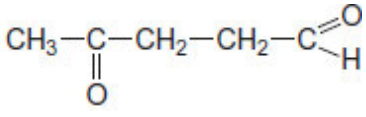
(2)

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

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



J



K

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(5)

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

L is methyl 2-methylpropenoate.

M is an ester that shows E-Z stereoisomerism.

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

P is an optically active carboxylic acid.

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

(5)
(Total 19 marks)

Q2. Samples of 1-chloropropane and ethanoyl chloride can be distinguished by the addition of an aqueous solution of silver nitrate.
State what you would observe with each sample.

Observation with 1-chloropropane

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Observation with ethanoyl chloride.

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(Total 2 marks)

Q3. Acyl chlorides such as CH_3COCl are useful compounds in synthesis.

(a) The acyl chloride CH_3COCl reacts with benzene.

(i) Write an equation for this reaction and name the organic product.

Identify a catalyst for the reaction.

Write an equation to show how this catalyst reacts with CH_3COCl to produce a reactive intermediate.

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(4)

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

Name of mechanism

.....

Mechanism

(4)

(b) Nucleophiles such as alcohols can react with CH_3COCl
The ion CH_3COO^- can act as a nucleophile in a similar way.

State the meaning of the term *nucleophile*.

Draw the structure of the organic product formed by the reaction of CH_3COO^- with CH_3COCl

Name the functional group produced in this reaction.

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(3)
(Total 11 marks)

Q4. Acyl chlorides and acid anhydrides are important compounds in organic synthesis.

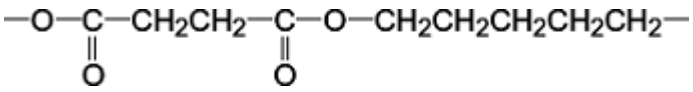
(a) Outline a mechanism for the reaction of CH_3CH_2COCl with CH_3OH and name the organic product formed.

Mechanism

Name of organic product .....

(5)

(b) A polyester was produced by reacting a diol with a diacyl chloride. The repeating unit of the polymer is shown below.



(i) Name the diol used.

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(1)

(ii) Draw the displayed formula of the diacyl chloride used.

(1)

(iii) A shirt was made from this polyester. A student wearing the shirt accidentally splashed aqueous sodium hydroxide on a sleeve. Holes later appeared in the sleeve where the sodium hydroxide had been.

Name the type of reaction that occurred between the polyester and the aqueous sodium hydroxide. Explain why the aqueous sodium hydroxide reacted with the polyester.

Type of reaction .....

Explanation .....

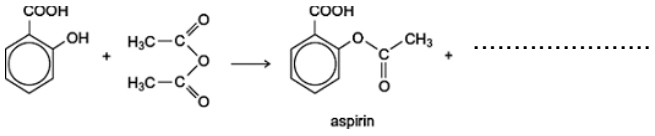
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(3)

(c) (i) Complete the following equation for the preparation of aspirin using ethanoic anhydride by writing the structural formula of the missing product.



aspirin

(1)

(ii) Suggest a name for the mechanism for the reaction in part (c)(i).

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(1)

(iii) Give **two** industrial advantages, other than cost, of using ethanoic anhydride rather than ethanoyl chloride in the production of aspirin.

Advantage 1 .....

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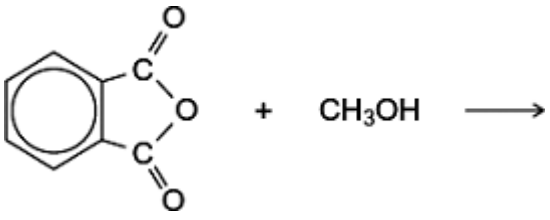
Advantage 2 .....

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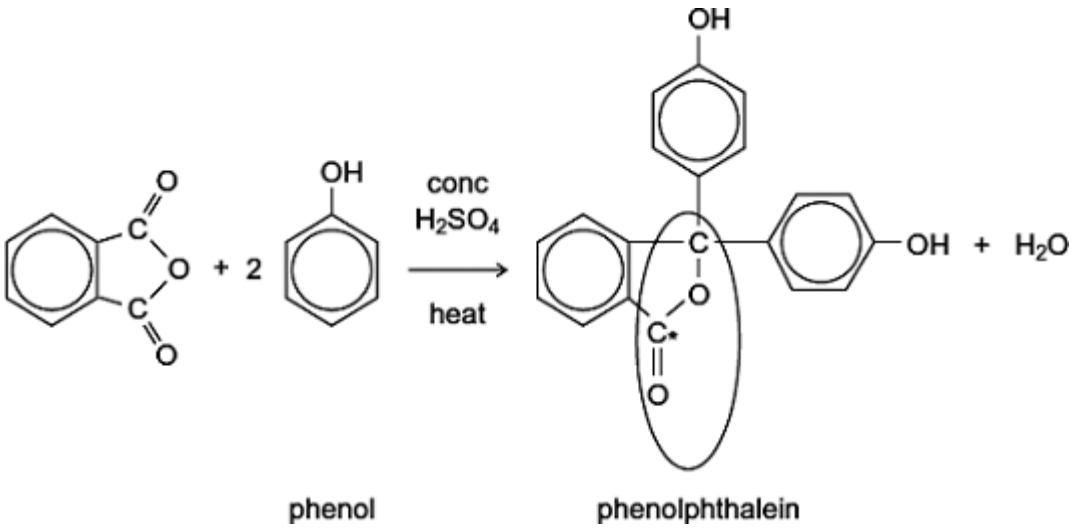
(2)

(d) Complete the following equation for the reaction of one molecule of benzene-1,2-dicarboxylic anhydride (phthalic anhydride) with one molecule of methanol by drawing the structural formula of the single product



(1)

(e) The indicator phenolphthalein is synthesised by reacting phthalic anhydride with phenol as shown in the following equation.



(i) Name the functional group ringed in the structure of phenolphthalein.

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(1)

(ii) Deduce the number of peaks in the ^{13}C n.m.r. spectrum of phenolphthalein.

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(1)

(iii) One of the carbon atoms in the structure of phenolphthalein shown above is labelled with an asterisk (*).
Use **Table 3** on the Data Sheet to suggest a range of δ values for the peak due to this carbon atom in the ^{13}C n.m.r. spectrum of phenolphthalein.

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(1)

(f) Phenolphthalein can be used as an indicator in some acid–alkali titrations.
The pH range for phenolphthalein is 8.3 – 10.0

(i) For **each** acid.alkali combination in the table below, put a tick (✓) in the box if phenolphthalein could be used as an indicator.

Acid	**Alkali**	**Tick box (✓)**
sulfuric acid	sodium hydroxide	
hydrochloric acid	ammonia	
ethanoic acid	potassium hydroxide	
nitric acid	methylamine	

(2)

(ii) In a titration, nitric acid is added from a burette to a solution of sodium hydroxide containing a few drops of phenolphthalein indicator.
Give the colour **change** at the end-point.

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(1)
(Total 21 marks)

Q5.(a) During the preparation of aspirin, it is necessary to filter the crude product under reduced pressure.

Draw a diagram to show the apparatus you would use to filter the crude product under reduced pressure. (Do **not** include the vacuum pump.)

(2)

(b) You are provided with a small sample of pure aspirin in a melting point tube. Describe briefly how you would determine an accurate value for the melting point of aspirin.

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(2)
(Total 4 marks)

Q6. Aldehydes can be prepared from acyl chlorides.

State how an aldehyde could be tested to show whether it is contaminated with traces of unreacted acyl chloride.
State what you would observe.

Test .....

Observation .....

.....

(Total 2 marks)

Q1. The reactions of molecules containing the chlorine atom are often affected by other functional groups in the molecule.

Consider the reaction of CH_3CH_2COCl and of $CH_3CH_2CH_2Cl$ with ammonia.

(a) For the reaction of CH_3CH_2COCl with ammonia, name and outline the mechanism and name the organic product.

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(Extra space) .....

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(6)

(b) For the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia, name and outline the

mechanism and name the organic product.

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(Extra space) .....

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(6)

(c) Suggest **one** reason why chlorobenzene (C_6H_5Cl) does **not** react with ammonia under normal conditions.

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(Extra space) .....

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(1)
(Total 13 marks)

Q2. (a) Name and outline a mechanism for the reaction of $CH_3CH_2NH_2$ with CH_3CH_2COCl

Name the amide formed.

(6)

(b) Haloalkanes such as CH_3Cl are used in organic synthesis.

Outline a three-step synthesis of $CH_3CH_2NH_2$ starting from methane. Your first step should involve the formation of CH_3Cl

In your answer, identify the product of the second step and give the reagents and conditions for each step.

Equations and mechanisms are **not** required.

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(6)
(Total 12 marks)

Q3. Esters have many important commercial uses such as solvents and artificial flavourings in foods.

Esters can be prepared in several ways including the reactions of alcohols with carboxylic acids, acid anhydrides, acyl chlorides and other esters.

(a) Ethyl butanoate is used as a pineapple flavouring in sweets and cakes.

Write an equation for the preparation of ethyl butanoate from an acid and an alcohol.

Give a catalyst used for the reaction.

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(4)

(b) Butyl ethanoate is used as a solvent in the pharmaceutical industry.

Write an equation for the preparation of butyl ethanoate from an acid anhydride and an alcohol.

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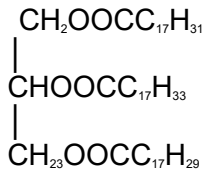
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(3)

(c) Name and outline a mechanism for the reaction of CH_3COCl with CH_3OH to form an ester.

(5)

(d) The ester shown below occurs in vegetable oils. Write an equation to show the formation of biodiesel from this ester.



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(3)

(e) Draw the repeating unit of the polyester Terylene that is made from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Although Terylene is biodegradeable, it is preferable to recycle objects made from Terylene.

Give **one** advantage and **one** disadvantage of recycling objects made from Terylene.

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(4)
(Total 19 marks)

Q4. Salicylic acid can be used to make aspirin. Before using a sample of salicylic acid to make aspirin, a student purified the acid by recrystallisation. The method for recrystallisation is outlined below.

Step 1: The sample is dissolved in a minimum volume of hot water.
Step 2: The solution is filtered hot.
Step 3: The filtrate is cooled in ice to form crystals.
Step 4: The crystals are collected by filtration, washed with cold water and left to dry.

Explain the purpose of each underlined point.

Minimum volume .....

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Hot water .....

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Filtered hot .....

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Cooled in ice .....

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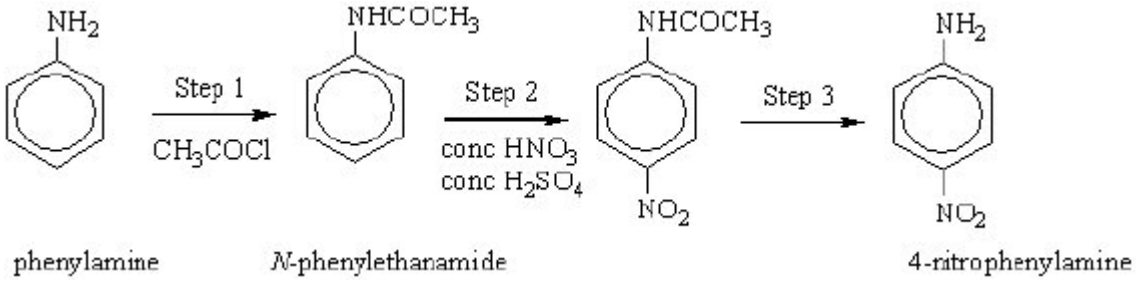
Washed with cold water .....

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(Total 5 marks)

Q1. Synthetic dyes can be manufactured starting from compounds such as 4-nitrophenylamine.

A synthesis of 4-nitrophenylamine starting from phenylamine is shown below.



(a) An equation for formation of *N*-phenylethanamide in Step 1 of the synthesis is shown below.

$$2C_6H_5NH_2 + CH_3COCl \rightarrow \underset{\textit{N}\text{-phenylethanamide}}{C_6H_5NHCOCH_3} + C_6H_5NH_3Cl$$

(i) Calculate the % atom economy for the production of *N*-phenylethanamide (M_r = 135.0).

(ii) In a process where 10.0 kg of phenylamine are used, the yield of *N*-phenylethanamide obtained is 5.38 kg.

Calculate the percentage yield of *N*-phenylethanamide.

(iii) Comment on your answers to parts (i) and (ii) with reference to the commercial viability of the process.

(7)

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

(5)

(c) The mechanism of Step 2 involves attack by an electrophile. Write an equation showing the formation of the electrophile. Outline a mechanism for the reaction of this electrophile with benzene.

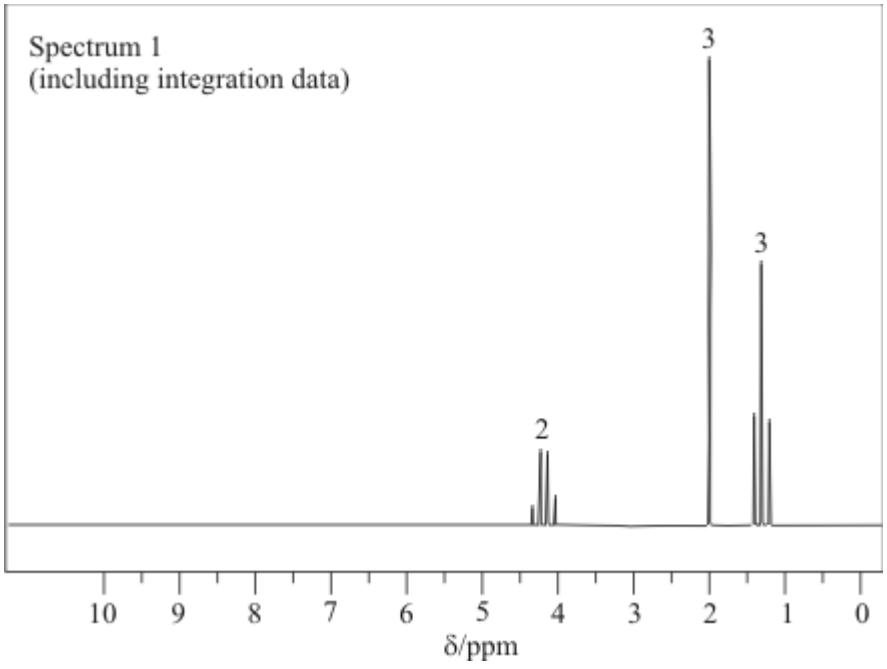
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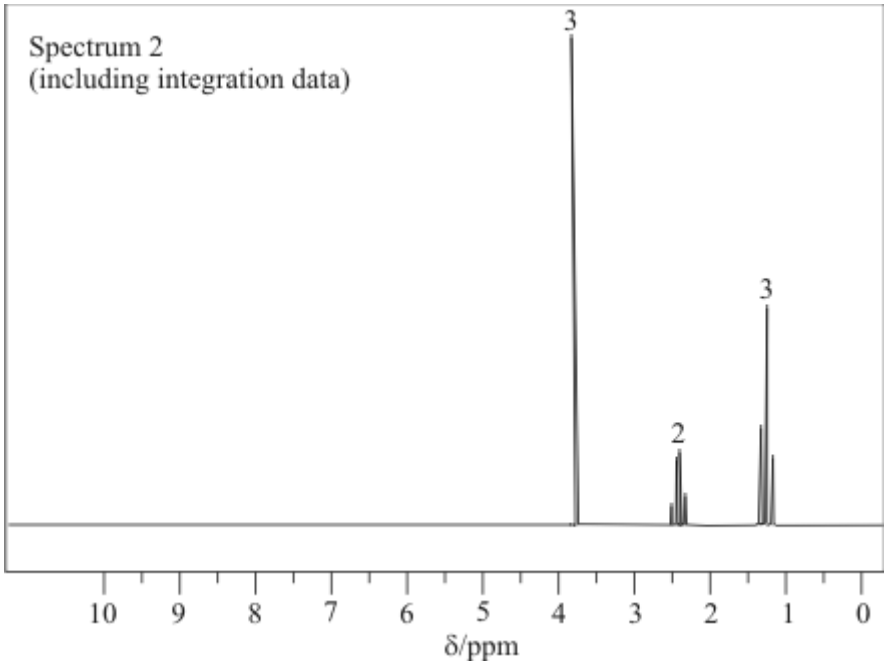
(Total 16 marks)

Q2. (a) Ester **X**, $CH_3CH_2COOCH_3$, can be produced by the reaction between propanoyl chloride and methanol. Name **X** and outline a mechanism for this reaction. Name the mechanism involved.

(6)

(b) The proton n.m.r. spectrum of **X** is shown below together with that of an isomeric ester, **Y**. Deduce which of Spectrum 1 and Spectrum 2 is that obtained from **X**. Use **Table 1** on the Data Sheet and the integration data on the spectra to help you to explain your deduction. Suggest a structure for **Y**.





(4)
(Total 10 marks)

Q3. (a) Write an equation for the formation of methyl propanoate, $CH_3CH_2COOCH_3$, from methanol and propanoic acid.

.....

(1)

(b) Name and outline a mechanism for the reaction between methanol and propanoyl chloride to form methyl propanoate.

Name of mechanism .....

Mechanism

(5)

(c) Propanoic anhydride could be used instead of propanoyl chloride in the preparation of methyl propanoate from methanol. Draw the structure of propanoic anhydride.

(1)

(d) (i) Give **one** advantage of the use of propanoyl chloride instead of propanoic acid in the laboratory preparation of methyl propanoate from methanol.

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(ii) Give **one** advantage of the use of propanoic anhydride instead of propanoyl chloride in the industrial manufacture of methyl propanoate from methanol.

.....

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(2)

(e) An ester contains a benzene ring. The mass spectrum of this ester shows a molecular ion peak at *m/z* = 136.

(i) Deduce the molecular formula of this ester.

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(ii) Draw **two** possible structures for this ester.

(3)
(Total 12 marks)

Q4. (a) Name the compound $(CH_3)_2NH$

.....

(1)

(b) $(CH_3)_2NH$ can be formed by the reaction of an excess of CH_3NH_2 with CH_3Br. Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(5)

(c) Name the type of compound produced when a large excess of CH_3Br reacts with CH_3NH_2 Give a use for this type of compound.

Type of compound .....

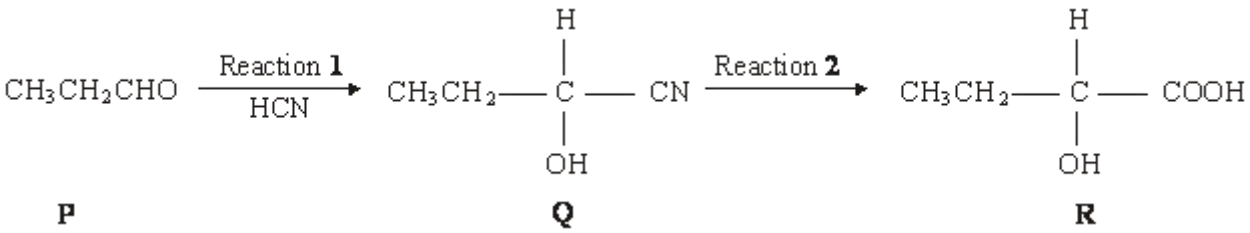
Use .....

(2)

(d) Draw the structures of the two compounds formed in the reaction of CH_3NH_2 with ethanoic anhydride.

(2)
(Total 10 marks)

Q5. Consider the sequence of reactions below.



P **Q** **R**

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

Name of mechanism .....

Mechanism

(5)

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

.....

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

(3)

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

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

(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

(3)
(Total 11 marks)

Q1. (a) Name and outline a mechanism for the reaction between propanoyl chloride, CH_3CH_2COCl, and methylamine, CH_3NH_2
Draw the structure of the organic product.

(6)

(b) Benzene reacts with propanoyl chloride in the presence of aluminium chloride.
Write equations to show the role of aluminium chloride as a catalyst in this reaction.
Outline a mechanism for this reaction of benzene.

(5)

(c) Write an equation for the reaction of propanoyl chloride with water. An excess of water is added to 1.48 g of propanoyl chloride. Aqueous sodium hydroxide is then added from a burette to the resulting solution.
Calculate the volume of 0.42 mol dm^{-3} aqueous sodium hydroxide needed to react exactly with the mixture formed.

(5)
(Total 16 marks)

Q2. (a) Addition reactions to both alkenes and carbonyl compounds can result in the formation of isomeric compounds.

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

Outline a mechanism for the formation of the major product.

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

(14)

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

(4)
(Total 18 marks)

Q3. (a) The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.

$2W(g) + X(g) \rightleftharpoons 3Y(g) + 2Z(g) \qquad \Delta H = -200 \text{ kJ mol}^{-1}$

Write an expression for the equilibrium constant, K_p, for this reaction.
State one change in the conditions which would both increase the rate of reaction and decrease the value of K_p. Explain your answers.

(7)

(b) Ethyl ethanoate can be prepared by the reactions shown below.

Reaction 1
$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l) \qquad \Delta H^{\ominus} = -2.0 \text{ kJ mol}^{-1}$

Reaction 2
$CH_3COCl(l) + C_2H_5OH(l) \rightarrow CH_3COOC_2H_5(l) + HCl(g) \qquad \Delta H^{\ominus} = -21.6 \text{ kJ mol}^{-1}$

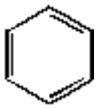
(i) Give one advantage and one disadvantage of preparing ethyl ethanoate by **Reaction 1** rather than by **Reaction 2**.

(ii) Use the information given above and the data below to calculate values for the standard entropy change, $\Delta S^{\ominus}$, and the standard free-energy change, $\Delta G^{\ominus}$, for **Reaction 2** at 298 K.

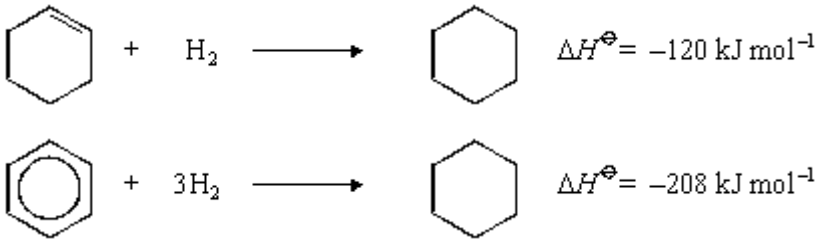
	$CH_3COCl(l)$	$C_2H_5OH(l)$	$CH_3COOC_2H_5(l)$	$HCl(g)$
$S^{\ominus}$/JK^{1}mol^{1}	201	161	259	187

(8)
(Total 15 marks)

Q1. (a) Use the following data to show the stability of benzene relative to the hypothetical cyclohexa-1,3,5-triene.

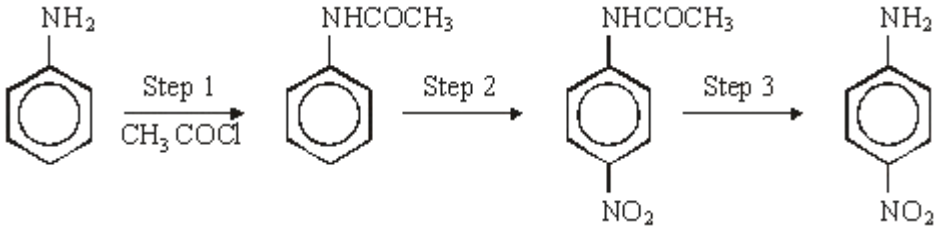


Give a reason for this difference in stability.



(4)

(b) Consider the following reaction sequence which starts from phenylamine.



(i) State and explain the difference in base strength between phenylamine and ammonia.

(ii) Name and outline a mechanism for the reaction in Step 1 and name the organic product of Step 1.

(iii) The mechanism of Step 2 involves attack by an electrophile. Give the reagents used in this step and write an equation showing the formation of the electrophile.
Outline a mechanism for the reaction of this electrophile with benzene.

(iv) Name the type of linkage which is broken in Step 3 and suggest a suitable reagent for this reaction.

(17)
(Total 21 marks)

Q2. (a) A flask containing a mixture of 0.200 mol of ethanoic acid and 0.110 mol of ethanol was maintained at 25 °C until the following equilibrium had been established.

$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$

The ethanoic acid present at equilibrium required 72.5 cm^3 of a 1.50 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the value of the equilibrium constant, K_c, for this reaction at 25 °C.

(ii) The enthalpy change for this reaction is quite small. By reference to the number and type of bonds broken and made, explain how this might have been predicted.

(9)

(b) Aspirin can be prepared by acylation using either ethanoyl chloride or ethanoic anhydride, as represented by the equations shown below.

$CH_3COCl + HOC_6H_4COOH \rightarrow CH_3COOC_6H_4COOH + HCl$

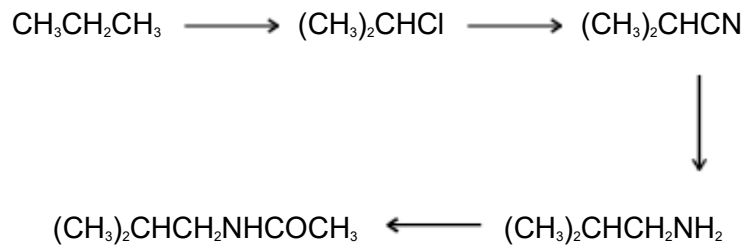
$(CH_3CO)_2O + HOC_6H_4COOH \rightarrow CH_3COOC_6H_4COOH + CH_3COOH$

(i) By a consideration of the intermolecular forces involved, explain why the product HCl is a gas but the product CH_3COOH is a liquid at room temperature.

(ii) Give **two** industrial advantages of using ethanoic anhydride rather than ethanoyl chloride in the manufacture of aspirin.

(4)
(Total 13 marks)

Q3. Which one of the following types of reaction mechanism is **not** involved in the above sequence?



A free-radical substitution

B nucleophilic substitution

C elimination

D nucleophilic addition-elimination

(Total 1 mark)

Q4. (a) Outline a mechanism for the reaction of $CH_3CH_2CH_2CHO$ with HCN and name the product.

Mechanism

Name of product .....

(5)

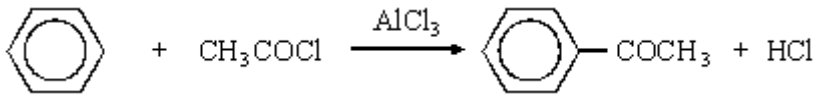
(b) Outline a mechanism for the reaction of CH_3OH with CH_3CH_2COCl and name the organic product.

Mechanism

Name of organic product .....

(5)

(c) An equation for the formation of phenylethanone is shown below. In this reaction a reactive intermediate is formed from ethanoyl chloride. This intermediate then reacts with benzene.



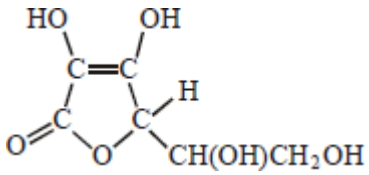
(i) Give the formula of the reactive intermediate.

.....

(ii) Outline a mechanism for the reaction of this intermediate with benzene to form phenylethanone.

(4)
(Total 14 marks)

Q1. Which one of the following is **not** a correct statement about vitamin C, shown below?



A It is a cyclic ester.

B It can form a carboxylic acid on oxidation.

C It decolourises a solution of bromine in water.

D It is a planar molecule.

(Total 1 mark)

Q2. 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)

Q3. Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

A CH_2O

B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

(Total 1 mark)

Q4. Which one of the following is **not** a correct general formula for the non-cyclic compounds listed?

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

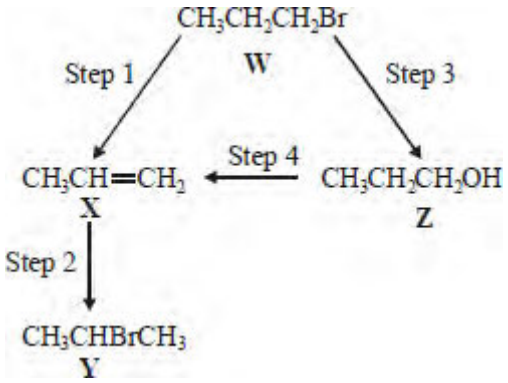
B aldehydes $C_nH_{2n+1}O$

C esters $C_nH_{2n}O_2$

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

(Total 1 mark)

Q5. For this question refer to the reaction scheme below.



Which one of the following statements is **not** correct?

A Reaction of **W** with sodium cyanide followed by hydrolysis of the resulting product gives propanoic acid.

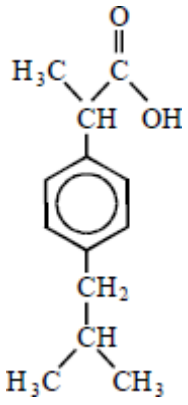
B Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.

C **Z** reacts with ethanoic acid to produce the ester propyl ethanoate.

C **W** undergoes addition polymerisation to form poly(propene).

(Total 1 mark)

Q6. Ibuprofen is a drug used as an alternative to aspirin for the relief of pain, fever and inflammation. The structure of ibuprofen is shown below.



Which one of the following statements is **not** correct?

A It has optical isomers.

B It liberates carbon dioxide with sodium carbonate solution.

D It undergoes esterification with ethanol.

D It undergoes oxidation with acidified potassium dichromate(VI).

(Total 1 mark)

Q7. Butan-1-ol was converted into butyl propanoate by reaction with an excess of propanoic acid. In the reaction, 6.0 g of the alcohol gave 7.4 g of the ester. The percentage yield of ester was

A 57

B 70

C 75

D 81

(Total 1 mark)

Q8. Which one of the following would **not** react with aqueous silver nitrate to produce a precipitate that is soluble in concentrated aqueous ammonia?

A $CaBr_2$

B $[COCl_4]^{2-}$

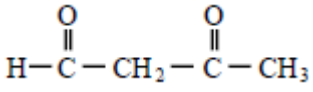
C $(CH_3)_4N^+I^-$

D CH_3COCl

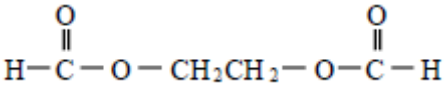
(Total 1 mark)

Q9. Which compound is formed by the reaction of ethane-1,2-diol with an acid?

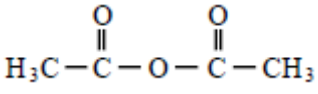
A



B



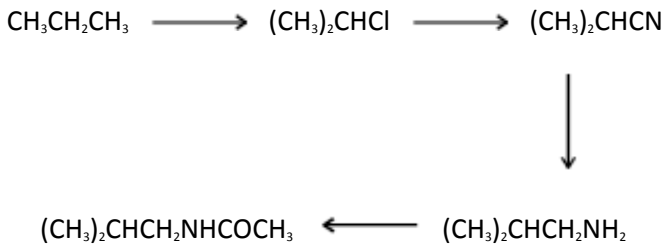
C



D CH_3CH_2 — O — CH_2CH_2OH

(Total 1 mark)

Q10. Which one of the following types of reaction mechanism is **not** involved in the above sequence?



A free-radical substitution

B nucleophilic substitution

C elimination

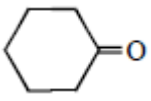
D nucleophilic addition-elimination

(Total 1 mark)

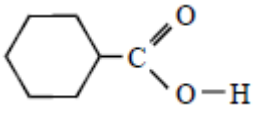
Q11. The compound lithium tetrahydridoaluminate(III), $LiAlH_4$, is a useful reducing agent. It behaves in a similar fashion to $NaBH_4$. Carbonyl compounds and carboxylic acids are reduced to alcohols. However, $LiAlH_4$ also reduces water in a violent reaction so that it must be used in an organic solvent.

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

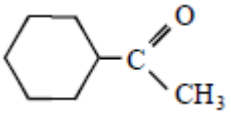
A



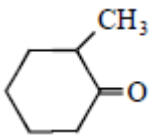
B



C



D



(Total 1 mark)

Q12. An excess of methanol was mixed with 12 g of ethanoic acid and an acid catalyst. At equilibrium the mixture contained 8 g of methyl ethanoate. The percentage yield of ester present was

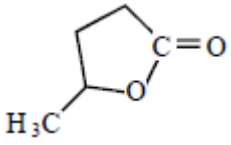
A 11

B 20

C 54

D 67

(Total 1 mark)

Q13. Acid hydrolysis of  produces

A $CH_3CH(OH)CH_2CH_2COOH$

B $CH_2(OH)CH_2CH_2CH_2COOH$

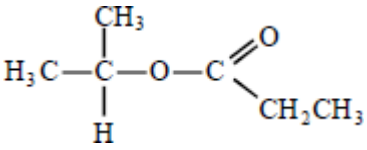
C $CH_3CH(OH)CH_2CH_2OCHO$

D $CH_2(OH)CH_2CH_2CH_2OCHO$

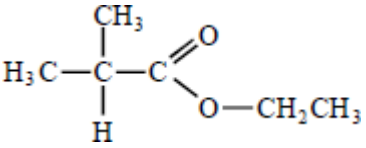
(Total 1 mark)

Q14. The structural formula of ethyl 2-methylpropanoate is

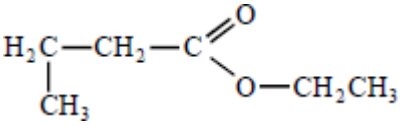
A



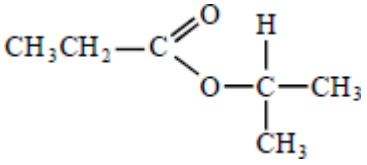
B



C



D



(Total 1 mark)

Q15. Hydrolysis of the ester, $CH_3COOCH_2CH_2CH_3$, produces ethanoic acid. In an experiment, 2.04 g of the ester was used and 0.90 g of ethanoic acid was produced. The percentage yield of ethanoic acid was:

A 44

B 59

C 75

D 90

(Total 1 mark)

Q16. How many structural isomers, which are esters, have the molecular formula $C_4H_8O_2$?

A 2

B 3

C 4

D 5

(Total 1 mark)

Q17. CH_2O is the empirical formula of

A methanol

B methyl methanoate

C ethane-1,2-diol

D butanal

(Total 1 mark)

Q18.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Isomers of the ester $HCOOCH_2CH_2CH_3$, include

(i) ethyl ethanoate

(ii) methyl propanoate

(iii) butanoic acid

(iv) butyl methanoate

(Total 1 mark)

Q1. Esters are used as raw materials in the production of soaps and biodiesel.

(a) A student prepared an ester by two different methods.

Method **1** alcohol + acid anhydride

Method **2** alcohol + acyl chloride

(i) An ester was prepared using method **1**, by reacting $(CH_3)_2CHOH$ with $(CH_3CO)_2O$

Write an equation for this reaction and give the IUPAC name of the ester formed.

Equation

.....

IUPAC name of the ester .....

(2)

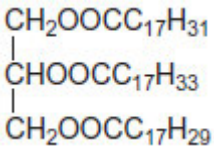
(ii) The same ester was prepared using method **2** by reacting $(CH_3)_2CHOH$ with CH_3COCl

Outline a mechanism for this reaction.

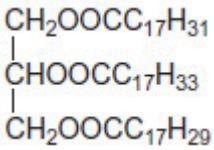
(4)

(b) The ester shown occurs in vegetable oils.

It can be hydrolysed to make soap and can also be used to produce biodiesel.



(i) Write an equation for the reaction of this ester with sodium hydroxide to form soap.



.....

(2)

(ii) Give the formula of the biodiesel molecule with the highest M_r that can be produced by reaction of this ester with methanol.

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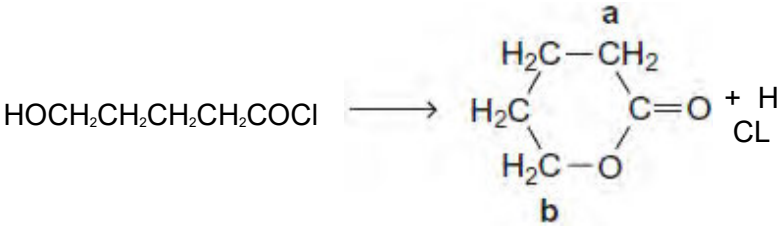
(1)

(Total 9 marks)

Q2. This question is about some isomers of $C_5H_8O_2$

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

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



H

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

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

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(7)

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

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

.....

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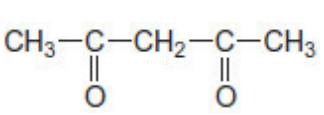
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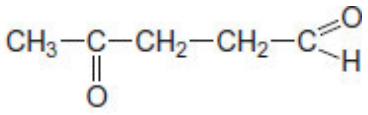
(2)

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

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



J



K

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(5)

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

L is methyl 2-methylpropenoate.

M is an ester that shows E-Z stereoisomerism.

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

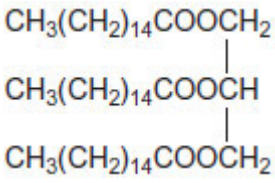
P is an optically active carboxylic acid.

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

(5)
(Total 19 marks)

Q3. The slowing down of chemical processes is important in food storage. Over time, fats may become rancid. This involves the formation of compounds that have unpleasant odours and flavours within the food.
Hydrolysis of fats is one way in which rancid flavours are formed. Fats break down to long-chain carboxylic (fatty) acids and glycerol.

(a) Complete the right-hand side of the equation below to show how hydrolysis affects the molecule of fat shown.



$+ \ 3H_2O \rightarrow 3$ ..... $+$ .....

(2)

(b) Other than by cooling, suggest **one** method that would decrease the rate of hydrolysis of fats.

.....

.....

.....

(1)

(c) Food can also acquire unpleasant flavours when the fatty acids, produced by hydrolysis of fats, are oxidised by air. This oxidation occurs by a free-radical mechanism.
Chemicals called anti-oxidants can be added to food to slow down the oxidation.
Suggest why anti-oxidants are **not** regarded as catalysts.

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(2)

(d) A student investigated the extent of hydrolysis in an old sample of the fat in part (a). The carboxylic acid extracted from a 2.78 g sample of this fat (M_r = 806.0) reacted

with 24.5 cm^3 of a 0.150 mol dm^{-3} solution of NaOH.
Calculate the percentage of the fat that had hydrolysed.
Show your working.

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(4)
(Total 9 marks)

Q4. Salicylic acid, $C_6H_4(OH)COOH$, reacts with magnesium to produce magnesium salicylate and hydrogen.

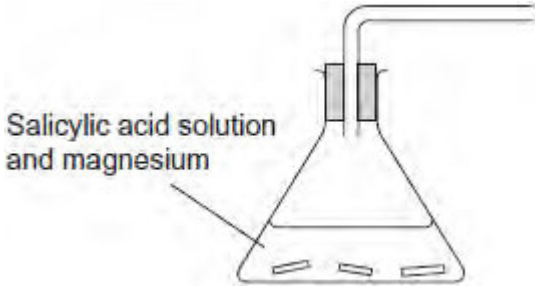
(a) Complete the equation for this reaction.

$C_6H_4(OH)COOH$

(1)

(b) In an alternative method for determining percentage purity, a student reacted a solution of salicylic acid with an excess of magnesium and collected the hydrogen gas that was released.

Complete the diagram below to show an apparatus that could be used to collect and measure the volume of hydrogen gas produced.



(1)
(Total 2 marks)

Q5. Esters are produced by the reaction of alcohols with other esters and by the reaction of alcohols with carboxylic acids.

(a) The esters which make up biodiesel are produced industrially from the esters in vegetable oils.

(i) Complete the equation for this formation of biodiesel.



.....

(2)

(ii) Write an equation for the complete combustion of $C_{17}H_{35}COOCH_3$.

.....

(2)

(b) The ester commonly known as diethyl malonate (**DEM**) occurs in strawberries and grapes. It can be prepared from acid **A** according to the following equilibrium.



A **DEM**

(i) A mixture of 2.50 mol of **A** and 10.0 mol of ethanol was left to reach equilibrium in an inert solvent in the presence of a small amount of concentrated sulfuric acid.
The equilibrium mixture formed contained 1.80 mol of **DEM** in a total volume, V dm^3, of solution.

Calculate the amount (in moles) of **A**, of ethanol and of water in this equilibrium mixture.

Moles of **A** .....

Moles of ethanol .....

Moles of water.....

(3)

(ii) The total volume of the mixture in part (b)(i) was doubled by the addition of more of the inert solvent.

State and explain the effect of this addition on the equilibrium yield of **DEM**.

Effect .....

Explanation .....

.....

(2)

(iii) Using **A** to represent the acid and **DEM** to represent the ester, write an expression for the equilibrium constant K_c for the reaction.

.....

.....

(1)

(iv) In a second experiment, the equilibrium mixture was found to contain 0.85 mol of **A**, 7.2 mol of ethanol, 2.1 mol of **DEM** and 3.4 mol of water.

Calculate a value of K_c for the reaction and deduce its units.

Calculation.....

.....

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Units.....

.....

(3)

(Total 13 marks)

Q1. The reactions of molecules containing the chlorine atom are often affected by other functional groups in the molecule.

Consider the reaction of CH_3CH_2COCl and of $CH_3CH_2CH_2Cl$ with ammonia.

(a) For the reaction of CH_3CH_2COCl with ammonia, name and outline the mechanism and name the organic product.

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(Extra space) .....

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(6)

(b) For the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia, name and outline the

mechanism and name the organic product.

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(Extra space) .....

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(6)

(c) Suggest **one** reason why chlorobenzene (C_6H_5Cl) does **not** react with ammonia under normal conditions.

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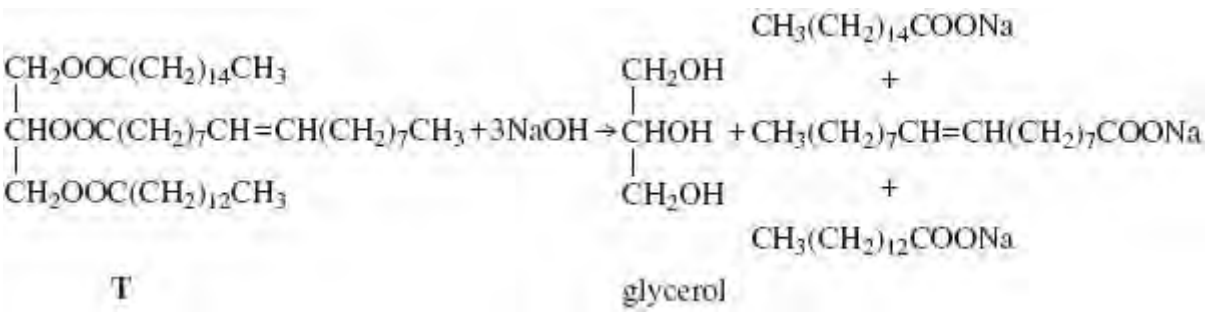
(Extra space) .....

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(1)

(Total 13 marks)

Q2. The triester, **T**, shown below is found in palm oil. When **T** is heated with an excess of sodium hydroxide solution, the alcohol glycerol is formed together with a mixture of three other products as shown in the following equation.



T glycerol

(a) (i) Give the IUPAC name for glycerol.

.....

(1)

(ii) Give a use for the mixture of sodium salts formed in this reaction.

.....

(1)

(b) When **T** is heated with an excess of methanol, glycerol is formed together with a

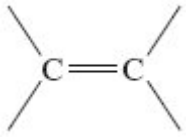
mixture of methyl esters.

(i) Give a use for this mixture of methyl esters.

.....

(1)

(ii) One of the methyl esters in the mixture has the IUPAC name methyl (*Z*)-octadec-9-enoate. Draw **two** hydrogen atoms on the diagram below to illustrate the meaning of the letter *Z* in the name of this ester.



(1)

(iii) One of the other methyl esters in the mixture has the formula $CH_3(CH_2)_{12}COOCH_3$
Write an equation for the complete combustion of one molecule of this ester.

.....

(1)
(Total 5 marks)

Q3.(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)

Q4. (a) Write an equation for the formation of methyl propanoate, $CH_3CH_2COOCH_3$, from methanol and propanoic acid.

.....

(1)

(b) Name and outline a mechanism for the reaction between methanol and propanoyl chloride to form methyl propanoate.

Name of mechanism .....

Mechanism

(5)

(c) Propanoic anhydride could be used instead of propanoyl chloride in the preparation of methyl propanoate from methanol. Draw the structure of propanoic anhydride.

(1)

(d) (i) Give **one** advantage of the use of propanoyl chloride instead of propanoic acid in the laboratory preparation of methyl propanoate from methanol.

.....

.....

(ii) Give **one** advantage of the use of propanoic anhydride instead of propanoyl chloride in the industrial manufacture of methyl propanoate from methanol.

.....

.....

(2)

(e) An ester contains a benzene ring. The mass spectrum of this ester shows a molecular ion peak at *m/z* = 136.

(i) Deduce the molecular formula of this ester.

.....

.....

.....

(ii) Draw **two** possible structures for this ester.

(3)
(Total 12 marks)

Q5. Synthesis gas is a mixture of carbon monoxide and hydrogen. Methanol can be manufactured from synthesis gas in a reversible reaction as shown by the following equation.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

(a) A sample of synthesis gas containing 0.240 mol of carbon monoxide and 0.380 mol of hydrogen was sealed together with a catalyst in a container of volume 1.50 dm^3. When equilibrium was established at temperature T_1 the equilibrium mixture contained 0.170 mol of carbon monoxide.

Calculate the amount, in moles, of methanol and the amount, in moles, of hydrogen in the equilibrium mixture.

Methanol .....

Hydrogen .....

(2)

(b) A different sample of synthesis gas was allowed to reach equilibrium in a similar container of volume 1.50 dm^3 at temperature T_1

At equilibrium, the mixture contained 0.210 mol of carbon monoxide, 0.275 mol of

hydrogen and 0.0820 mol of methanol.

(i) Write an expression for the equilibrium constant K_c for this reaction.

.....

.....

(1)

(ii) Calculate a value for K_c for the reaction at temperature T_1 and state its units.

Calculation ….....

.....

.....

.....

.....

Units .....

.....

(4)

(iii) State the effect, if any, on the value of K_c of adding more hydrogen to the equilibrium mixture.

.....

(1)

(c) The temperature of the mixture in part (b) was changed to T_2 and the mixture was left to reach a new equilibrium position. At this new temperature the equilibrium concentration of methanol had increased.

Deduce which of T_1 or T_2 is the higher temperature and explain your answer.

Higher temperature .....

Explanation .....

.....

.....

(3)

(d) The following reaction has been suggested as an alternative method for the production of methanol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

The hydrogen used in this method is obtained from the electrolysis of water.

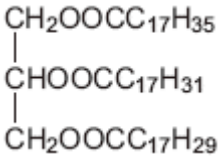
Suggest **one** possible environmental disadvantage of the production of hydrogen by electrolysis.

.....

.....

(1)

(e) One industrial use of methanol is in the production of biodiesel from vegetable oils such as



Give the formula of **one** compound in biodiesel that is formed by the reaction of methanol with the vegetable oil shown above.

.....

(1)

(Total 13 marks)

Q1. Which one of the following is **not** a correct general formula for the non-cyclic compounds listed?

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

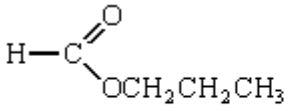
B aldehydes $C_nH_{2n+1}O$

C esters $C_nH_{2n}O_2$

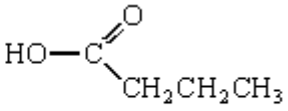
C primary amines $C_nH_{2n+3}N$

(Total 1 mark)

Q2. (a) Consider the following pair of isomers.



C



D

(i) Name compound **C**.

.....

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

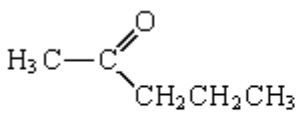
Reagent .....

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

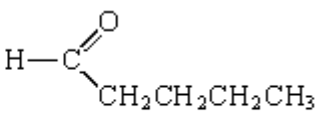
*Observation with **D***.....

(4)

(b) Consider the following pair of isomers.



E



F

(i) Name compound **E**.

.....

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

Reagent .....

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

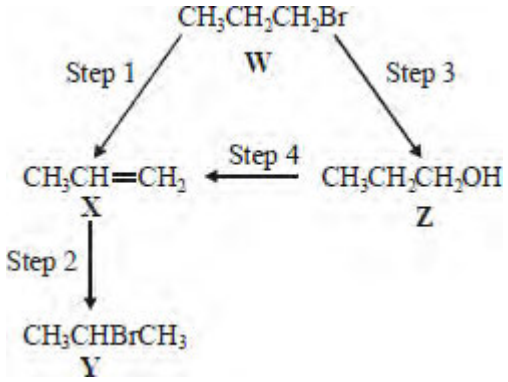
*Observation with **F***.....

(4)

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

(1)
(Total 9 marks)

Q3. For this question refer to the reaction scheme below.



Which one of the following statements is **not** correct?

A Reaction of **W** with sodium cyanide followed by hydrolysis of the resulting product gives propanoic acid.

B Mild oxidation of **Z** produces a compound that reacts with Tollens' reagent, forming a silver mirror.

C **Z** reacts with ethanoic acid to produce the ester propyl ethanoate.

C **W** undergoes addition polymerisation to form poly(propene).

(Total 1 mark)

Q4. Esters have many important commercial uses such as solvents and artificial flavourings in foods.

Esters can be prepared in several ways including the reactions of alcohols with carboxylic acids, acid anhydrides, acyl chlorides and other esters.

(a) Ethyl butanoate is used as a pineapple flavouring in sweets and cakes.

Write an equation for the preparation of ethyl butanoate from an acid and an alcohol.

Give a catalyst used for the reaction.

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(4)

(b) Butyl ethanoate is used as a solvent in the pharmaceutical industry.

Write an equation for the preparation of butyl ethanoate from an acid anhydride and an alcohol.

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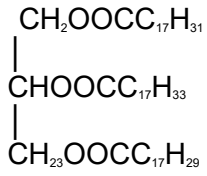
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(3)

(c) Name and outline a mechanism for the reaction of CH_3COCl with CH_3OH to form an ester.

(5)

(d) The ester shown below occurs in vegetable oils. Write an equation to show the formation of biodiesel from this ester.



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(3)

(e) Draw the repeating unit of the polyester Terylene that is made from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Although Terylene is biodegradeable, it is preferable to recycle objects made from Terylene.

Give **one** advantage and **one** disadvantage of recycling objects made from Terylene.

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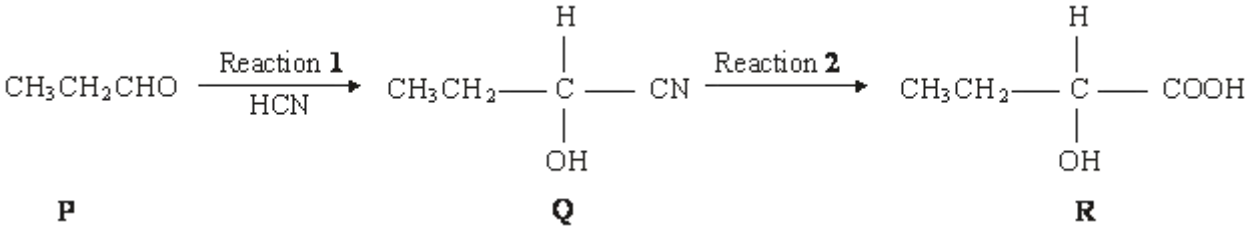
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(4)
(Total 19 marks)

Q5. Consider the sequence of reactions below.



P **Q** **R**

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

Name of mechanism .....

Mechanism

(5)

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

.....

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

(3)

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

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

(ii) acidified potassium dichromate(VI);

(iii) concentrated sulphuric acid in an elimination reaction.

(3)
(Total 11 marks)

Q6. Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

A CH_2O

B $C_2H_6O_2$

C $C_2H_4O_2$

D C_2H_4O

(Total 1 mark)

Q7. (a) Compound **A**, $HCOOCH_2CH_2CH_3$, is an ester. Name this ester and write an equation for its reaction with aqueous sodium hydroxide.

Name …….....

Equation .....

(2)

(b) The initial rate of reaction between ester **A** and aqueous sodium hydroxide was measured in a series of experiments at a constant temperature. The data obtained are shown below.

Experiment	Initial concentration of NaOH / mol dm^{-3}	Initial concentration of **A** / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}

3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	to be calculated

Use the data in the table to deduce the order of reaction with respect to **A** and the order of reaction with respect to NaOH. Hence calculate the initial rate of reaction in Experiment 4.

*Order with respect to **A*** .....

Order with respect to NaOH .....

Initial rate in Experiment 4 .....

.....

(3)

(c) In a further experiment at a different temperature, the initial rate of reaction was found to be 9.0×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of **A** was 0.020 mol dm^{-3} and the initial concentration of NaOH was 2.00 mol dm^{-3}.
Under these new conditions with the much higher concentration of sodium hydroxide, the reaction is first order with respect to **A** and appears to be zero order with respect to sodium hydroxide.

(i) Write a rate equation for the reaction under these new conditions.

.....

(ii) Calculate a value for the rate constant under these new conditions and state its units.

Calculation .....

.....

.....

Units .....

(iii) Suggest why the order of reaction with respect to sodium hydroxide appears to be zero under these new conditions.

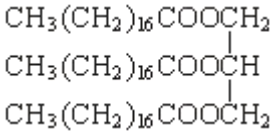
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(6)

(d) A naturally-occurring triester, shown below, was heated under reflux with an excess of aqueous sodium hydroxide and the mixture produced was then distilled. One of the products distilled off and the other was left in the distillation flask.



(i) Draw the structure of the product distilled off and give its name.

Structure

Name .....

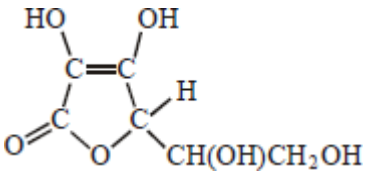
(ii) Give the formula of the product left in the distillation flask and give a use for it.

Formula .....

Use .....

(4)
(Total 15 marks)

Q8. Which one of the following is **not** a correct statement about vitamin C, shown below?



A It is a cyclic ester.

B It can form a carboxylic acid on oxidation.

C It decolourises a solution of bromine in water.

D It is a planar molecule.

(Total 1 mark)

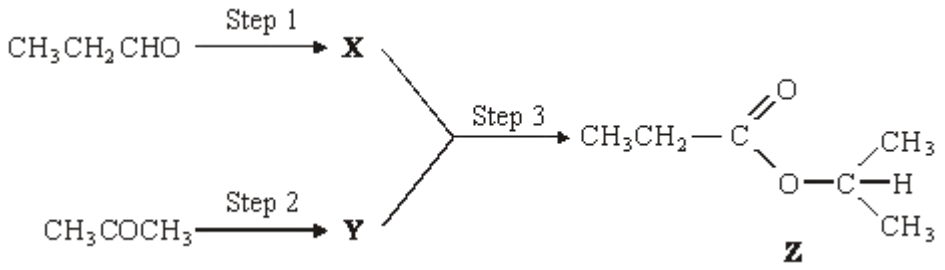
Q1. (a) Describe how propanal, CH_3CH_2CHO, and propanone, CH_3COCH_3, can be distinguished using

(i) a chemical test and

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

(5)

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



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

(10)
(Total 15 marks)

Q2. Butan-1-ol was converted into butyl propanoate by reaction with an excess of propanoic acid. In the reaction, 6.0 g of the alcohol gave 7.4 g of the ester. The percentage yield of ester was

A 57

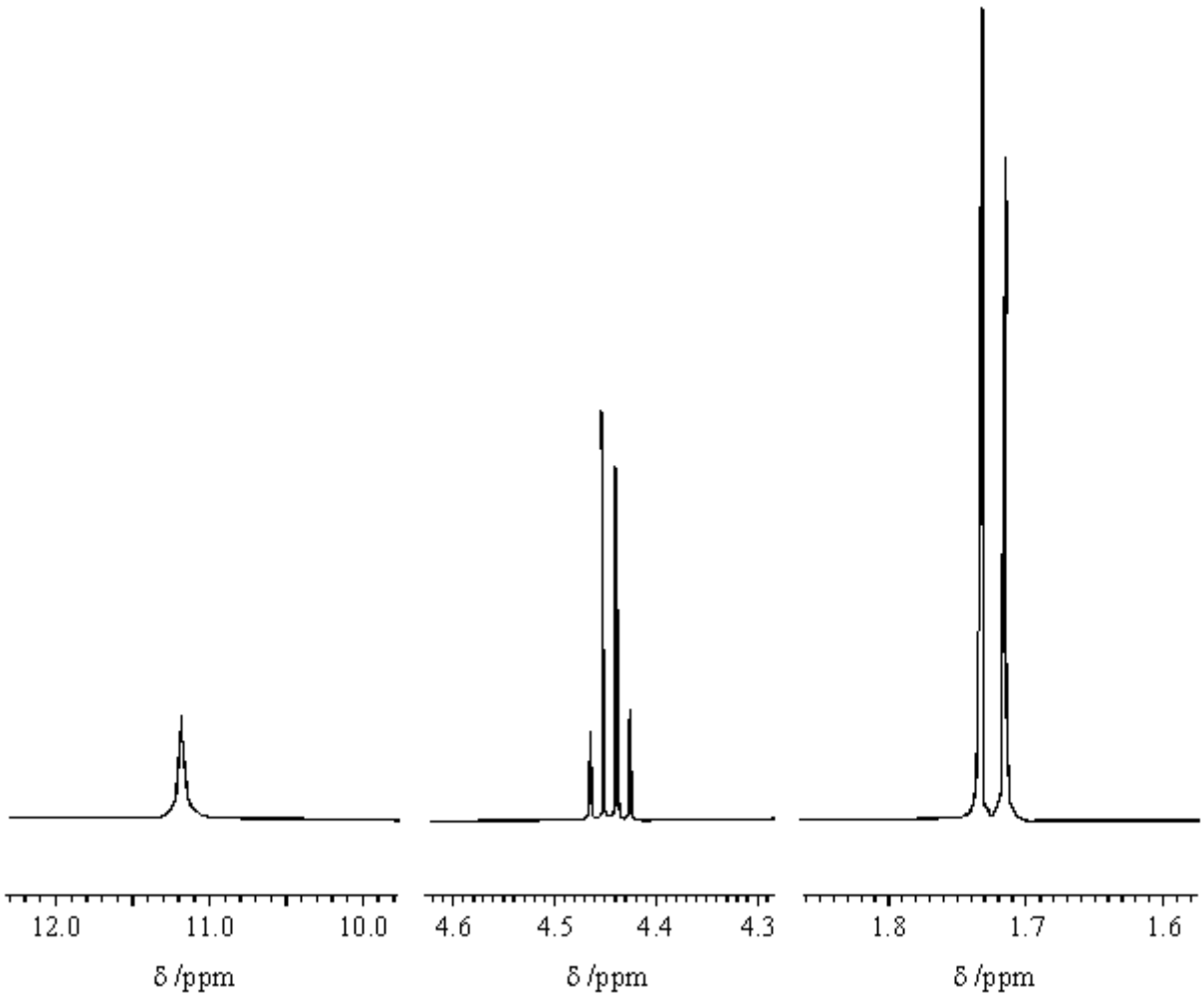
B 70

C 75

D 81

(Total 1 mark)

Q3. Three sections of the proton n.m.r. spectrum of $CH_3CHClCOOH$ are shown below.



(a) Name the compound $CH_3CHClCOOH$

.....

(1)

(b) Explain the splitting patterns in the peaks at δ 1.72 and δ 4.44

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.....

.....

(2)

(c) Predict the splitting pattern that would be seen in the proton n.m.r. spectrum of the isomeric compound $ClCH_2CH_2COOH$

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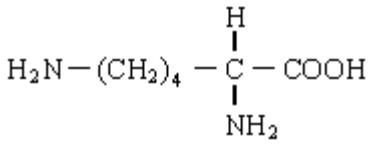
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(1)

(d) The amino acid *alanine* is formed by the reaction of $CH_3CHClCOOH$ with an excess of ammonia. The mechanism is nucleophilic substitution. Outline this mechanism, showing clearly the structure of *alanine*.

(5)

(e) The amino acid *lysine* has the structure



Draw structures to show the product formed in each case when lysine reacts with

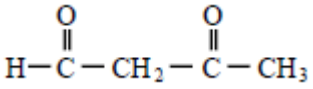
(i) an excess of aqueous HCl,

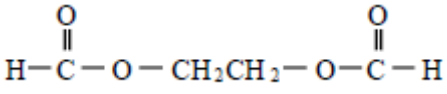
(ii) an excess of aqueous NaOH,

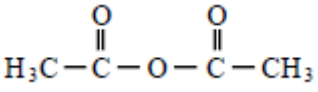
(iii) another molecule of lysine.

(3)
(Total 12 marks)

Q4. Which compound is formed by the reaction of ethane-1,2-diol with an acid?

A 

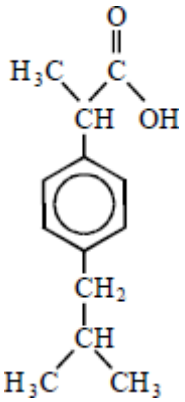
B 

C 

D CH_3CH_2 — O — CH_2CH_2OH

(Total 1 mark)

Q5. Ibuprofen is a drug used as an alternative to aspirin for the relief of pain, fever and inflammation.
The structure of ibuprofen is shown below.



Which one of the following statements is **not** correct?

A It has optical isomers.

B It liberates carbon dioxide with sodium carbonate solution.

D It undergoes esterification with ethanol.

D It undergoes oxidation with acidified potassium dichromate(VI).

(Total 1 mark)

Q6. Butenedioic acid, HOOCCH=CHCOOH, occurs as two stereoisomers. One of the isomers readily forms the acid anhydride $C_4H_2O_3$ when warmed.

(a) Draw the structures of the two isomers of butenedioic acid and name the type of isomerism shown.
Use the structures of the two isomeric acids to suggest why only one of them readily forms an acid anhydride when warmed. Draw the structure of the acid anhydride formed.

(6)

(b) Identify one electrophile which will react with butenedioic acid and outline a mechanism for this reaction.

(4)

(c) Write an equation for a reaction which occurs when butenedioic acid is treated with an excess of aqueous sodium hydroxide.

(2)

(d) Describe and explain the appearance of the proton n.m.r. spectrum of butenedioic acid.

(3)
(Total 15 marks)

Q7. (a) The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.

$2W(g) + X(g) \rightleftharpoons 3Y(g) + 2Z(g) \qquad \Delta H = -200 \text{ kJ mol}^{-1}$

Write an expression for the equilibrium constant, K_p, for this reaction.
State one change in the conditions which would both increase the rate of reaction and decrease the value of K_p. Explain your answers.

(7)

(b) Ethyl ethanoate can be prepared by the reactions shown below.

Reaction 1

$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l) \qquad \Delta H^{\ominus} = -2.0 \text{ kJ mol}^{-1}$

Reaction 2

$CH_3COCl(l) + C_2H_5OH(l) \rightarrow CH_3COOC_2H_5(l) + HCl(g) \qquad \Delta H^{\ominus} = -21.6 \text{ kJ mol}^{-1}$

(i) Give one advantage and one disadvantage of preparing ethyl ethanoate by **Reaction 1** rather than by **Reaction 2**.

(ii) Use the information given above and the data below to calculate values for the standard entropy change, $\Delta S^{\ominus}$, and the standard free-energy change, $\Delta G^{\ominus}$, for **Reaction 2** at 298 K.

	$CH_3COCl(l)$	$C_2H_5OH(l)$	$CH_3COOC_2H_5(l)$	$HCl(g)$
$S^{\ominus}$/JK^{-1}mol^{-1}	201	161	259	187

(8)
(Total 15 marks)

Q1. An excess of methanol was mixed with 12 g of ethanoic acid and an acid catalyst. At equilibrium the mixture contained 8 g of methyl ethanoate. The percentage yield of ester present was

A 11

B 20

C 54

D 67

(Total 1 mark)

Q2.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Isomers of the ester $HCOOCH_2CH_2CH_3$, include

(i) ethyl ethanoate

(ii) methyl propanoate

(iii) butanoic acid

(iv) butyl methanoate

(Total 1 mark)

Q3.

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Products from the acid hydrolysis of the ester $CH_3CH_2COOCH_2CH_3$ include

(i) CH_3CH_2COOH

(ii) CH_3COOH

(iii) CH_3CH_2OH

(v) $CH_3CH_2CH_2OH$

(Total 1 mark)

Q4. How many structural isomers, which are esters, have the molecular formula $C_4H_8O_2$?

A 2

B 3

C 4

D 5

(Total 1 mark)

Q5. Hydrolysis of the ester, $CH_3COOCH_2CH_2CH_3$, produces ethanoic acid. In an experiment, 2.04 g of the ester was used and 0.90 g of ethanoic acid was produced. The percentage yield of ethanoic acid was:

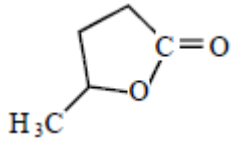
A 44

B 59

C 75

D 90

(Total 1 mark)

Q6. Acid hydrolysis of  produces

A $CH_3CH(OH)CH_2CH_2COOH$

B $CH_2(OH)CH_2CH_2CH_2COOH$

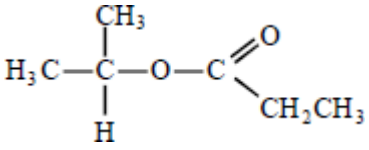
C $CH_3CH(OH)CH_2CH_2OCHO$

D $CH_2(OH)CH_2CH_2CH_2OCHO$

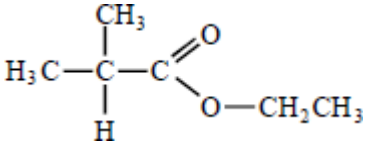
(Total 1 mark)

Q7. The structural formula of ethyl 2-methylpropanoate is

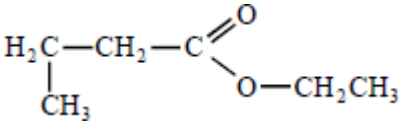
A



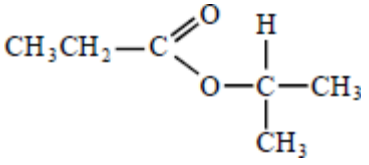
B



C



D



(Total 1 mark)